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Patentometrics as Performance Indicators for Allocating Research Funding to Universities

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Patentometrics as Performance Indicators for Allocating Research Funding to Universities

Peter S. Mortensen[1]

Abstract

This paper is part of a preliminary investigation of potential indicators on the performance of universities and other public research institutions to be used for allocating general and other research funding. The paper will describe and discuss potential patentometrics and how they can be used in different types of analyses and evaluations in general and relating to universities and other public research institutions. Further, the relevance and possibility of including some patentometrics in the allocation of research funding is discussed. Also, other metrics regarding academic linkages with industry and other sectors are considered.

Keywords: Patentometrics, university funding, performance indicators, citations

JEL Classification: O31, O34, O21

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1. Introduction

When allocating general university funding for research some criteria are needed. This may also be the case, when other types of funding are to be allocated. In a later paper a typology of potential performance indicators will be presented, including peer reviews, bibliometrics, webometrics and patentometrics. This paper deals with patent metrics as performance indicators, while other review papers will deal with webometrics and bibliometrics.

The paper is organised in 5 parts excluding this introduction. Part 2 describes the patenting procedure and the data that can be extracted from this process from the registers of patent offices and other sources. Part 3 evaluates in detail these data in relation to measuring the amount and impact of patents and co-operation through patents. Part 4 is focusing on the role of universities, public research organisations (PRO's) and their faculty members in patenting and the type of indicators described in Part 3 and from other sources that may be relevant. Part 5 discusses the possibilities of including some indicators of patenting in academia as performance indicators when allocating general and other research funding. Lastly, some ideas of the further investigations of the possibilities of including patent metrics in performance indicators are presented.

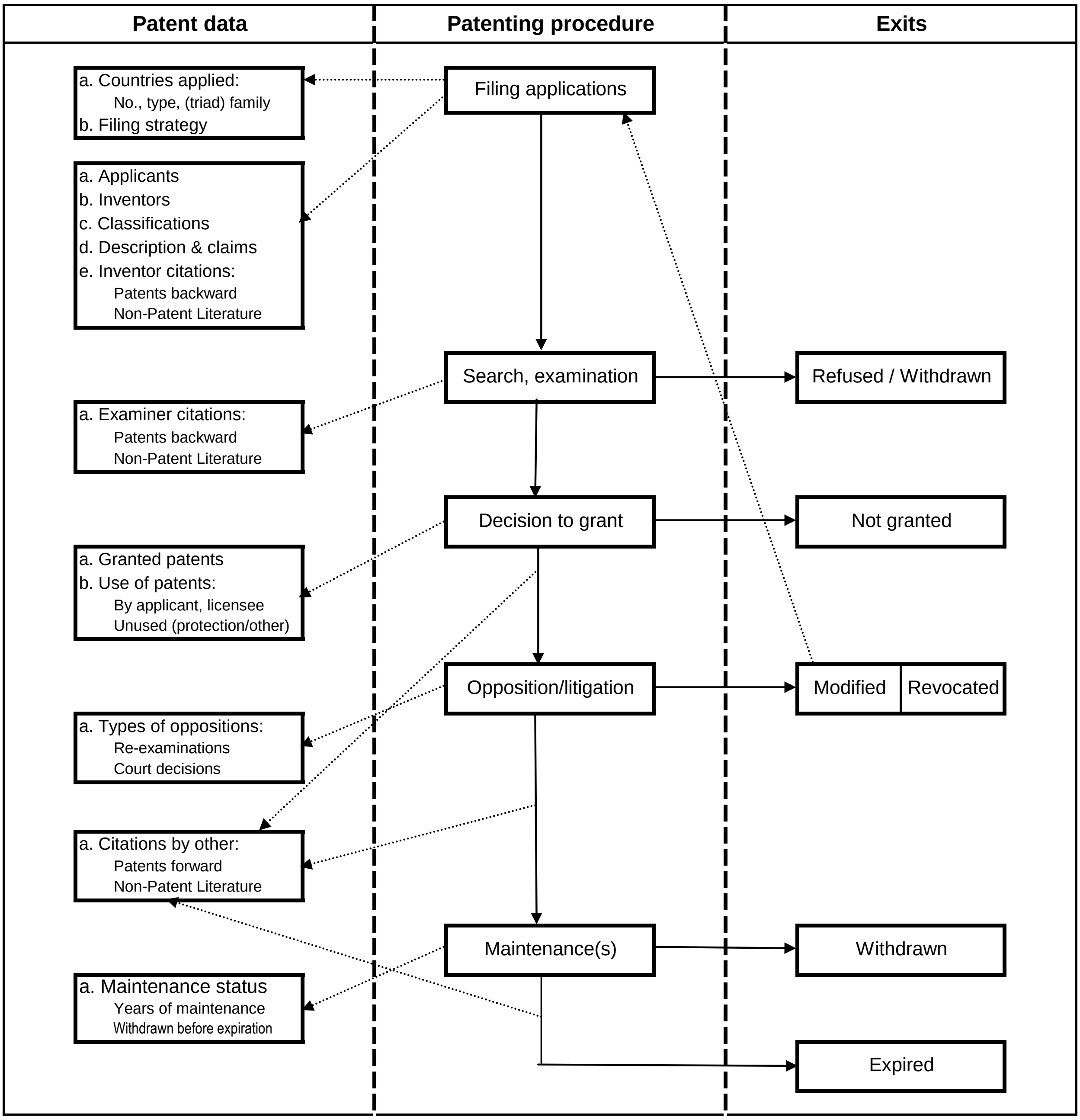
This paper does not discuss more general issues about patents and patent metrics. Here, the OECD Patent Statistics Manual (OECD, 2009) can be recommended.

2. Patent data

Information on patents is stored in huge databases in National, European and International patent offices all over the world. These databases have been the basis for extracting relevant statistical information on patents for a long time, OECD(1994). The most prominent examples are the NBER-database of patents from the US Patent Office (USPTO), see Jaffe;Trajtenberg(2002,2008) and Hall(2010), and the PATSTAT-database of patents worldwide, see EPO(2011). Also, larger surveys like PatValEU(2005), have included supplementary data for a given period and a given number of countries, while smaller surveys, e.g. Reitzig(2003a), concentrate on delimited parts.

These statistical databases include different kind and amount of information, partly because the patenting procedure differs significantly between patent offices, see OECD(2005). In the description in this paper the potential patent data are identified based on a standardised patenting procedure, described in Figure 2.1.

Figure 2.1. Potential patentometrics from the patenting procedure



Filing applications

When patent applications are sent to a patent office, they need to include information on a number of elements to be accepted for filing and examination. Some of this information is suitable for statistical uses directly or indirectly (transformed and/or combined). The number and type of designated coun-tries have been suitable as a qualifier of patent, see Lanjouw;Pakes;Putnam(1998), and also the filing strategy, that is where, how and when a patent is handed in for filing, see Stevnsborg;Potterie(2007) regarding the EPO-office.

In an application one or more applicants can be identified and also one or more inventors, one of them eventually being the (provisional) applicant. Much work is needed to make this information valid for statistical use. Names may be spelled differently, different legal units of a group may be used as applicants, and individuals may move or change name or have unknown affiliations. For both the NBER and the PATSTAT database such work has been carried through for the applicants, see i.e. OECD (2010a). For inventors, it has seemingly only been done for smaller groups, i.e. faculty members, see Lissoni;Sanditov;Tarasconi(2006). For applicants the relevant information for statistical purposes is sector/industry, group, Nationality and also affiliation for individual applicants. For inventors the relevant information is affiliation and Nationality. The applicants and inventors combined are the basis for statistics on cooperation between companies and industries, between science and technology, and across borders.

Applications for patents are classified according to one or more technical classes, in which the patent belongs. The *IPC-classification*[2] is used in most countries, while the *USPC-classification*[3] is used in US. Concordance tables between these classification systems do exist. The technical classes are very detailed (USPC has more than 160,000 subdivisions), so main groups may be needed in the forming relevant statistical indicators. However, newer technologies like biotechnology and ICT include classes across the main groups, so detailed specifications of technical classes have been set up to cover these subjects, see OECD (2008a). The main class(es), but also the number of technical classes claimed, may be used in patent statistics for the type and scope of patents.

More straightforward information in the application is the claims. They define the scope and the boundaries of the protection applied for/granted in a standardized way in single-sentence format and numbered 1,2, …. Most patents contain about 10-20 claims, although there are some patents with only one claim and others with hundreds of claims. Each claim includes three parts: the preamble, a transitional word or phrase, and the body. An example could be: *"An apparatus for catching mice, said apparatus comprising a base for placement on a surface, a spring member..."* The validity of a patent is judged by comparing the claims against the prior art, containing all information relevant to a patent's claims of originality that is available to the public in any form before a given date. The number of claims may be used as an indicator of the expected impact of a patent. Other ways of using the claims are possible. The description of the claims may be used in a latent semantic analysis to identify *technology spheres*, see Gibbs(2005), and other aspects of the claims may also serve as indicators, see Barney(2006a).

The inventors may specify part of the prior art by including one or more references to former patents applications or granted patents – inventor citations of patents backwards – and by including one or more references to scientific or technical articles – inventor citations of non-patent literature. The number of such citations may be used as statistics for the scope and quality of patents, see Lanjouw; Schankerman (2004). However, the requirements to inventor's citations differ between the main patent offices, and more applications may relate to the same invention and thus have overlaps of citations, see OECD(2009).

[2] See http://www.wipo.int/ipcpub/#refresh=page
[3] See http://www.uspto.gov/patents/resources/classification/index.jsp

Search and examinations

Applications are examined in one or more steps before granting are decided. During the examination a search for more references is included, however in different degree in different patent offices, see Lemley;Sampat(2010) for USPTO. This results in examiner citations of patents backwards and in examiner citations of non-patent literature. These citations may be added to the inventors' citations as statistics for the scope and quality of patents, see i.e. Alcácer;Gittelman(2006).

Decision to grant

The decision to grant patent applications is a statistics in itself, indicating accept of the content of the applied patent as an invention and thus a qualifying indicator, see Zeebroeck(2009). Also, information on whether the patents are utilised – by the applicant, a licensee or new owner – or are unused – for protection or because of low/no value – would be a relevant statistics, but only partly registered as patent data.

Opposition/litigation

A third party may oppose the granting of a patent when it has been published. This opposition may be tried at the patent office through a re-examination or as litigation at a court. Patents that have passed through such a process have on average a higher impact, see Harhoff;Scherer;Vopel(2003,2004), making this information a candidate for an impact indicator of patents. There is, however, a timeliness problem, if only settled oppositions are to be included. In average, EPO-oppositions lasted 7 years (in the 1990's), see Reitzig(2003b).

Citations by third party

After the publication of a patent it will be possible for new patent applications to refer to the patent and it will also be possible for non-patent literature to refer to the patent. These forward citations of patents by other patents (Narin,1994) and by non-patent literature (Glänzel;Meyer,2003) are important as impact indicators of patents.

Maintenance/renewal

After patents have been granted they need to be renewed (US: maintained) by paying a fee every year (US: every 4 year) until they expire. The fees increase year by year at some patent offices. Patents may be withdrawn before they expire, signalling an expected value, lower than the fee. Thus information on how long patents have been maintained or when they were withdrawn may be used as an indicator of the value of a patent, see Lanjouw;Pakes;Putnam(1998).

3. Patentometrics as performance indicators

The rich information on patents, described in the former Chapter, makes it possible to consider indicators for many aspects related to patenting. In this paper the aspect is *performance*, that is how well one or more groups of individuals or legal units are performing regarding patenting. The general indicators for that would be the amount and impact of their patents and the networking through patents as output. Here, the usefulness of the patent information described in the former Chapter will be evaluated regarding these general indicators.

The impact of a patent may be some kind of a quality indicator or an estimate of some kind of value of the patent. While the quality indicator may be estimated using the patent data from the patent offices, this can not be done directly for the value. Instead, one may either conduct surveys to get estimates of the value of samples of patents, see i.e. the PatValEU survey described in Giuri;Mariane et al.(2005), or predefine one or more of the patent data in Chapter 2 as substitute(s) for the value of patents, see Zeebroeck (2009). In both cases models may be set up to estimate the relation between the estimated values of patents and the characteristics of the same patents.

3.1. The amount of patents

Who are patenting

Depending on the purpose of a performance study either the applicants or the inventors – or both – might be of interest. Performance studies on applicants would tell, how well the groups (industries, Nations, universities …) perform regarding getting the rights to use or license inventions. Performance studies on inventors would tell where inventions take place (sectors, Nations, institutions …).

Both for applicants and inventors there are problems harmonizing the names, either of legal units or individuals, see Chapter 2. Also, it may be quite a task to identify the sector and affiliations of the inventors and this information may be crucial in a performance study. If possible, a manual verification procedure may be established when using automatic assignment of sector and/or affiliation.

When counting the number of inventors or applicants belonging to a group one has to decide how to count patents with more inventors or applicants. In official patents statistics fractional counting is used, i.e. a patent having 5 inventors of which 2 are from the group/country in question will count as 2/5.

The number and characteristics of the inventors themselves seem also to have an influence on the impact of a patent. Gay;Latham;LeBas(2008) has shown that foreign inventors and inventors with more than 10 patents produce patents of higher value – in average. Gibbs(2008) included the number of inventors in his model of value as a measure of *technical sophistication* and *sustainability in opposition* based on the analytical results of Reitzig(2003b).

Patent office

Patents may be applied for at one or more patent offices. However, the procedures differ between the offices, so seemingly alike information from two or more patent offices cannot be added without caution and even corrections. Also, the probability of being granted seems to vary between the main patent offices, according to an econometric model by Webster;Paralangkaraya;Jensen(2007).

Furthermore, the procedures for patenting have continuously been changed and the structure of European and international patent offices have changed too, see OECD(2009). This means that adding patent information over the years may also require some reservations and even corrections. The decision on which patent offices to include should also include considerations regarding the group(s) to evaluate – i.e. is it only groups from one country – and whether and how the information on *No. of countries applied* should be included in the patent metrics used.

The patenting procedure, see Figure 2.1., involves activities from sending the application to the first patent office until the patent final has expired (or withdrawn for some reason) at all patent offices. This makes it necessary to decide, when to include patents in the performance study and when to exclude patents. The time from the first application until the first granting of a patent may last more years and granted patents will thus not give much impression of the performance during the last 3-4 years. So, like in official patent statistics, patents would often need to be included as soon as they are published – at most offices 18 month after filing. The decision regarding when to exclude patents still maintained should be made in the light of the purpose of the performance study.

In continuation of this, one also has to take into considerations that often there are more patents referring to the same invention. The closest ones are those with exactly the same priorities, called *equivalents of a patent*, see Webb;Dernis(2005). A wider concept is *patent family* which includes the set of patents that share one or more priority applications. There are more ways of defining patent families, see Martinez(2011), and the definition may influence the impact of the families. However, the *Triadic family* has been accepted as a way to identify valuable inventions. To be a triadic family the patent family should have been applied at EPO and the Japanese patent office (JPO), and granted at USPTO, see Dernis;Guellec;Potterie(2001).

This means that one has to decide which patent offices to include in the performance study and also how to handle patent equivalents and patent families. The importance of this is stressed by the fact that the impact of a patent seems to increase as one moves from a patent just being National applied, to also being applied at EPO or USPTO, to being a member of a Triadic family, see Zeebroeck(2009) and others.

3.2. The impacts of patents

Like with bibliometric and webometric indicators it is necessary to include data on the impact of each item (here: patents) to get a more accurate estimate of the total performance for some group (here: of inventors or applicants) of the metric in question. However, with patents we are in a more complex situation due to the larger amount of data regarding each patent. Also, the potential impact of patents has more dimensions. The impact may be through (forward) citations and usage (i.e. access to homepage of patent office) like in bibliometrics and webometrics, or may be through economic value generated to the applicants from licensing or protection of own production until expiration or to society (social value). Gibbs(2005) includes two more value-dimensions, legal value and technical value, determined by a multitude of variables from the patent documents. For universities and PRO's a fourth type of value, the scientific value, would be of relevance, see Freedman(1987) for a definition.

No comprehensive data on usage of patent information has been found yet, but will probably be available some day, using webometrics.

The economic value of a patent can only be investigated through surveys, and this is seldom possible in a performance study due to cost constraints. Instead, samples of patents have been drawn and information of the value of the patents have been collected using questionnaires or interviews, lately in an EU-financed project, PatVal, see Giuri;Mariani et al.(2005) and Kaiser(2006). By merging the information in the patent databases with the surveys one may disclose the correlations between the economic value and the patent data listed in Chapter 2.

Below, candidates for being part of indicators of patent impact are being discussed, ending up with examples of compound indicators for patent impact.

Citations

In the patenting terminology there can be more types of citations connected to a patent. First, a patent application will refer to former patents and non-patent literature (backward citations = references), and next an examiner will include more former patents and non-patent literature citations before granting the patent. The patent itself may be cited after the publication, either by new patent applications or by new non-patent literature (forward citations). The latter is parallel to citations in bibliometrics. All these types of citations have been proposed and used as indicators of the impact of patents.

The use of citations is full of pitfalls. A number of these will be discussed. First, the rules for including citations in applications differ between patent offices. At USPTO a full list of prior art is required by the applicants, while this is optional at EPO. At USPTO the examiners may supplement the citations, but at EPO the examiners are responsible to include all relevant information within a minimum number of citations. Callaert et al.(2006) has analysed the number of references (backward citations) for granted patents in 1991-2001 at USPTO and EPO:

Patent office	USPTO Average / Pct with none	EPO Average / Pct with none
Patent references	11.3 / 10%	4.09 / 2%
Non-patent references	2.20 / 66%	0.86 / 62%

Source: Callaert et al.(2006)

These figures tell that backward citations from the two patent offices cannot be compared directly. This is also documented by Michel;Bettels(2001), who included more patent offices. On top of this the procedures and practices are changing over time, so comparisons over time should also be conducted with care.

Citations are a mix of inventor[4] and examiner citations. In analyses of patent data from USPTO Sampat(2005) found significant lower shares of non-patent citations and of citations non-USPTO patents by examiners and Alcácer;Gittelman(2006) has shown that including examiners citations in descriptions of inventors knowledge are biasing the metric as a performance indicator and overinflating its significance. Criscuolo;Verspagen (2005) found in a regional analysis of knowledge spill-over that 63 % of the inventor citations in EPO-patents related to the same region, while only 31 % of the examiner citations did. Also Jaffe;Trajtenberg;Fogarty(2000a) found in a survey among inventors that citations added by attorneys or examiners seldom have had any influence on the invention. These types of citations may thus be included in an indicator of impact of the patent, but it will be more problematic to include them in a knowledge flow indicator among inventors, see Part 4.5. This was also concluded by Meyer(2000b), who called the examiner citations an indicator of the technological relevance.

[4] or the inventor's patent attorney.

Some of the citations may be self-citations, being citations to one of the inventors of the patent or to the same legal unit/group. First of all, it may be difficult to identify self-citations, unless names have been harmonized and groups of companies identified, see Chapter 2. Next, the question is whether to include or exclude self-citations or to handle them in some other way when defining indicators based on citations. Not surprisingly, Criscuolo;Verspagen(2005) found that more self-citations from a sample of EPO-patents came from inventors than examiners. Hall;Jaffe;Trajtenberg(2001) concluded after preliminary analyses of USPTO-patents that the motive of self-citation may be to increase "the patent thicket" or to appropriate downstream impacts. In all, these two opposite motives of self-citations end up with a positive significance with a higher coefficient than that for other citations when modelling the impact of USPTO-patents, see Hall;Jaffe;Trajtenberg(2005). The same result is obtained by Sapsalis; Potterie(2007) for self-citation of non-patent literature in EPO-patents from universities, while backward self-citations correlated negatively with the impact. Alcácer;Gittelman (2006) and Sampat(2005) found that there are more motives for self-citation, i.e. the mobility of inventors and little devotion to searching for prior art (at USPTO). In all, the conclusion seems to be that self-citations cannot be excluded when forming citation-based indicators of impact.

Both backward and forward citations have been found to be indicators of impacts of patents. The backward citations give an indication of the novelty of the invention and this would correlate with the impact. This may be rather unreliable, see Gibbs(2008), also depending on the type of citation (patent/non-patent) and type of EPO-class of the citation, see Harhoff;Reitzig(2004). A large number of analyses on the influence of backward citations on various direct or indirect aspects of impact of patents have been published[5].

One advantage compared to forward citations is the timeliness, as the backward citations are available when the patent application is published. If impact indicators are to be used as short-term measures it is only possible to include forward citations partly. This could be ensured by using a fixed period after publication, in which citations are counted, i.e. 3 years, see Reitzig(2003b) or 5 years, see Lanjouw; Schankerman(2004), Wang(2007) and Mariani;Romanelli(2007). Further, the expected forward citations could be estimated based on truncation, see Hall;Jaffe;Trajtenberg(2005). Sapsalis;Potterie; Navon(2006) used time-dummies to correct for age differences of up to 15 years! Finally, the citations could be calculated per year since publication.

In all analyses reviewed, forward citations are a significant indicator, whatever direct or indirect aspect of impact studied, i.e. Harhoff et al.(1999). However, one still needs to include more indicators of the impact to get reliable estimates i.e. by using model-based estimation. Wang(2007) has documented this in a case-based approach.

The two types of citations – citations to other patents and to non-patent literature – have different influence on different types of impact. Broadly spoken, citations to other patents reflect technology, while citations to non-patent citations reflect science. Most non-patent citations are to journals and conference proceedings (see Callaert et al.,2006), so more information on the citations may be brought in from bibliometric databases like Web of Science or Scopus[6]. When the two types of citations are separated in multiple estimations of impact, they both are significant, but at different levels and depending on technological class, see Harhoff;Scherer;Vopel(2003,2004).

[5] Value at company level: Lanjouw;Schankerman(2004). Patent value/importance: Harhoff;Scherer;Vopel(2003); Jaffe;Trajtenberg;Fogarty(2000). Opposition: Harhoff;Reitzig(2004). International knowledge diffusion: MacGarvie(2005).

[6] Web of Science: http://thomsonreuters.com/products_services/science/science_products/a-z/web_of_science and Scopus: http://info.scopus.com/

The raw citation counts per patent may be sophisticated in different ways to make them more valid when used as (part of) indicators for impact. When using the counts directly in multiple estimation of impact, most analyses transform the counts by log +1. Also, an originality index and a generality index of a patent can be calculated like a Herfindahl concentration index on technological classes, the originality index referring to the backward citations and the generality index to the forward citations, see Trajtenberg;Henderson;Jaffe(1997). The relation of a patent to science can be measured as the share of non-patent citations of all backward citations, being called an index of basicness (ibid).

The level of most citation measures – from the very raw to i.e. the generality index – depends on some of the other characteristics of patents. This means that using citations as the single indicator for impact would be biased. Most discussed is the influence of the year of the application, as the number of citations to patents has increased over a longer period of time, see Hall(2004). Also, the number of citations has different levels depending on the main technological class of the patent, see Hall;Jaffe; Trajtenberg(2001). This means that part of the explanation of differences in citation levels would be differences in the distribution of technology and time when comparing citations across technological classes and over medium to long-term periods. One way to overcome this would be to normalise the citations in groups of classes and time periods (fixed effect approach), while another way would be to estimate the effect of year and technology in an econometric model, see Hall;Jaffe;Trajtenberg(2001).

The *Citation ratio* uses both backward and forward citation as it is calculated as the ratio of forward to backward citations, see Webster;Paralangkaraya;Jensen(2007). It is seen as a proxy for non-obviousness (though the arguments for this have not been found).

Of course, not all relevant citations can be expected to be included in an application. There may be prior art, either in the same class or in different classes disclosing similarities and there may be co-pending patents – “concurrent art” – with similarities, see Gibbs(2005).

In all, patent citations are the most important indicators for the impact of patents, but there are a number of challenges to overcome transforming – and supplement – them to unbiased estimates of impact.

Claims and specification

The number of claims has been used as an indicator of “size” of a patent by Tong;Frame(1994) and as a major part of a quality index for patents by Lanjouw;Schankerman(1999,2004) and a model of perceived value by Jaffe;Trajtenberg;Fogarty(2000b). Neifeld(2001) argued that both breadth and strength of the claims need to be included when valuating a patent. To achieve that, Neifeld included length, type and number of claims, classified by independency of each claim. *Ocean Tomo*(2006), another commercial provider of patent ratings, has also included these dimensions of claims plus “*specific limiting language”* in their patented method (Barney;Barney;McLean,2003), while Wang(2007) only investigated the number of words in the first claim. Both commercial providers have included the length of the specifications and number of figures (ibid). Due to the inflation in the number of claims over time and deviations between technological areas Stevnsborg;Potterie(2007) has suggested using the log of the number of claims relative to the median number in that year for that technical class.

A third commercial provider, PatentCafe(2006), has investigated the full text of the claims in a *Latent Semantic Analysis*, see Landauer;Foltz;Laham(1998), to identify the 100 patents most close to the claims of the patent being analysed. In this way, some of the un-cited and concurrent prior art can be identified and be included in the estimation of the impact of the patent.

Technical classes

The technical classes of patents can be used in two ways, either to estimate the scope of a patent or to fine-tune the impact of a patent. The scope of patents is measured by the number of subclasses of a patent, see Lerner(1994). However, Harhoff;Scherer;Vopel(2003,2004) found the impact of scope non-significant when included in an econometric model with other indicators and Guellec;Potterie (2000) even found a slightly negative correlation with granting.

The main technical class has been used by Harhoff et al.(1999), Barney(2006b) and Gay;Latham; LeBas(2008) in econometric modelling of impact, and most of the dummies representing the technical classes were found to be significant. Sampat(2005) found different patterns of citations depending on technical class, so one needs to include the technical classes somehow as citations are an important indicator of impact. Gibbs(2005) has created a detailed ad-hoc classification where each patent belongs to a group of 100 neighbour patents, according to a latent semantic analysis of the claims, see above.

Designated countries/families/filing strategy

Counts of equivalents of a patent from different patent offices or counts of patent families (see the difference in Part 3.1) have been used as measures of impact. Early modelling of USPTO patents suggested a linear (Lanjouw;Pakes;Putnam,1998) or log-linear (Harhoff;Scherer;Vopel,2003) correlation with some impact measure, while Lanjouw;Schankerman(2004) simplified the representation of family to "*only domestic"* vs. "*also applied abroad"*.

For EPO patents, Reitzig(2003b) included the number of families in the construction of one of a number of latent impact factors, while Sapsalis;Potterie(2007) found no correlation (with forward citation as dependent variable); instead they successfully used dummies for equivalents to USPTO and to JPO. Guellec;Potterie(2000) found an inverse U-shape relation - with granting as dependent variable – even when qualifying the counting of family members (qualifiers: DE+FR+UK). Zeebroeck (2009) disclosed that the number of family members depend on the technical class and on the year of application (due to changes in conditions for patenting). As a consequence he made a fixed-effect correction of the family size, before using it for calculating a latent variable of the impact of an EPO patent. Also, he included a dummy for being member of a triadic family.

The filing strategy was included by Guellec;Potterie(2000) in the form of dummies for National priority, EPO priority and PCT[7], Chapter 1 or 2, see technical details in OECD(2005). The *EPO* priority and *PCT, Chapter 1* were found to have a significant lower probability of being granted. Zeebroeck; Potterie(2008) included filing speed (*accelerated search requested*) and drafting style[8] to cover patent strategies more broadly – from "*good will & fast track"* to "*deliberate abuse of the patent system"* – inspired by an analysis of Stevnsborg;Potterie(2007).

Applicants and inventors

The inventors and applicants may influence the impact of patents. Regarding organisation(s) applying for a patent, PatVal-EU(2005) found an influence depending on company size (the smaller company, the larger value) and sector (lowest for universities and government institutions). The number of applicants – being mostly one – has no significant influence on the value, see i.e. Reitzig (2003b), but

[7] See http://www.wipo.int/pct/en/

[8] Included are: Excess and lost claims relative to the median number (year/technology); the mix of priorities and equivalents (patent thicket); divisionals (the split of one application in more).

Sapsalis;Potterie(2007) found that the type of a co-applicant influenced the impact, highest for public research institutions.

The number of inventors has been regarded as a potential indicator of impact. Gibbs(2005) included the number in a dimension of technical impact and Reitzig(2003b) also tried, but found no significant influence when explaining technical and non-technical "value drivers". Gambardella;Harhoff;Verspagen(2008) and Zeebroeck;Potterie(2008) found significant influence of the log of the number of inventors in comprehensive models of the value of patents (estimated by the main inventor and by a composite indicator), while Gay;Latham;LeBas(2008) found a quadratic form being significant in a model with forward citations as dependent variable.

Ernst;Leptien;Vitt (2000) found a significant influence of the number of patents that the inventor has been involved in, using a composite impact measure with {citations, US in the family, granted, still valid}. Gambardella;Harhoff;Verspagen(2008) found that the log-value of the number of inventors had a significant influence on the value of the patent. Gay;Latham;LeBas(2008) further confirmed this using a dummy variable which was switched to ONE when the inventor had listed at least 10 former patents. They also found a significant influence regarding foreign inventors, coded as a dummy variable. In an earlier study by Guellec;Potterie(2000) this was investigated in more detail, revealing a significant higher probability of granting when inventor and applicant were from different countries and when more nationalities were represented in the group of inventors.

Granted patents

An obvious impact indicator is whether a patent application has been granted or not. Granting has been used by Ernst;Leptien;Vitt(2000) as part of a quality indicator for inventors, and Guellec;Potterie (2000) has used granting as a proxy for the value of patent applications.

The use of granting as an impact indicator becomes more complicated when investigating a portfolio of patents over more years and including all published patent applications, because the time from publication to granting/refusing may vary significantly. One way to overcome this has been to view the non-granted patent applications as "truncated" and then estimate the probability that they will be granted. This will be as a function of the time from publication of the application. More or less sophisticated models may be used, see Hall;Jaffe;Trajtenberg(2000, 2005). The probabilities of granting may be used as an extra weight for patent applications, i.e. if the probability of 3-years old non-granted patent applications being granted has been estimated to 25%, a weight of 0.25 will be assigned to the indicator "*granted*" for each of these patent applications.

The time from applying to granting has also been used as an indicator of quality and complexity, included in a model of opposition, see Harhoff;Reitzig(2004).

Opposition / litigation

Any opposition, be it to the patent office or the court, are costly, so opposition may be seen as an indicator of a valuable patent, see Chapter 2. This is confirmed in the studies by Harhoff;Scherer; Vopel(2003,2004) and Gambardella;Harhoff;Verspagen(2008), where patent values were reported in surveys of inventors and patent holders. In the study of Harhoff;Scherer;Vopel litigations at the Central German Patent Court are isolated from oppositions to the patent office. The coefficient of the indicator for litigation is much higher than that of the opposed patents.

Zeebroeck(2009) has performed a factor analysis with 5 indicators of impact and found that opposition seems to form its own dimension[9] and Gibbs(2005) used proxy indicators for opposition and litigation.

Lanjouw; Schankerman(1998) indirectly showed that litigated patents at USPTO were more valuable. They sat up a model for the probability of a patent to be litigated. The probability increased with the number of claims and the number of forward citations, being indicators of impact (see above). In the same way Harhoff;Reitzig(2004) found for EPO-patents the same indicators to increase the probability of opposition, but also the family size had a positive influence on the probability.

In all, opposition and litigation are significant indicators of a more valuable patent. However, the indicator is dichotomous and may thus only be used as one among more when measuring the impact of patents.

Renewal / maintenance

The renewal of a patent signals that the patent still has a value – and even a higher value if the fee is increasing. For this reason renewals may be used as an indicator of the value of a patent, either measured as the number of periods that the patent have been renewed or as the fee paid, be it in $, € or DKK.

The renewals are included in composite indicators for impact in a number of proposals. Gibbs(2008) used the term *enforceability* and included renewals in an indicator for *legal value*, Potterie;Zeebroeck (2008) constructed a *scope-year index,* that is a combination of renewals and designated countries. Finally, Zeebroeck(2009) has constructed a composite ranking index using a number of indicators including renewals and correcting for technical classes and time.

Barney(2006b) has used the renewal information as dependent variable in a survival analysis with 35 individual indicators, while Pakes(1986), Lanjouw;Pakes;Putnam(1998) and Bessen(2006) all have used the renewal fees as dependent variables in econometric models to estimate the value of patents – in $, € or DKK.

Composite indicators

As described above there are a number of indicators which are correlated with some kind of measure of impact. Also, it seems that some indicators ex ante can be assumed to be indicators of impact. The substance of impact may be economic value, but also other types of values or more loosely aspects of quality could be the substance, eventually in more dimensions. All this suggest the need of using some composition of measures to set up an indicator of impact.

Different approaches have been used to estimate the impacts of patents, see Zeebroeck;Potterie (2008). The first once looked at the economic value, see also Griliches(1990):

1. **Surveys** have been used a few times to measure the **economic value** as a type of impact for patents. The method is by nature restricted to be a sample – consisting of granted patents of a certain age. The results may subsequently be used to estimate which mix of the "early" patent data from Chapter 2 that best fit the economic values from the survey, using some econometric model.

   Examples:

   - About 1,000 German patent owners of full-term renewed patents made an estimate of the asset-value of their patents. Harhoff et al.(1999) estimated a model with forward citations and

[9] The other indicators were forward citations, grant decisions, families and renewals.

technical classes as independent variables, while Harhoff;Scherer;Vopel(2003,2004) estimated models for each technical class and included scope, family size, backwards and forward citations, and outcome of oppositions and litigations.

- About 9,000 owners[10] of EPO-patents granted 6-10 years ago made an estimate of the asset-value of their patents, see Giuri;Mariani(2005). Gambardella;Harhoff;Verspagen (2008) sat up more models. One included forward and backward citations, claims, opposition, family size, 30 technology classes, country dummies, and year dummies. Another model included character-ristics of the inventor(s) and the applicant, the type of knowhow (basic, technical, customer-based), the funding and the location.

2. **Renewal fees** have been used in several ways as a proxy for the **economic value** or **quality**, letting the renewal fees being the dependent variable in an econometric model where the best mix of the "early" patent data from Chapter 2 were included as indicators. The information on renewal fees is typically based on all or most of the lifespan of the patents.

   Examples:

   - Advanced econometric modelling was used to estimate the economic value of patents on the basis of renewals/withdrawal and renewal fees, see Schankerman;Pakes(1986) and Baudry;Dumont(2006). Also, Schankerman(1998) included technological fields and Nationality of ownership, while Lanjouw;Pakes;Putnam(1998) included designated countries and Bessen(2006) included backward and forward citations, claims and litigations.
   - Survival analysis of the renewal with 35 individual indicators organised in a number of factors like technology, prior art, claims, prosecution and ownership, is used by OceanTomo (2006) to estimate the quality of patents.

3. **Other indicators used in econometric models** have been granting and oppositions. Some examples:

   - The probability of a patent application to be granted has been modelled by Guellec;Potterie (2000,2002) based on EPO-patents. The designated countries, the scope and characte-ristics concerning the inventors and applicants (co-operation; multi-national) were included. Different forms of representing the type and number of designated countries were used.
   - The probability for EPO-patents of being opposed was modelled by Harhoff;Reitzig(2004). Other quality indicators like citations, designated countries and a dummy for PCT-application[11] were included, but also the scope, the number of claims, the country of the applicant, the size of the applicant's patent portfolio and the crowdedness (the cumulative number of patents within the main four-digit IPC-class) were included.
   - The probability for USPTO-patents of being litigated has been modelled by Lanjouw; Schankerman(1998), merging court data with patent data. They included citations, but measured in more ways: per claim in a quadratic function, as self-citations in separate variables and as "crowdedness", being the share of citations from the same technology class. Also, log of the claims and the type of owner (whether individual; whether foreign) were included.

[10] The owners were from 6 EU-countries. Later, the survey was also conducted in Denmark, see Kaiser(2006).

[11] A PCT-application is a type of broad international patent protection under the Patent Cooperation Treaty, see footnote 7.

4. **Composite indicators** for the **quality or value** of patents have been constructed in several ways based on more or less solid ground. Some examples:
   - A Patent Quality Index was estimated as a latent variable based on the logs of claims, family size, backward and 5-year forward citations conditioned on the technology class. The loadings were recalculated to weights, adding to 1, see Lanjouw;Schankerman(1999, 2004). The index was included in an econometric model with the patent value as dependent variable by Gambardella;Harhoff;Verspagen(2008), also including 30 technology classes and country dummies. The index was highly significant.
   - The patenting quality of a portfolio of European patents was estimated by summing the share of patents granted, patents still valid and patents also applied in US. Also, the average citation ratio was added, see Ernst;Leptien;Vitt(2000).
   - In a macro economic model Neifeld(2001) used "*the strength and breadth of the claims*" , being a function of characteristics of the claims and specifications, the references, the inventors "*etc.*". It is not described how these measures were combined to one single compound indicator. The indicator is determining the value of the patents valuated by this method. Neifeld(2004) also argued that using asset value for single patents may be misleading.
   - Potterie;Zeebroeck(2008) has proposed a simple indicator of patent value, the scope-year index. The index is based on the number of designated countries and the number of years of validity[12] in each country relative to the maximum value (all potential countries in all years). Each country could be weighted with the market size, the GDP or the population size.
   - "*The confidence that you may have on the existence of some market for the patented invention*" has been estimated by Zeebroeck(2009) using 5 indicators which each are ranked conditional on technology class and time. The indicators are forward citations, grant decisions, family sizes, renewals and oppositions. The 5 indicators – supplemented with dummies for triadic family and survival of opposition – are united in a composite ranking of patent value, still conditional on technology class and time. An earlier version did not include granting, but more details on the outcome of any opposition, see Zeebroeck;Potterie (2008).
   - Reitzig(2003b) tried to set up latent variables of technical and non-technical value drivers, but in vain – for more reasons.
   - The quality of patents are measured in three dimensions by PatentCafé, see Gibbs(2008), being a legal, a commercial and a technology quality dimension, based on 20 computed indices. These are estimated by transforming available patent data, including a latent semantic analysis of the claims to find the 100 most relevant patents to compare with.

   Also, the coefficients of the explanatory variables in the econometric analyses may be used to estimate the impact of new patents / patent applications.

5. **Single indicators** for the **quality or value** of patents have been suggested, too. In the models of 2-3 renewals, oppositions/litigations and granting were used as proxies of quality or value.

   Most used are the forward citations, extensively studied in a book edited by Jaffe;Trajtenberg (2002), with articles like Trajtenberg(1990). In Hall;Jaffe;Trajtenberg(2000,2005) the forward citations were more significant than the number of patents in a model of the financial market valuation of firms. In Gay;Latham;LeBas(2008), forward citations are used as "*the imputed value of patents"* in an econometric model of the effects of different types of inventors.

[12] This is another way of observing the renewals.

In all, this comprehensive amount of studies – and more can be found – tell that more indicators correlate well with the impacts of patents, but also that more is needed to fully take into account the different influences of these indicators on impact.

3.3. Patent networking

It is possible to form indicators of cooperation and net-working with patents as focal point using the information of each patent application on applicants and inventors and on backward citations of patents and non-patent literature. Also, forward citations from newer patent applications would contribute to that. Further information on cooperation and networking regarding patenting can only be revealed through supplementary surveys like the PatValEU survey, see Giuri;Mariani et al.(2007). The first level of co-invention is when there are more inventors. These may be affiliated to different organisations, eventually from different countries. In the PatValEU survey two third of the patents surveyed had more than one inventor, but only 21 % with other organisations. A foreign inventor among the inventors is a sign of international cooperation and a larger inventor group, see Gay;Latham;LeBas(2008). Also, the experience of the inventors, measured as the number of previous patents, has an impact on the value of the patent (see Gambardella;Harhoff;Verspagen,2008) and is thus an indicator of the quality of the co-operation.

Patents with more applicants may also be a sign of co-operation. The share of patents with more applicants is, however, low – in the PatValEU survey just 3.6 % among independent organisations (Giuri;Mariani et al, 2007). In the modelling of Gambardella;Harhoff;Verspagen(2008) this type of cooperation does not increase the value of the patent and Hagedoorn;Kranenburg;Osborn(2003) does neither find any relations except with former patent cooperation, while Guellec;Potterie(2000) estimates an increased probability of granting if there are applicants from more countries involved in a patent application, but also if applicant and inventor is cross-border. Finally, Fontana;Genua(2009) described 3 types of patent networking, through co-applicants, through co-inventors only and through non-registered co-operation only (from the PatVal-EU survey); "any cooperation" and "type of cooperation" is modelled. The probability of *Any Cooperation* depends on country and technology class, firm size and public involvement (information, funding, university participation), while the *type of cooperation* depends on characteristics of the inventors, the breadth and complexity of the patent and also country and technology class.

Both backward and forward citations are traces of knowledge diffusion and thus a looser type of networking or information sources, either between inventors (patent citations) or between science and technology (non-patent citations). When defining indicators for this kind of networking, one should, however, take into consideration that some of the citations are self citations, thus describing another dimension. Also, some of the backward citations may have been included by the examiner of the patent office and thus not being an indication of information source or networking between inventors. Indicators of these types are of special relevance when they include faculty staff or employees at other public institutions. This is addressed in the next Part.

4. Patenting by universities, PRO's and their staff

Any legal unit may apply for the patenting of a novel, non-obvious and industrial applicable invention. This means that the potential applicants (US: assignees) include public units like universities, public research organisations (PRO's) and individuals e.g. faculty members. The latter may also be stated as inventors of patents. This Part will include all patents applied by universities, public research organisations or their employees as applicants and patents with faculty members as inventors, whoever the applicants are. Crespi;Geuna;Verspagen(2006) concluded on the basis of the PatVal EU-survey that there are no significant differences between the two types (university-owned vs. (only)university-invented) when correcting for observable patent characteristics, but that two-third of the European university-related patents belonged to the latter type.

4.1. The legal basis

The first question is who is going to be the applicant/assignee of a patent application for an invention where faculty members of a university are involved as inventors. As a general rule it depends on the funding of the research leading to the invention. If the funding is non-governmental, a (contractual) agreement would normally include rulings between the external funder and the university or faculty member and these rules would often be in favour of the funder. If the funding is governmental, the rules would be included in some Governmental law or executive order. More types of rules have been in force in different countries at different times:

1. One or more government agencies retain title to the patentable innovations that they wish (US up to 1980).
2. Inventors retain title to patent their inventions (often called "the professors' privilege"). (Denmark: 1955-1999; Germany: up to 2002; Norway: up to 2003; Sweden: still like that[13]).
3. Universities retain title to the patentable innovations that they wish (US: since 1980; Denmark: since 2000; France: since 1982; Belgium: since 1995[14]).

In most sets of rule the other part may retain title if the first one refrains.

The set of rules in force affects the pattern of applicants and the level of patenting. The change in US from 1) to 3) in 1980 entailed a dramatic growth in university assignees, see Henderson;Jaffe; Trajtenberg(1998). They also concluded that the quality of the patents had been declining after 1980, but this was later rejected by a thorough analysis of Sampat;Mowery;Ziedonis(2003). However, Rosell;Agrawal (2006) has been able to show that there was a better *breadth of knowledge flows* in US-academic patents before 1980 compared to firm patenting, but this declined by over half during the 1980s. Also, Shane(2004) shows that it is only after 1980 that patents correlates with the effectiveness of licensing in US (measured by line of business), meaning that license opportunities have become an incentive for universities to increase patenting.

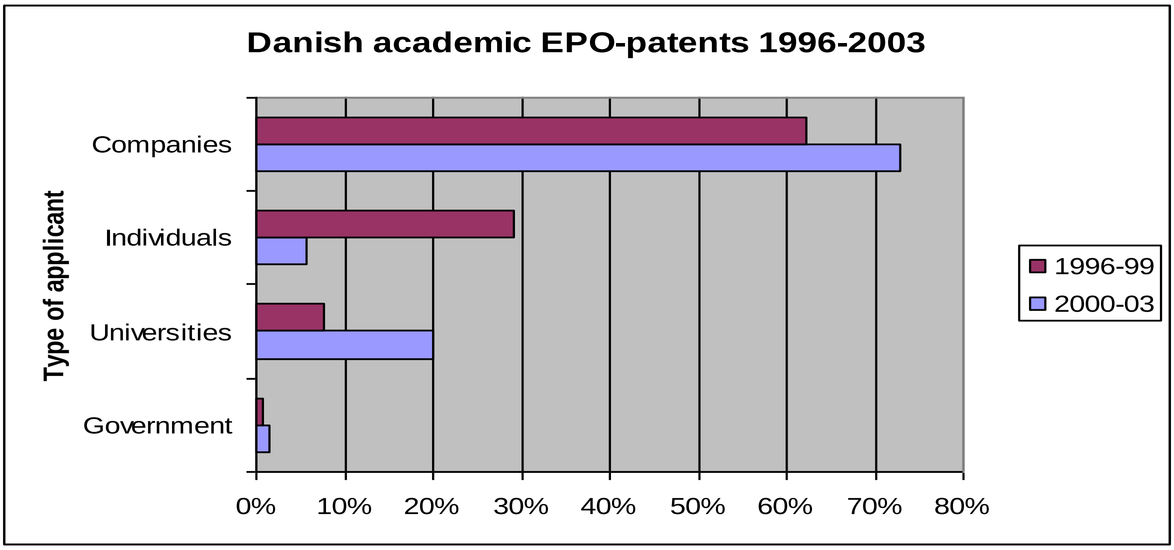
A sample of patents from US-faculty inventors revealed that in 1994-2002 the share of "unassigned" patents (held by inventors themselves) was 5.3 % and the share assigned by firms was 26.4 %, see Thursby;Fuller;Thursby(2007). These patents were less basic according to the measure of basicness (Trajtenberg;Henderson;Jaffe,1997) than those held by universities. Also one-third was applied by

[13] In 2007, see Lissoni et al.(2009), Kilger;Bartenbach(2002), Iversen et al.(2007) and Valentin;Jensen(2007).
[14] Thursby;Fuller;Thursby(2007) and Looy et al.(2003)

companies, where the inventor was a principal. Many of these patents are thus expected to be bypassing the rules.

In Denmark the new set of rule (from 1. to 3.) increased the number of applications from universities to Danish and international patent offices from 3.5 per year in 1996-99 to 33 per year in 2000-03, see Baldini(2006) – and 130 in 2009, see to FI(2010a). In the Danish extension of the KEINS database of EPO-patents[15], invented by academics (professors in 2001 or 2005), one find larger numbers – 1996-99: 32.5 per year; 2000-03: 51.3 per year – but a much lower increase, even though the sample underestimates the former figure. The changes in the distribution of applicants are more striking, see Figure 4.1.

Figure 4.1. Danish academic EPO-patents by type of applicant, before and after changes in rules



Source: Lissoni et al.(2009)

As expected the universities' share of applied patents with academics as inventors increased with the new rules. The increase was more than 12 percentage points. Also the companies' share increased – by close to 10 percentage points. The inventors' share declined comparably, however still leaving close to 6 percent to the inventors. Whether these figures can be interpreted like the US-figures is difficult to say without further investigations of the 340 EPO-patent applications, but the aim of the new rules cannot say to have been fulfilled yet in 2003.

An analysis by Valentin;Jensen(2007) of the patenting of dedicated biotech companies had the focus on academic inventors in the applications. They compared Denmark with Sweden (still with the professors' privilege) before and after the new rules using a difference-in-difference methodology. The main conclusion is that *"…part of the* (Danish) *inventive potential of academia … seems to have been rendered inactive as a result of the reform … with a simultaneous substitutive increase of non-Danish academic inventors"*. For this specific field the new set of rules has decreased the amount of company patents with academic inventors. This may mean that the academic inventions are filed by the universities and licensed by the companies or that cooperation between (Danish) academics and biotech companies has been reduced – or both.

[15] The original database included France, Italy and Sweden, see Lissoni;Sanditov;Tarasconi(2006)

However, one ting is the legal basis; another is the attitude of the academics. A survey among life science researchers in Denmark 5 years after changing from professors' privilege to university patenting revealed that a substantial proportion were sceptical about the impact, mostly among basic researchers and the less productive ones, see Davis;Larsen;Lotz(2011).

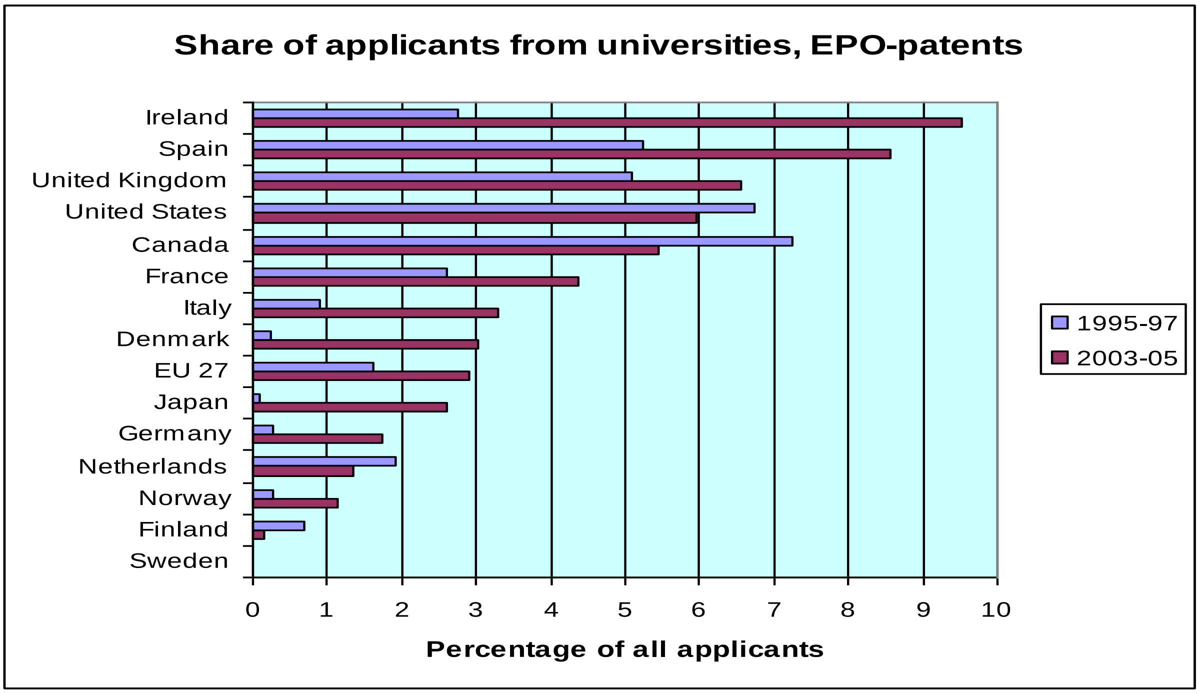
4.2. The amount of academic patents

When describing the amount of patents from universities one may either look at universities – and other public research institutions – applying for patents or at inventors being faculty members. In both cases one needs to identify the group in question, and that is not a trivial work.

The harmonisation of applicant names has former been done on an ad hoc basis, but now there have been developed algorithms to harmonise the names both for USPTO- and EPO-patents, see Hall(2010) and OECD(2010a). Still, when coding the harmonised names into sectors like business sector, non-profit sector, government sector and households – and further split the government sector into universities, public research institutions and other – then a non-negligible part cannot be identified or identified correctly. As an example of the latter, some universities have set up limited companies or non-profit institutes to take care of patenting, licensing and spin-offs (see Looy;Callaert;Debackere, 2003), and thus it may be difficult to identify the sector of the patents correctly.

In spite of these shortcomings, classification according to sector gives a good impression of the differences among countries in different periods. The most comprehensive patent statistics by sector comes from OECD(2008a), where EPO-patent applications from 1995-97 is compared with 2003-05 for a number of countries, see Annex, Table 1 and Figure 4.2.

Figure 4.2 Share of patents with universities as applicants by country, 1995-97 and 2003-05



In both periods, 4 percent of the EPO-patent applications in the world can be identified to be applied by a university, and 1.8 percent by other governmental institutions, see Annex. In EU-27, the share of universities has nearly doubled from the first to the second period, while the share of other governmental institutions has decreased by 1/3. The reason is the abolition of *professors' privilege* in a number of European countries like Germany, Denmark and Ireland, but obviously also in Japan. However, this is not the case in Sweden and Finland by 2005. There is a huge variation in the share of university-owned patents even taking the different rules in consideration, e.g. Spain and Ireland with around 9 percent and Germany with 1.7 percent. Also, the share of *Other Government*-owned patents varies a lot, from 5.3 percent in France to none in more countries. For US-patenting at USPTO Mowery;Sampat(2005) reported that the share of patents applied from research universities increased from 0.8 percent in the late 70's to 3.6 percent in 1999. No newer figures have been found.

There are more reasons to include all patents with faculty members as inventors as academic patents: The different set of rules among countries and over time for ownership of publicly funded inventions; the problem of identifying all applications from universities; the independent influence on the research of the faculty; and the potential cooperation with the business sector, see Saragossi;Potterie(2003) and Azagra-Caro (2009).

The main obstacle for valid figures of patents with faculty members as inventors is the identification of inventors, having been faculty members during the relevant time period. No systematic work on setting up algorithms to identify academic inventors has been found. Instead, databases of academic employees at universities have been used to identify potential academic inventors in the patent databases, followed by a verification procedure, see Meyer;Utecht;Goloubeva(2003). Examples of country-based estimations are Italy (Balconi;Breschi;Lissoni,2004) with 3.8 percent of EPO-patents (1978-2000) having academic inventors involved and Norway (Iversen;Gulbrandsen;Klitkou,2007) with close to 10 percent of Norwegian patents (1998-2003) with Norwegian academic inventors. Both figures are underestimates, as some inventors cannot be verified. An international example is the KEINS database of French, Italian and Swedish academics, see Lissoni;Sanditov;Tarasconi(2006). The share of patents verified to have at least one academic inventor was 2 percent in 1985 and 4 percent in 2000, see Lissoni et al.(2009). These figures are clearly underestimates due to the sampling procedure. Later KEINS was supplemented with Denmark, but the share has not been published, see Kaiser(2006).

Another way is to perform a survey like the EU-funded PatVal-EU survey, which included DE, ES, FR, IT, NL and UK. Here, 3.2 percent of the patents granted in 1993-97 by EPO had a faculty member as inventor. Further 2 percent were employed at a public research institution. These figures are to some degree underestimates, as only one inventor of each granted patent was contacted in the survey.

At the level of the individual university one finds large differences in the amount of patenting. The main factor is the fields of science and thus the main technological classes which each university cover. In the Norwegian example (see above) 21 percent of the patents in *Chemicals & pharmacy* included a faculty member, while the share was 7.7 percent for *Electronics* and only 0.4 percent for *Consumer goods*. In a parallel study in Finland, see Meyer(2003), the top 4 areas among a more specified classification were *Telecommunications; Analysis, measurement, control; Pharmaceuticals;* and *Biotechnology*. Also, more individual conditions may determine the amount of patenting from universities. Foltz;Barham;Kim(2000) has analysed a number of these factors using US-data. They end up with a model of the number of university patents including significant factors like total Government R&D funding, rating of the graduate schools at the university and the number of employees at the office of technology transfer (quadratic relationship). In a parallel model by Azagra-Caro;Lucio;Gracia (2003) for Portuguese data the R&D funding from industry is also significantly influencing the level of university patenting.

4.3. The impacts of academic patenting

The possible impacts of patents were discussed in Part 3.2. The impacts were classified as values either of economic, legal, technical or scientific nature. The contents of these value change somehow when academics are involved in a patent, either as applicant or inventor:

- For academic applicants **the economic value** would primarily come from licensing or spin-off companies[16], while academic inventors would get some monetary or promotional reward and/or get better access to government and industry funding of new long-term research, according to Azagra-Caro;Lucio;Gracia (2003). In fact, Lach;Schankerman(2003) found that when academic inventors were paid a larger share of the royalties, the total royalties increased, as more and better inventions were generated by the academic inventors.

  In the models of patent value, based on the PatVal-EU survey, there were marginal declines in the value, when the inventor was employed in a university or public research institution, while there were marginal increases when university-labs or non-patent literature have been involved and when public funding has been involved, see Gambardella;Harhoff;Verspagen(2008). Also, Sampat;Ziedonis(2010) have found a positive correlation between the number of forward citations and whether a university-owned patent is licensed. For the probability that patents lead to spin-offs, Shane(2001) has set up a model, where the importance, radicalism and scope of the patents[17] were significant indicators. Sapsalis;Potterie(2007) have estimated a model for the value of university-owned patents, using forward citations as proxy for value and selecting proxies for technical knowledge (self and other public backward patent citations), scientific knowledge (self non-patent citations), cooperation (co-assignees by sector) and protection (applied at USPTO; at JPO). This model has been estimated with similar corporate patents by Sapsalis;Potterie;Navon (2006) and the structural differences are few.

  The understanding of economic value in the paragraph above is purely the profit of the owner of a patent. Trajtenberg(1990) tried to broaden this by introducing the social value, defined as the increments in producer and consumer surplus. In later years, the social value is seen as one part of economic value, the second being the private value, see i.e. Bessen;Meurer(2008). While the social value is a very relevant extension for public funded patent applications, it is very hard to get a proper estimation of the benefits for consumers and society. A more qualitative assessment would be needed, see the general discussion by Mazzolini(2005).

- The elements of **legal value** comprise in general *enforceability, scope breadth, validity confidence, sustainability in opposition proceedings,* and *litigation avoidance* according to Gibbs(2005). The importance of these elements depends on the use of the patents. According to the PatVal-EU survey (Giuri;Mariani, 2005) universities and public research institutions use a higher share of their patents for licensing and for stock holding (i.e. unused) and lesser shares for internal use and for blocking competitors than other applicants. When licensing the quality of the claims is important, but – according to Meyer;Tang(2007) – normally the licensees of university patents are expected to involve in any litigation (or take part in it). Also, if patents in

[16] A new company expressly established to develop or exploit IP or know-how created by the PRO and with a formal contractual relationship for this IP or know-how, such as a license or equity agreement. Include, but do not limit to, spin-offs established by the institution’s staff. Exclude start-ups that do not sign a formal agreement for developing IP or know-how created by the institution.

[17] Time-invariant measures of number of forward citations (=importance), number of other 3-digit patent classes in backward cited patents (=radicalism) and number of international patent classes in the patent itself (=scope).

the portfolio of unused university patents are threatened with litigation, universities typically try to make a license agreement.

- **<u>The technical value</u>** comprises of *technological advancement, technical sophistication, coupled technologies* and *cogency* according to Gibbs(2005). These concepts can only partly be measured by available patent data. Suggestions are backward patent citations, (advance-ments), forward citations (sophistication), differences in IPC-classes (coupling), and number of inventors/applicants (cogency) – all measured relatively within some technical class. Gibbs used technical classes based on latent semantic analysis.

  Trajtenberg;Henderson;Jaffe(1997) have suggested a couple of measures which describe the technical value. From the backward citations they suggest:

  - ORIGINAL, a Herfindahl index of concentration of the backward citations on IPC-classes subtracted from 1, so higher values represent a broader coverage.
  - $TECH_B$, a measure of the distance in the technology space[18]

  The same measures are defined, using the forward citations. They are named GENERAL and $TECH_F$. Estimations on basis of patents granted in 1975 and 1980 showed only few differences between university patents and corporation patents.

  At applicant-level Guan;Gao(2009) suggests using the *h*-index[19]. A value of *h* for patents would mean that *h* of the patents from the applicant (e.g. a university) have received at least *h* citations from later patents. Kuan;Huang;Chen(2011) refines the measure by taking the full curve of the ranked *h*-index vs. total citations in consideration.

- For public research institutions and universities a fourth type of value, **<u>the scientific value</u>**, has been introduced, see Freedman(1987). Trajtenberg;Henderson;Jaffe(1997) has suggested a couple of measures which may be used to describe the scientific value:

  - SCIENCE, the share of non-patent citations among all backward citations.
  - $IMPORT_B$, the sum of the backward citations and their citations, discounted by 0.5, that is the base of previous important innovations for the patent.
  - $IMPORT_F$, the sum of the forward citations and their citations, discounted by 0.5, that is the follow-up advances partly build on the patent.

  For universities higher values are expected for SCIENCE and $IMPORT_F$ and lower for $IMPORT_B$, compared to corporations. This is also the case with the 1975-80 US-patents analysed by Trajtenberg;Henderson;Jaffe(1997).

4.4. The effects of academic patenting

As illustrated in the former Part there has been a massive increase in patenting by universities and faculty members. This has been caused by a number of factors, starting with a political will to ease the way from scientific findings to inventions and commercial use by changing the set of rules and the funding systems. Most universities and faculty have accepted these changes of priority and have

[18] 0=3-digit in common; 1/3=2-digit in common; 2/3=1-digit in common; 1=no common digits.
[19] Developed by Hirsch(2005) for bibliometrics.

established or expanded Technological Transfer Offices (TTO's) with the aim of evaluating innovations, patenting and licensing or establishing spin-offs. In Denmark, e.g. both the number of patent application and the signed license agreements involving universities and public research institutes were more than doubled from 2000 to 2009, see FI(2010a).

The effects of this increased academic patenting are vigorously debated at academic and policy level, see e.g. Leaf(2005). An actual case – the entrepreneurial transformation of Chalmers University of Technology – has been described by Jacob;Lundqvist;Hellsmark(2003): the role of uncertainty, the controversial stance of exploiting public funded research, and taking care not to be too successful, as that might perhaps reduce the public funding.

On the one hand, a number of benefits for the universities, the industry and society have been pointed out and investigated (see Murray;Stern,2007 including references). Summarizing they conclude that

> *IPR (*Intellectual Property Rights*) may facilitate the creation of a market for ideas, encourage further investment in ideas with commercial potential and mitigate disincentives to disclose and exchange knowledge which might otherwise remain secret. … In other words, IPR may enhance the ability of society to realize the commercial and social benefits of a given discovery.*

On the other hand, a number of negative effects of academic patenting for science, teaching, industry and society have been pointed out and heavily investigated. In a review article by Baldini(2008) the arguments and evidence from 82 papers up to 2006 are sorted and presented. Much of the evidence is, however, related to a specific field of science like life science and biotechnology or a specific university/country. This could be one of the reasons for the differing conclusions observed. Baldini categorized the negative effects in 4 groups: Threats to scientific progress, changes in the characteristics of the research performed, threats to teaching activities, and threats to industry.

A. Threats to scientific progress

The main threat to scientific progress is <u>disclosure restrictions</u> during the progress of researching and developing some that might become patentable. This is even contractual in most cases, when projects include cooperation with industry, see a survey by Lee(2000). Of the same reasons there may also be <u>restrictions on data sharing and research tools</u>.

A more complex threat is that the expansion of patents and other IPRs is "privatizing" the scientific commons, often ending up with fragmented ownership. This effect is called <u>anti-commons</u> as it inhibits the free flow and diffusion of scientific knowledge and the ability of researchers to build cumulatively on each other's discoveries, see Heller;Eisenberg(1998). Murray;Stern(2007) found evidence for a general, modest anti-commons effect by pairing patent-paper and use a difference-in-difference methodology. Bahn;Hansen(2009) has conducted a survey among Danish biotech companies and found some evidence of an anti-commons-effect. Maurer(2006) conducted a case study in biotechnology (human mutation) and found a heavy anti-commons effect that affected around 100 academic biologists. They even tried to make a mutual agreement, but ended in a deadlock-situation.

B. The characteristics of the research activities performed

The characteristics of the research activities performed may also be changing due to more focus on patenting and spin-offs. This effect has been investigated in a large number of analyses. The most direct effect is the potential <u>substitution between basic and applied research</u>, or by the words of Nelson(2001): *patenting crowding out basic research*. Azoulay;Ding; Sturart(2009) found that among

4,000 US life scientists some of the patentees were shifting their focus, while Looy et al.(2004, 2006), Breschi;Lissoni;Montobbio(2007) and Thursby;Thursby(2002) could not find evidence for such a hypothesis based on researchers at University of Leuven in Belgium, Italian academics and selected US universities. Gulbrandsen;Smeby(2005) modified the findings by showing that industrial funded scientists in Norway were involved in more patenting and did more applied research than the rest. Also Thursby;Fuller;Thursby(2007) showed that the group of academic innovators having firms as the applicants of their patents did less basic research.

Another obvious effect would be a substitution between publications and patents. This has been investigated in a numerous number of analyses, see the review of Larsen(2011). Gulbrandsen; Smeby(2005) did not find any correlation between publications and patents (or entrepreneurial activities) for inventors, Agrawal;Henderson(2002) could not make patent volume predict publication volume for MIT-inventors.

This is contradicted by Breschi;Lissoni;Montobbio(2007), as they found a rather a strong positive relationship between publishing and patenting, and also in basic science, meaning complementarity instead of substitution. However, Crespi et al.(2011) found a substitution effect above a certain level of patenting output, while below this level patenting complemented publishing. More findings on complementarity is found by:

- Stephan et al.(2007) in the form of strong correlation between number of patents and publication in the US survey of doctorate recipients;
- Renault(2006) in a logistic regression where an increase in publications yielded a 6 percent increase in patenting;
- Looy et al.(2004,2006);
- Klitkou;Gulbrandsen(2010) conditioned on field, university, age and gender;
- Carayol;Matt(2004) with French laboratories as units (highly publishing labs also patent much);
- Meyer(2006a,b) in European nanotechnology where patenting scientists outperformed the solely publishing peers in quantity of publications;
- Looy et al.(2011) in a model with European universities, and neither with trade-offs to contract research or spin offs;
- Thursby;Thursby(2011) in models of invention disclosures of faculty members.

The relation between patenting and publishing seems to be dependent of the sector of the applicant. Czarnitzki;Glänzel;Hussinger(2009) found a negative correlation with the quantity of publication output when corporations were applicants and a positive correlation when others were. Wang;Guan(2010) found for Chinese nanotech-researchers a negative correlation when they them-selves were assignees. Fabrizio;Minin(2008) found for a broad US-sample a positive correlation between publishing and patenting when the university of the inventor is applying, but no correlation when companies or themselves are applying. However, Breschi;Lissoni;Montobbio(2007) found that the relationship between patenting and publication was even stronger when the patents were applied by companies, probably caused by the advantage and inspiration to research from solid linkages with industry. Finally, Calderini;Franzoni;Vezzulli(2007) found no difference between firm applicants and universities, or inventors themselves.

These findings are expanded in other studies: Noyons et al.(1994) found for academic laser medicine patenting that when an academic was preparing a patent application, the activities in science were increased and there were more cooperation with companies. Azoulay;Ding;Stuart(2007,2009) found for academic life scientists that patenting events were preceded by a flurry of publications, so patenting behaviour was also a function of scientific opportunities. This is supported by Calderini; Franzoni;Vezzulli(2007) for Italian academics in Materials Science. They found that when scientists that were moving along applied research trajectories performed more academic research, it lead to more exploitable results, compared to their colleagues engaged in the quest for very fundamental understanding. More academic research by them only made it more unlikely that they would find the time to produce industrial applications. Azagra-Caro;Luico;Gracia(2003) estimated a production function for patents including costly and long-term elements, indicating that patenting is the outcome of research at the frontiers of science. Looy et al.(2004) concluded that there also is a Matthew-effect (see Merton,1988) over time with more and diverse resources available for those combining entrepreneurial and scientific performance.

Another aspect of the characteristics of the research activities performed is the quality of publications[20]. The simplest indicator of the quality of an article is the citations in a given period. Breschi; Lissoni;Montobbio(2007) used that and found a positive relationship with patenting. So did Azoulay; Ding;Stuart(2009), describing the effect as weak and positive, and Agrawal;Henderson(2002) which could not make patent volume predict publication volume, only publication citations. Meyer(2006a,b) observed a bend in the linear relation between patenting and citation of publications at the very top. This is confirmed by Fabrizio;Minin(2008), using an econometric approach: repeatedly patenting faculty members received fewer citations to their publications, and that could be a sign of a re-focusing of their research and of property rights inhibiting the use of their published research in follow-on studies.

Czarnitzki;Glänzel;Hussinger(2009) found a positive effect when the inventors themselves or NPI's are the applicants, but found a negative effect to the citations of publication output when corporations are applicants. They introduced the *Journal Impact Factor*[21] as a measure of quality and used this as weights of the publications. This reduced the effects some, but still they were significant. Calderini; Franzoni;Vezzulli (2007) also used the Journal Impact Factor as measure of quality of publications. In their econometric model the impact factor was only significant, when interaction with the number of articles was included. This means that patents are more likely to come from medium-to-high impact research, but less likely from very high impact research – and especially not if they also were very productive.

C. Threats to the teaching activities

There are four threats to the teaching activities according to Baldini(2008). Firstly, Geuna;Nesta(2006) has argued that teaching activities are likely to suffer the highest time and commitment reduction when engaged in patenting. Secondly, students may be directed into topic areas useful for the patenting activities and even transfer students unpublished works or ideas to own patenting. Thirdly, graduate or PhD-students may receive funds from industry on the condition of keeping emerging proprietary information confidential. Fourthly, work in laboratories and informal discussions with faculty could be hampered by the commercial involvement of faculty.

[20] The quality of patents was addressed in Part 4.1.
[21] Definition: JIF(X) = the average number of citations in a given year of all articles, published in a journal during the preceding X years.

The evidence of these threats are weak, see the references in Baldini(2008), and one should not forget the positive effects of involving students at all levels in applied research activities including contacts to industry.

D. Threats to industry

The first type of threat to industry of an increased patenting activity by universities is the risk of restrictions and delays on knowledge diffusion. Mowery et al.(2001) concluded that other types of knowledge diffusion to industry are being hampered by the patenting activities – and this may be enforced through administrative emphasis on licensing by TTO's at universities. The second threat regards the industry-university cooperation. Hall;Link;Scott(2001) found that barriers from university-industry partnership were much about appropriability.

The evidence of these threats are weak, see the references in Baldini(2008). Crespi et al.(2011) only found them where much patenting were taking place, while a positive correlation between patenting and other types of cooperation with industry was found with more modest stocks of university patenting. One should not forget the positive effects for industry and society of academic patenting and licensing, ensuring that inventions are made applicable and better spread through the disclosure of patents and thus promoting cooperation with industry.

4.5. Academic patenting as linkages with other sectors

The most important political motive to promote academic patenting is to increase and improve the diffusion of knowledge from public funded science to technology, i.e. from universities and PRO's to society and industry. The possible linkages to enhance this diffusion through patenting will be described along with potential indicators and evidence of their measurability and magnitude.

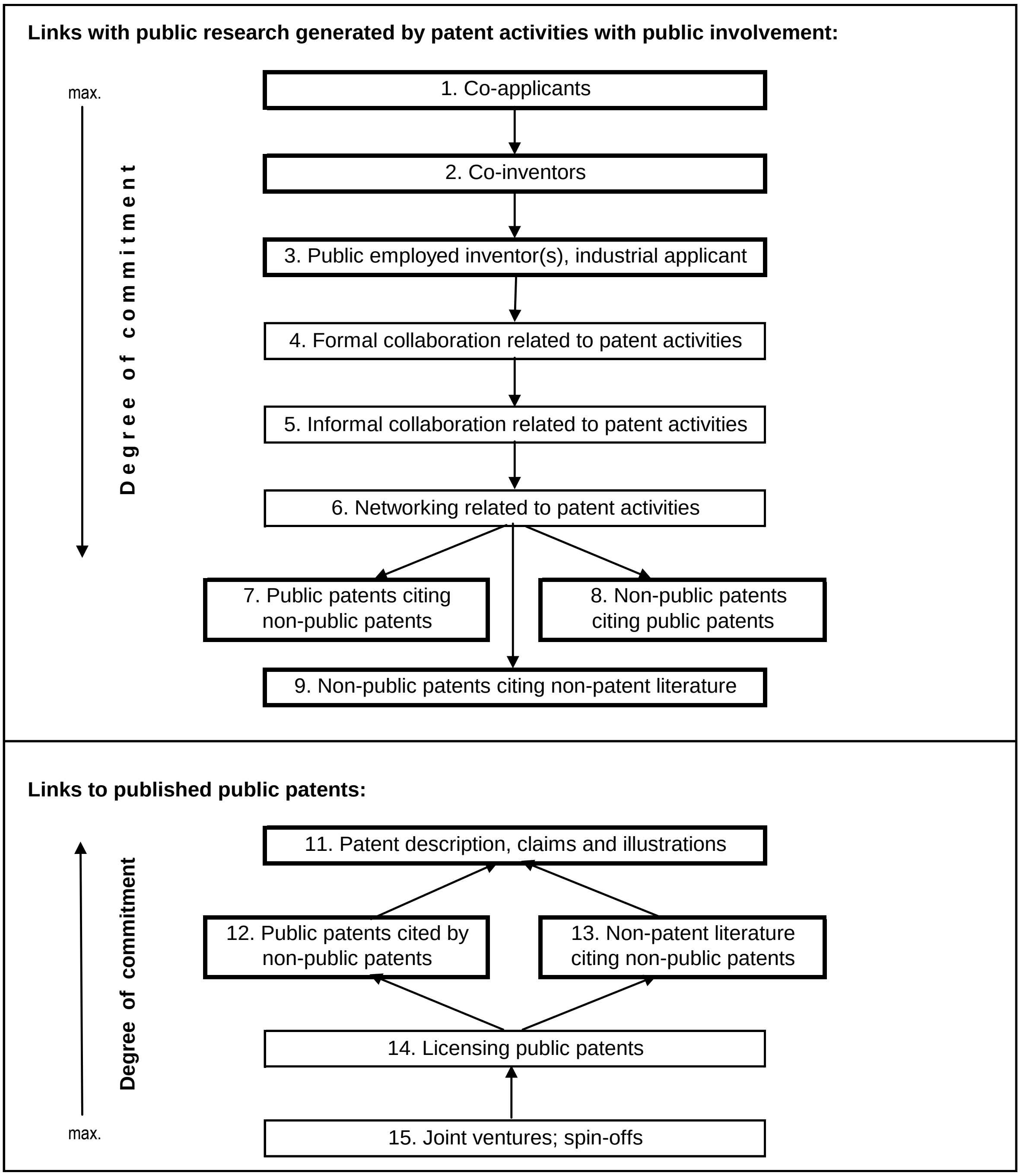
It is important to stress that patenting is only one of more ways to diffuse knowledge from public funded science. Other ways are (see a more detailed list in Tijssen,2006):

a. Publications (articles, proceedings, and reports)
b. Conferences and meetings
c. Consultancy (informal and formal) and contract research
d. Hires, training and exchanges
e. Joint ventures and spin-offs

Cohen;Nelson;Walsh(2002) reported from a US-based survey on industrial R&D in 1994 that a-c were much more important for knowledge diffusion than patenting, while d-e had the same importance. Roughly the same results were found by D'Este;Patel(2007) in a UK-survey, by Murray(2002) in bio-medicine and by Ramos-Vielba et al.(2010) in Andalusia. Still, many academics are involved in patent-related cooperation and also, some of the other five types of cooperative activities may indirectly promote patenting in industry. In all, patenting is an important dimension of knowledge diffusion, related to spin-offs and joint R&D projects according to a factor analysis by Ramos-Vielba et al.(2010). Two other dimensions refer to *training of HR* and *consultancy/common project work*.

There are more options when considering indicators for patent-based linkages between academia and industry. This is described by 14 boxes in Figure 4.3. The headline implies that all boxes relate to situations with both academics and industry involved, e.g. "*1. Co-application*" implies that a public and a private unit are among the applicants. Also, it is implied that non-patent literature mentioned in the prior arts are produced by academics, though some are not, see Callaert et al.(2006)[22].

Figure 4.3: Linkages between public research and industrial R&D through patents



First, the potential indicators are divided into two groups, those related to the creation of a patent (1-9) and those related to existing patents (11-15). Next, they have been sorted according to the degree of commitment that is associated with the linkage. Also, boxes in **bold** frames indicate that the

[22] In two samples from USPTO and EPO covering 1991-2001 at least 74 % and 92 % were classified as scientific citations, though some may be produced by scientists from the private sector.

information is available form the patent applications, given the applicants and inventors can be classified as public/ non-public where needed. This is not a given thing; see the discussions and references above.

Some comments to each potential indicator, based on investigations so far are given below:

(1) Co-applicants. The sector of most of the applicants can be identified after a name harmonization, so valid figures for co-application may be retrieved from patent databases. However, no examples of this have been found. Instead, examples using surveys can be found.

From the results of the survey of European inventors (PatVal-EU) published by Giuri;Mariani et al. (2005) and Fontana;Geuna(2009) one finds that among the public applications 9 % were co-applied with some other independent organisation (which could also be public!). For the subgroup *Universities*, 5.5 % of the applications were co-applied, while for non-public applicants (mostly firms) the share of co-application was only 3.3 %.

(2) Co-inventors. As described in Part 4.2 much patenting involving public employed inventors do not include a public organisation among the applicants. A large part of these patents would include co-operation between public employed scientists and non-public employed staff (scientists or technicians). Information on sector of inventors is not available in the patent databases. Ad hoc identification of academic inventors has been employed either based on surveys or on matching databases of university staff.

In the PatValEU-survey, see above, 44 % of the patents with public employed inventors had co-inventor(s) from another organisation – which could be another public unit. For the other patents, only 13 % had co-inventors, see Fontana;Geuna(2009). This survey-finding is confirmed by an Italian register-based study by Balconi;Breschi;Lissoni(2004) of networks using graph theory. The average number of inventors is 3.0 for academic teams and 1.7 for teams without academics. The average *degree centrality*, that is the number of connections through co-inventors, is 3.9 for academic inventors and 2.0 for non-academic inventors, but like the PatValEU-survey some connections would be with other academic inventors.

The co-invented patents with public employed inventors can be used to form a mapping of co-invention in a specific technical field, see Meyer;Bhattacharya(2004) for *thin films* and Klitkou; Nygaard;Meyer (2007) for *fuel cells*. One or more of the measures from graph-theory could then be used as indicators.

(3) Public inventor/non-public applicant. Another type of patenting involving public employed inventors is patents which only have non-public applicant(s). The same problem as in (2) on identifying sectors of inventors exists here – and the same methods have been used, see the references in Part 4.2. An example was the register-based KEINS-project, revealing e.g. that 73 percent of all Danish academic EPO-patents in 2000-03 were applied by firms, see Figure 4.1.

(4-5) Formal and informal collaboration. There may be partners involved in the research leading to a patent but without having them included as inventors. They may be involved in a formal manner including some contract between the parties or they may be involved in a more informal manner. This information is not included in patent applications, so the information has to be collected through surveys.

The PatValEU-survey included a question on formal and informal collaboration. 16 percent were involved in formal and 5 percent in informal collaboration among all surveyed. Fontana;Geuna (2009) did split this up according to sectors, but did only provide the sum of formal and informal collaboration. For patents with public employed inventors there was reported collaboration for 53 percent of the patents, of which some could be with other public-related collaborator. For other patents only 19 percent reported formal or informal collaboration. Cohen;Nelson;Walsh (2002) found that 36 percent of R&D-performing companies in a US-innovation survey expressed importance for their R&D from informal interaction with academia and 21 percent for contractual research. However, this importance may not have been implemented in patents.

(6) Networking related to patent activities. Inventors may get hold of further information to support their patent-related research in a more loose way. Inventors may be inspired by academia through conferences and workshops, through personal contacts and through the use of university labs and libraries. This type of information can only be collected through surveys – and even that is not without problems. The PatValEU-survey asked about the importance of a number of sources for the patent-related research, among them *technical conferences and workshops* (important for 38 percent) and *university labs* (important for 22 percent). Cohen;Nelson;Walsh(2002) found that 35 percemt of the R&D-performing companies expressed that meetings and conferences have importance for their R&D. However, this importance may not have been implemented in patents.

Another way to describe the network of academic inventors in a specific technical field would be to find their co-authors of their scientific papers and make a mapping of the network, see Klitkou; Nygaard;Meyer(2007).

(7-8) Backward patent citations between public and non-public patents. Citations are an important indicator of the value of the patent, se Part 4.3, but citations also reveal some type of linkage between two patents. Jaffe;Trajtenberg;Fogarty(2000a,b) found in a survey of 330 patents from all sectors that 18 percent have had direct communication with the inventor of a cited patent and another 18 percent have studied the patent thoroughly. On the other hand, one-third had not learned about the cited patent before the survey, probably because the reference has been put in the application by an attorney or examiner. This tells that backward patent citations are rather noisy indicators of knowledge diffusion between inventors, even if self-citations are excluded. This has been confirmed by Alcácer; Gittelman(2006).

Nelson(2009) pointed to another problem with citations – that they only cover a little part of the knowledge flow. One way to improve that is to include the patents that cited the cited patents, called “two-step” citations by Nelson. In his case – all patents in DNA technology – the two-step citations increased the number of cited public research organisations and universities fourfold. Still, more needs to be included according to Nelson: non-patent literature and licenses see (9) + (14).

More levels of citations may be included, forming patent citations networks. These may be described by *Connectivity analysis*, see Verspagen(2005). Some measures of the networks have been defined, and the methodology seems to give good insight in specific areas, see Fontana; Nuvolari;Verspagen(2009) and David;Fernando;Itziar(2011), but one single indicator to be used for a more general purpose has not been defined.

(9) Non-public patents citing non-patent literature (NPL). Most citations of non-patent literature in non-public patents would be linkages between science and technology, see Callaert et al.(2006), and according to Pavitt(1998) and Tijssen;Buter;Leeuwen(2000) thus be telling how university research contributes to technical changes. However, not all of these citations would be between public science and non-public technology. E.g. reported Tijssen(2001) about self-citations by Dutch researchers from large companies like Philips. Citations inserted by the examiner is another factor that makes this indicator a noisy one.

Bramstetter;Ogura(2005) found that there was an increase in NPL’s at USPTO during the 1990’s, but most came from new technologies. Verbeek et al.(2002) found a very skewed citation distribution with 65 percent of the USPTO-patents in the late 1990’s without NPL-citations; also they found large differences between technologies. Verbeeck;Debackere;Luwel(2003) described how to use NPL's for regional analyses. Thomas;Breitzman(2006) found that one of the indicators for a patent to be an important, high-impact technological invention is citations of government-funded scientific papers. From the other point of view, Meyer;Debackere;Glänzel (2010) found that patent-cited papers were cited more than other papers, thus also having a larger scientific impact.

The meaning of the indicator has been discussed, but now there are general agreement that there is no inherent causal interaction from science to technology (the linear model), but much more reciprocal impact. This is argued by Meyer(2000a), and Hicks et al.(2001) found that in some of the new technologies most NPL's in patent applications were *scattered, older set of documentation, much of which is not research related*. Instead, the technology referenced in the patent application was newer than the state of science. Even patenting may be too slow for these technologies, so firms have to rely on lead time and secrecy, see Cohen;Nelson;Walsh(2000).

Nelson(2009) included the NPL's in his combined indicator of knowledge spill-over from patents. In this way he included more universities and other public research organisations which were not included when only looking at patent citations and also when this included two-step citations. In his example the number of universities was doubled when also including the NPL's.

(11) Patent description, claims and illustrations. The information presented in a published patent application is an explorative way of passing on knowledge. When academics are involved as inventors in patent application, this would be an open linkage to the public. At the same time, of course, some propriety rights are reserved.

(12) Public patents cited by non-public patents. These forward citations are mirrors of (8). The survey referred in (8) by Jaffe;Trajtenberg;Fogarty(2000b) also included a parallel sample of the cited inventors. As expected the cited inventors reported a higher likelihood that the citing inventors had been aware of or relied upon knowledge in their patents. This diminishes the noise in this indicator when used to measure knowledge spill-over.

(13) Non-patent literature citing non-public patents. These citations are reverse compared to (9) and thus indicators of science receiving knowledge flow from technology. Glänzel;Meyer(2003) found that almost 30,000 patents (from USPTO) were cited by scientific research papers included in the bibliometric database ISI in 1996-2000. However, a good deal of these patents would probably be public patents and even self-citations by academics. A later study of the biotech field, see Glänzel; Zhou(2011) revealed that the patent-cited papers performed better than other biotech-paper regarding Journal Impact and relative performance.

(14) Licensing public patents. The licensing of publicly owned patents has become a major goal for many universities, most having set up *Knowledge* or *Technology transfer offices* to promote this. Murray(2002) found in in-depth interviews that licensing is an important way of co-mingling between universities and companies and Thursby;Kemp(2002) found that there was an enormous increase in the licensing by US-universities in the 1990's.

In the PatVal-EU survey (see Giuri;Mariani,2005) the use of patents for licensing was much higher for public employed inventors, 23 percent compared to 5.3 percent for other inventors. However, in the analysis of a survey among US manufacturing companies with R&D Cohen;Nelson;Walsh (2002) found that licensing is only of major importance for 10 % of the companies (see the higher shares for (5) and (6)). The absolute number of licenses per year obtained by Danish universities and PRO's can be read from the Danish statistics, see FI(2010a), but not in relation to their stock of granted patents.

The analysis of Nelson(2009) indicated that licensing does identify more linkages on top of those identified through patent citations. The linkages identified by "two-step" citations were nearly doubled when including licensing organisation. Also, Fontana;Geuna(2009) found substitution (negative relationship) between licensing and co-operation, be it either as co-assignment, co-invention or other collaboration.

(15) Spin-offs. The creation of a new firm is an alternative to licensing regarding the commercial exploitation of a public-owned patent. The way such firms are formed differs depending on rules, the applicant(s) and type of institution. Still, it is a relevant indicator as it is a main goal to promote spin-offs for most technology transfer offices.

In the PatVal-EU survey (see Giuri;Mariani,2005) 5 percent of the inventors reported that new firms have been created from the patented innovation. This figure includes all sectors. Shane;Kharuna (2003) only investigated patents from MIT in1980-1996, and among these public patents 26 percent were exploited by starting up a new company. In UK, 175 new spin-offs were reported for 2002 (see Davis,2002), while the figures in the Danish statistics are very small, from 2-16 per year in the 2000's, see FI(2010a).

The many types of linkages can be used individually as indicators or some of the linkages may be chosen and even combined in a compound indicator. The only example of this is Nelson(2009) who calculated the union of organisations which had either patent citations (one- and two-step), NPL-citations or licenses common with a portfolio of patents. An EU Expert Group has recommended some core indicators for technology transfer offices, including the number of patent applications, patent grants, licences executed and spin-offs established and license income, see EU(2009) .

All linkages described were supposed to be between universities or public research institutions and industry, though much of the evidence presented did not distinguish between sectors. The linkages between universities/public research institutes themselves could be included, eventually as separate indicators. A further expansion would be to distinguish between regional, national and international linkages.

5. Allocating research funding using patent performance indicators

In this Part it will be discussed if and how some of the data on academic patenting presented in the last Part could be included in performance indicators of universities and PRO's when the purpose is to let the performance indicators be part of the allocation mechanism of public research funding. The underlying basis for this discussion will be that some performance indicators are needed to ensure a proper allocation of research funding. This will be further discussed in a later paper.

5.1. Any patent performance indicators to be included

Most of the arguments in Part 4 regarding the usefulness and validity of patenting for universities and PRO's also hold good when considering the inclusion of patent indicators in the performance indicators of universities and PRO's for allocating research funding. The main reason is that most countries have accepted the triple-helix concept for universities, the new, third element being the communication and exploitation of research through relations to industry and society.

One part of the policies to promote the triple helix would be to include the level of performance regarding patents in the allocation of basic and other funding. However, as described in Part 4.5 there are other ways of establishing relationships with industry and society, and these are often considered more important, see also Meyer(2009). Also, too much focus on the technological aspects may have a negative impact on research and teaching activities. However, the evidence presented in Part 4.5 did not confirm this in general. Rather, it seems as if scientists moving along applied research trajectories and doing more (impactful) academic research end up with more exploitable results, see Calderini; Franzoni;Vezzulli(2007). Thus, a balance between science and technology is needed as part of an institutional policy, see Looy et al.(2004) and also regarding teaching, see Baldini(2006).

Another point of view is that public patenting often generates funding from licensing and spin-offs, exacerbating the differences in financial resources (Geuna;Nesta,2006), so why increase that further through extra public funding to those patenting. One could ask the same question regarding the inclusion of external non-public funding in the performance indicator for allocating public funding. Both are seen as seals of approval, so more public funding is expected to give good value for the money!

Finally, patenting has a different volume in different fields of science, so one might – like Coccia(2001) when modelling "R&D Performance Score" – exclude patent indicators in some fields.

In all, it seems relevant to include patent indicators, but some caution should be exercised: not making the indicator dominant and also considering including other indicators of the third element in the triple-helix concept. An awareness of the possible risk of distortion of the indicators through misuse – patenting for the sake of patenting – is needed for these and other indicators measuring performance and being used for allocating funds. One way would be not to make the indicators too simple.

5.2. Type of patent performance indicators to be included

In Part 4 a number of potential indicators for public patenting were presented, based on the more general approach in Part 3. These Parts showed that simple counts of patents would be unreliable indicators, as the value of patents is widespread and very much skewed. While patenting may be seen as an object in itself, also obtaining the object of involvement with industry and society through patenting would be relevant to measure. The income side – generated by licensing and spin-offs – is a third dimension to take into account.

When the purpose of the performance indicators is to be part of the decision of the amount of funding to universities/PRO's in the coming year/period, then the indicators used should not be too outdated, that is depending on achievements performed years ago. E.g. Daim et al.(2007) calculated an average time lag of 6 years between the research funding and the granting of the derived patents in a US-based survey. The first decision, when designing the indicators, would thus be to delineate which patents to include, time-wise but also regarding patent offices and applicants.

A. The amount of patents:

Patents might be included in a performance indicator as soon as it is disclosed from the patent office of the first filing. However, the value of a published patent application depends on the office of publication and the filing procedure used, see Guellec;Potterie(2000) and Lanjouw;Schankerman (2004). The latter has to be taken into account, as the filing strategies may differ much between universities, see Meyer;Tang(2007)'s findings through interviews with British TTO's. This means that some weighting is needed if more ways of filing patents are to be included. This would be of further relevance if also patents with academic inventors and non-public applicants are to be included in the performance indicators.

Time-wise, it would probably not be acceptable to include the full portfolio of patents from a university, as some of the patents might be up to 20 years old. Instead, some time limit is needed, e.g. 5-6 years, see Meyer;Tang(2007). This means that published patent applications would need to be the main part of the portfolio. Any granting within the period chosen is known to increase the value and thus be a part of the weight to assign, while the expected value might decrease as the period is running out without any granting. If a patent application is withdrawn or not renewed/maintained, the value would turn to zero – and so should the weight.

In Part 4 it was argued that both patents with universities as applicants and patents with faculty members as inventors could be included in the group of public patents. This needs to be further considered, when the purpose is to construct performance indicators for public funding and the universities as employers hold the first right to the inventions of their researchers. However, when looking at Figure 4.1 from Lissoni et al.(2009) and the arguments of Meyer(2009) one sees that an inclusion would better cover diffusion of knowledge from science and linkages between academia and industry.

The question of identifying patent applications from universities and applications with public-employed inventors has been addressed in former parts. Both sector- and name-identification of public applicants and name-identification of academic inventors are time-consuming activities, the latter so much that other methods are needed like in the KEINS-database, see Lissoni;Sanditov;Tarasconi (2006) or by asking the faculty members to make reporting.

Another option would be to use the surveys on *University Commercialisation Activities,* which are conducted in more countries. In USA and Canada they started in 1991 as a *Licensing Activity Survey*, see AUTM(2010), in UK in 2001 (Binks;Vohora,2003) and in Denmark in 2000, see FI(2010a). These surveys include data on patents (applications and grants), licenses, spin-offs and revenue from the activities for each university and other public research organisation. The surveys would need to be extended regarding the identification of each patent and regarding patents with employees as inventors and another legal unit than the university/PRO as applicants.

B. The value:

A number of patent data was identified from the patenting procedure in Figure 2.1, and in Part 3.2 many of these data were identified as indicators of (expected) impact and value of patents. Some of these indicators were pointed out as specific suitable for academic patenting in Part 4.3, taking into account the main uses of academic patenting – licensing, spin-offs, portfolio formation (stock holding) and royalties (as inventors). The performance indicators for patenting would be a subset of those presented in Part 4.3, taking into account the demand for timeliness and broad coverage regarding patent offices and universities/PRO's as applicants and employees as inventors.

Some of the indicators can only be used partially, as only interim outcome within the recommended time frame will be available. This applies to forward citations, granting, renewals, licensing, spin-offs, opposition and litigation. As these indicators were found to be highly correlated with some of the dimensions of value of patents in Part 3.2, they should not be left out in advance, but be handled according to their limitation, that is being conditional on the time since publication of the patent.

Table 5.1 gives a list of the indicators proposed, mostly on public or science-related patents. Also, the simple (log)-count or yes/no is included for the type of indicators mentioned.

Table 5.1. Indicators of patent value for performance indicators for allocating research funds

Time	Type of indicator	Indicator	Used by
Patent application	Protection	(Log of) no. of patent offices	
		USPTO	Sapsalis;Potterie, 2007
		JPO/Triadic	Sapsalis;Potterie, 2007
	Technical classes	(Log of) no. (3-digits)	
		Difference	Gibbs, 2005
		Distance	Trajtenberg;Henderson;Jaffe,1997
	Claims	(Log of) no.	
		Lenght, type	Neifeld,2001
	Backward citations	(Log of) no.	
		Self citations	Sapsalis;Potterie, 2007
		Public citations	Sapsalis;Potterie, 2007
		Citations of the citations	Trajtenberg;Henderson;Jaffe,1997
		Concentration of citations in IPC-classes	Trajtenberg;Henderson;Jaffe,1997
		Scope breadth	Gibbs, 2005
	Non-patent citations	(Log of) no.	
		Self citations	Sapsalis;Potterie, 2007
		Share of all citations	Trajtenberg;Henderson;Jaffe,1997
	Joint applicants	(Log of) no.	
		Public	Sapsalis;Potterie, 2007
	Joint inventors	(Log of) no.	Gibbs, 2005
Published patents	Forward citations	(Log of) no.	
		Concentration of citations in IPC-classes	Trajtenberg;Henderson;Jaffe,1997
	Granting	Granted	
		Probability of being granted	Hall;Jaffe;Trajtenberg,2005
After granting	Renewals	Renewed	
		Probability of renewal	Zeebroeck,2009
	Licenses	Licensed	
		Probability of being licensed	Sampat;Ziedonis,2010
	Spin-offs	Spin-off"s	
		Probability of being a spin-off	Shane,2001

One also needs to relate to the dimensions of value. Which of the dimensions described in Part 4.3 should be included, if not all. There are some overlaps between the indicators suggested for measures of the economic, technical and scientific value of academic patenting, while the relevant parts of the legal value is concentrated on the quality of the claims, see Part 4.3.

C. Linkages:

As described in Part 4.5 patenting is one of more ways of meeting the political objective of establishing knowledge flow from universities and PRO's to the business sector and society. This makes it relevant to include this aspect of patenting as a performance indicator for allocating research funds.

Figure 4.3 gave an overview of possible patent-based linkages between public research and the business sector. Most of these indicators are also important indicators for the value of patents, see Table 5.1, and may thus be used for that purpose (e.g. citations, co-operation and licensing/spin-offs). The possible indicators for linkages can be organised in three parts:

- Dissemination of information through citations or patent descriptions

  The forward citations are parallel to the citations in bibliometric and could be partly included, only covering the citations between universities/PRO's and industry. Also, the backward citations of non-public patents of publicly owned patents and non-patent literature could be included. The information flow from public patent descriptions is not feasible to measure, but some proxy could still be included in the value indicator (e.g. the quality of the claims).

- Co-operation, informal, formal or as co-inventors/applicants

  The number of patents with a mix of public and industrial applicant(s) and inventors could be used as an indicator of co-operation, if sectors of applicants and affiliation of inventors are known. Other types of co-operation (4-6 in Figure 4.3) could only be included, if it is collected in some commercialisation survey for universities/PRO's. This is in fact suggested by an EU Expert Group, see EU(2009) and being implemented in e.g. Denmark, see FI(2010a). The suggestion is, however, not limited to co-operation regarding patenting, but to all *research agreements*.

- Licensing, royalties or spin-offs

  Licenses, royalties and spin-offs of patents may be counted and the revenues included. Some commercialisation survey for universities/PRO's may be providing this information for the part where a university/PRO is involved, see FI(2010a). It would probably not be feasible to get information on the royalties - and other output – from the patenting of academic inventors with non-public applicants by using sampling.

  The revenues from licensing could be included in the external funding, if external funding of universities/PRO's is part of the performance indicator for allocating research funds.

D. Composite patent performance indicator(s)

More performance indicators for public patents were identified as relevant and measureable in the last paragraphs A-C. The patents to be included in the indicators were considered in paragraph A, while paragraph B showed that the value of these depend on a number of dimensions. The aim would therefore be to establish a way to calculate a <u>composite indicator for the value</u> of the public patents which would be tailored for the purpose of allocating funds including the element in Table 5.1 and having a limited time-frame. One way would be to use some of the methodologies reported in the references of Part 4.3 to select the variables to include and the weights to assign to each variable. Also, the weights may be assigned using other methods, see the discussion in Part E.

The output of patent-based linkages would include co-patenting and the derived revenues. These could also be combined using some weighting, eventually as Revilla;Sarkis;Modrego(2003) did in a DEA-analysis[23] of Spanish concerted projects.

E. Inclusion of patent performance indicators with other indicators

Obviously, patent performance indicators will not be the only indicators for allocating research funds to universities or other public research organisations. This means that the weighting of the determinants of the patent value and the weighting of determinants of the patent-based linkages need to be followed by – or combined with – weighting with other scientometrics or other indicators of performance, see Annex 2. This will be described in a later paper, but a short description with focus on patenting will be given here.

When a number of performance indicators are to be used for allocating research funds, they need to be combined somehow, unless the role of the performance indicators is to serve as information in a peer review process like in UK, see RAE(2009):

> *… these experts will draw on appropriate quantitative indicators to support their professional assessment of RAE submissions, (*but*) expert review remains paramount.*

All quantitative indicators may be combined to one single composite indicator by establishing some weight to each of them. The weights for calculating the value of a composite indicator for each university- and PRO-unit may either be established based on subjective judgement or on objective criteria. The subjective weights are established without use of the values of the indicators – thus also called *a priori weights*. The objective weights are calculated using the values of the indicators – thus often called *a posteriori weights*.

A simple example of **subjective weights** is an estimation of the performance of departments of a technical university by Wallmark;McQueen;Sedig(1988). The authors compose the weights themselves (e.g. patents=3; spin-offs=10) and admit that *"(the weights) has not been sanctioned by the university"*. Kao;Pao(2009) is a bit more sophisticated, as they asked 10 experts to judge the importance of 3 indicators by allocating 100% among them; the averages are then used as weights.

The *Analytical Hierarchy Process* (AHP) is a well-established method for subjective judgements between more factors, see Saaty(1977). This method can, among others, be used to establish subjective weights for performance factors, based on the judgements of a number of experts. The experts are asked about the relative importance for each pair of indicators (w_i/w_j) on a 9-point scale. From this information the weights can be extracted, based on eigenvalues. Often, a hierarchy of factors is established to reduce the judgements and make the judgements simpler. E.g. Ding;Qiu(2011) selected 13 performance indicators for Chinese universities. This would result in 78 pairs (1:2, 1:3, … 12:13) to be judged by the selected experts and university principals – and some of the pairs would be rather odd. So, they organised the indicators in 4 groups, and now only 21 pairs need to be judged and each group has the same theme. E.g. one group included *Granted patents*, *Patent application* and *Transfer income*.

[23] A standard textbook on DEA: Cooper,W; Seiford;L; Tone,K. (2007): Data Envelopment Analysis, 2nd Ed.

There are more methods for estimating **objective weights**, so a (subjective) selection of method is needed, depending on available supplementary information. A linear model could be used if some proxy for the values of the composite indicator is available for a sample, so coefficients could be estimated – just like suggested for the value of patents. The estimated coefficients could be used as weights on all units in the performance study. Also, proxy values could be available for all units, so a linear model could estimate the weights. E.g. Ding;Qiu(2011) uses the last 5 years subjective composite performance indicator of the universities as proxy values.

As mentioned in Part D the DEA-analysis has been used by Revilla;Sarkis;Modrego(2003). The DEA-analysis is, however, a method for estimating the relative efficiency of the units included. This means that (a) indicators of input are also needed; (b) more units may be efficient; (c) the weights differ between units to allow for different prioritisation.

a. As input indicators Revilla;Sarkis;Modrego(2003) uses *R&D expenses*, *Employees* and *Turnover* for the cooperating companies, while Kao;Hung (2008) - for university departments – also includes *Space used by department*. In both examples it seems that the weights estimated are dependent of less relevant variables. Instead Kao;Pao(2009) substitutes the input indicators with a unity-restriction on the weights ($\sum w_i=1$) and optimises the performance value of each unit, accepting at first different weights ($\sum Y_{ij} \bullet w_{ij}$).
b. In a simple DEA-analysis one often finds more units to be efficient. One way to vary that would be to include an estimation of each unit's sensitivity to changes, see Revilla;Sarkis;Modrego (2003). Another way would be to put restrictions on the weights, see c.
c. It seems not acceptable to use different weights for different units, when calculating a common composite indicator for performance. One way to address this would be to introduce restrictions on the weights in the estimation of a DEA-model. These restrictions may in fact be based on the subjective judgement of experts. This is suggested by Kao;Hung(2003) and used in Kao;Hung (2008) based on top administrators and in Kao;Pao(2009) based on members of an evaluation committee. Another way would be to see the standard DEA-solution as the "ideal" scores and then find a set of common weights that minimizes the sum of the squared deviation from each unit's ideal solution and the solution when using the common weights, see Kao;Hung(2005):

   $$\min \sum (I_{ij} - \sum Y_{ij} \bullet w_i)^2 \qquad (I_j = \text{ideal score};\ w_i = \text{common weights})$$

   This method was also used by Ma;Fan;Huang(1999) without referring to DEA, while Kao;Pao (2009) went one step further and kept the weight-restrictions from the experts when estimating the weights.

Finally Ding;Qiu(2011) has suggested a way to estimate objective weights that is not derived from the DEA-models. Instead, it is based on the differentiating ability of the indicators. Mathematically, the total sum of weights is set to 100 % and is then divided between the indicators proportional with their coefficient of variation[24].

In some of the modifications of the DEA-model a priori weights were included indirectly as restrictions. A more direct combination of subjective and objective weights is presented by Ma;Fan;Huang(1999). They combine a set of AHP-based judgements with a modified DEA-model with common weights by optimising both sets simultaneously. However, they need to specify the influence of the two sets, e.g. fifty-fifty, and their example shows that this choice has consequences for the ranking.

[24] Calculated as the standard deviation divided by the average

Ding;Qiu(2011) avoids this by using a calculation, parallel with their later use of the coefficient of variation. First they estimate the weights according to both a subjective approach (coefficient of variation) and an objective approach (a linear model). Then the combined weights are calculated multiplicatively, that is the product of the weights for an indicator divided with the sum of all products:

$W_j = P_j \bullet Q_j / (\sum P_i \bullet Q_i)$ (P_j is the subjective weights and Q_j is the objective weights)

5.3. State of art: Use of patent performance indicators

In this last Part some examples of using patents as performance indicators will be described. The description is based on desk research and builds on two main sources, an EU-report from 2008 (Eurydice,2008) and papers from an OECD-workshop in 2010 (OECD,2010b). This means that the list of examples is not a full description of all ways that patent performance indicators are included in allocating research funds, cf. this comment in Eurydice(2008):

Every country that ties public funding to results has a different way of assessing the importance of the indicators to determine the amounts.

A prerequisite for using patent performance indicators is that the building blocks are available or can be made available at reasonable costs. The possibility of getting that from patent data bases has been discussed in the former Chapters and also commercialisation surveys were mentioned in Part 5.2.A. More information than the statistics from these two sources may be needed, so dedicated reporting from universities/PRO's may have to be established, ad hoc or continuously.

The first step of including patentometrics among research performance indicators would be to include patent indicators in evaluations. Some examples are listed in Table 5.2, including references. Most involve evaluation of specific areas like research programs, university-industry collaboration and knowledge transfer, but also departments and universities are subject for evalua-tions. The IPR-indicators used only include simple measures like number of invention disclosures, patent applications, patent grants, licenses and spin-offs, but also income from these IPRs. In most of the examples other types of performance indicators are included, see Annex 2. Most of the examples end up with a single measure, either expressed in a 5-point scale (research programs), in a ranking (consorted projects; universities), or some score (knowledge transfer; departments), making it possible to use them in some allocation of funding. In fact, one may be in doubt whether the university-ranking described by Ding;Qiu(2011) is used by the Chinese Ministry of Science and Technology for allocating funds.

Patent performance indicators have been involved directly in the allocation of research funds in more ways, but in a modest scope and in simple ways. The modesty is caused by the combination with other indicators, i.e. bibliometric or external funding, and the simplicity can be seen from the listing in Table 5.2 compared with the considerations in former Chapters. Too, the funds allocated are modest in a number of the examples listed, while they also include funding for teaching and general operation in other examples. The scales are just as different as with the evaluations – from a 5-point scale to some scores. The selection of scale seems to depend on how directly the composite performance indicator is determining the funding. In many of the examples in Table 5.2 the composite performance indicator is combined with some peer reviewing. This may either be as an involvement in the weighting of the indicators or as users of the performance indicator(s) as supplementary information when rating the units.

Table 5.2. Use of IPR-indicators in measures of research performance

Type	Country	Conductor	Purpose	IPR-indicators included	Methodology	Final measure	Other sources
Statistics	DK	Agency for STI	Statistics	Inventions, applied/granted patents, licenses, spin-offs	Census among all universities	Counting	FI,2010a
	UK	Nottingham University; UNICO	Statistics	Licenses, invention disclosures, total income	Survey	Counting	Binks;Vohora,2003
	US, CND	Assoc. of University Transfer Managers	Statistics	Inventions, patents, licenses, spin-offs, income	Survey among universities	Counting	AUTM, 2010
Evaluation	CHINA	Center for Chinese science evaluation, Wuhang Univ.	Evaluation of universities	Patents - applied,granted, Transfer income	AHP-weighting & subjective weighting	Ranking	Ding;Qiu,2011
	CND	Academics	Evaluation of commercialisation	The AUTM-statistics	Survey among academics	Dimensions of commercialisation	Langford et al.,2006
	ES	Academics	Evaluation of uni-industry collaborations	Exploitation of patents	Survey - Andalusian universities	Dimensions of collaboration	Ramos-Vielba et al., 2010
	ES	Academics	Evaluation of "Consorted projects"	Patents; Income generated	DEA-analysis	Ranking	Revilla;Sarkis; Modrego, 2003
	NL	Association of NL Universities	Evaluation of research programs	Patents	Counting	5-point rating scale (informed peer review)	Geuna;Martin,2003
	SE	Academics	Evaluation of departments	Patents, spin-offs	Subjective weights	A merit figure	Wallmark;McQueen; Sedig,1988
	UK	Nottingham University; UNICO	Evaluation of TTO's	Licenses, invention disclosures, total income	DEA-analysis	Efficiency scores	Chapple et al., 2004
Allocation	AT	Ministry of Science and Research	Allocation of grants for operation incl. teaching	Income from R&D-projects; Patents	All activities of the universities	Weighted indicator	
	AUS	Australian Research Council	Evaluation for allocation by fields of universities	Granted patents; Commercial income	Integrated with peer review	5-point rating scale	AUS Research Council, 2011
	BE (Fl)	Ministry for the Flemish Community	Allocation of public research funds	Patents and spin-offs	Share of all, weighted with other indicators	Weighted indicator	Noyons;Luwel; Moed,1998
	DK	Agency for STI	Allocation of part of the basic grants	Granted patents	Weighted formula	Scores	FI,2009
	EE	Ministry	Allocation of basic grants	Licenses	Funding formula	-	
	IT	Ministry of Universities and Research	Allocation of basic grants	Patents and designs	Quality index	Ranking (informed peer review)	Abramo;D'Angelo; Caprasecca,2009
	PL	Ministry of Science and Higher Education	Allocation of basic grants	Licenses, granted patents		- (informed peer review)	
	PT	A panel of international experts	Allocation of basic/other grants (research centers)	Patent application activities		Classification of inst. (informed peer review)	
	SK	The Acadmic Ranking & Rating Agency	Allocation of basic grants	Results of technological activities		More indicators (informed peer review)	
	UK	HEFCE (RAE,2008)	Allocation of grants for research	Patents, patent applications		5-point rating scale (informed peer review)	RAE,2009

Main sources: Eurydice(2008) and OECD(2010)

With at least 10 countries having included patent performance indicators in their allocation of research funds it seems that there is an acceptance of the need for this inclusion, though in a minor role[25]. Still, the patent indicators used are too simple.

[25] In the Danish indicator for allocating research funds only 0.34 % of the total score in 2010 was from granted patents (FI,2010b)

6. Conclusions

This review has indicated that some patentometrics is relevant to include as part of performance indicators for allocating research funds. This would ensure that dissemination activities would be fully accepted as relevant activities of universities and prevent these activities from being assigned a lower priority if only e.g. bibliometrics are included in the performance indicator. However, other dissemination activities also play an important role and should thus be included in a common indicator for the dissemination of knowledge to industry and society.

The patent performance indicators used for the allocation of research funding have until now mostly been rather simple counting. This should be replaced by estimates of value, and indicators of cooperation should be included. Also, the effects of patenting should be included, that is licensing, spin-offs and royalties (number or income).

A number of dimensions need to be specified. The most important ones would be which patent offices, period, types of applicants and inventors to include. Also, the variables to be used for constructing the indicators suggested – patent value, cooperation, commercial income – should be decided on, based on availability and applicability. Here, the need for dedicated surveys like commercialisation survey has been stressed, but also inquiries about patent inventions to academics like in the KEINS-database, see Lissoni;Sanditov;Tarasconi(2006).

Finally, the way to calculate or model the composite indicators needs to be decided on, probably through experimentations.

The overall conclusion is that patentometrics and other indicators of cooperation should be included in a performance indicator for allocating general and other university funds, but in a more sophisticated way than used now. Some development work is therefore needed, based on the vast amount of theoretical and empirical work described in this paper.

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Looy	Callaert; Debackere	Publication and patent behaviour of academic researchers - conflicting, reinforcing or merely co-existing	Research Policy	35,4,2006 596–608
Looy	Landoni;Callaert; Pottelsberghe;Sap-salis;Debackere	Entrepreneurial effectiveness of European universities - An empirical assessment of antecedents and trade-offs	Research Policy	40,4,2011 536–564
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Mazzonlini		University patents, R&D competition and social welfare	Economics of Innovation and New Technology	14,6,2005 499-515

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OECD		Compendium of Patent Statistics	OECD	2005
OECD		Compendium of Patent Statistics	OECD	2008a
OECD		OECD Patent Daabase	OECD	June 2008b
OECD		OECD Patent Statistics Manual	OECD	2009
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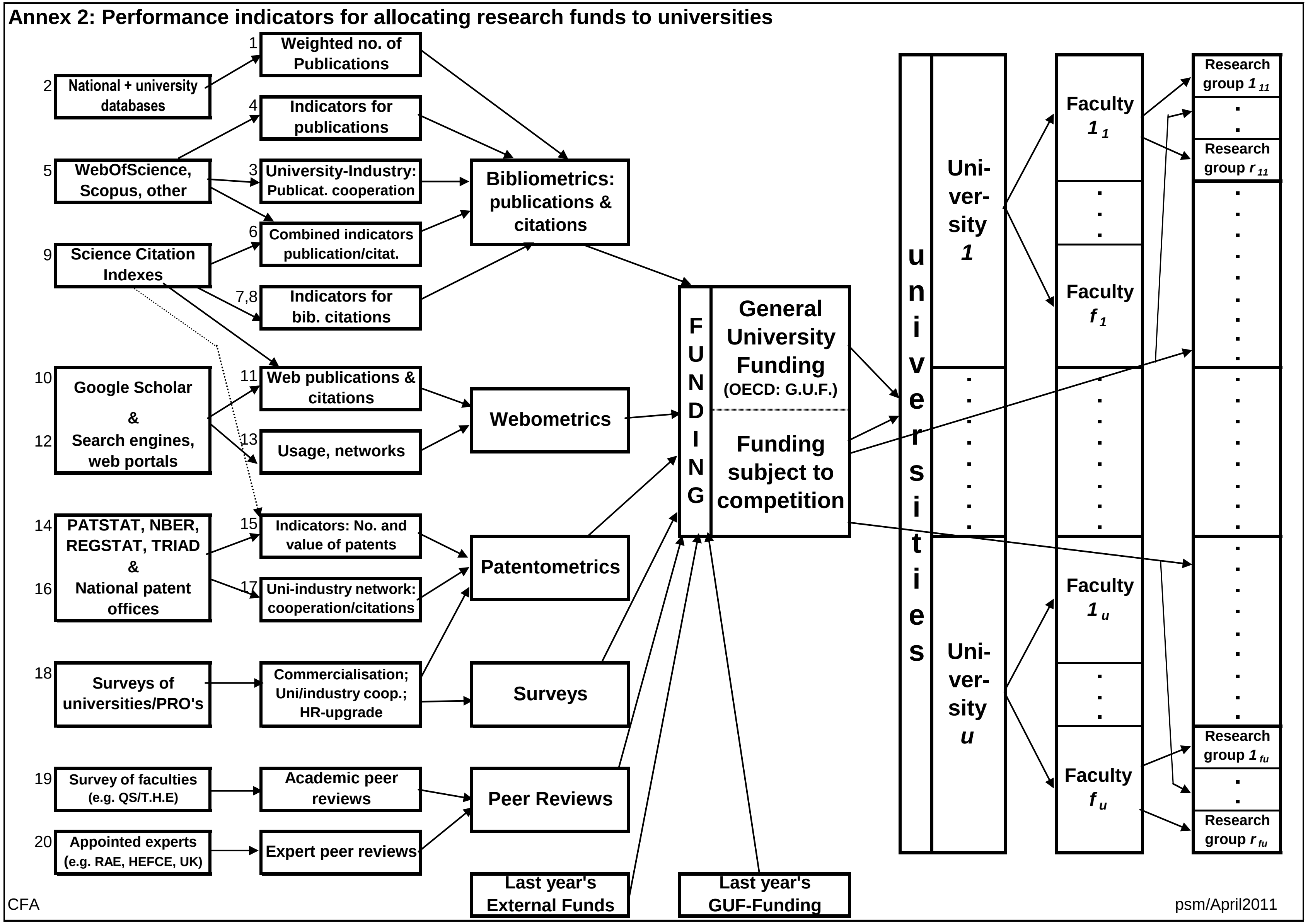
Annex 1: Table of Patent applications under the PCT, at international phase

EPO designations by sector, 1995-97, 2003-05

Country	1995-97								
	Total	Industry		Universities		Government		Individuals, NPI,?	
	Abs	Abs	Pct.	Abs	Pct.	Abs	Pct.	Abs	Pct.
Australia	2,748	1709	62.2	142	5.2	99	3.6	798	29.0
Austria	1,236	913	73.9	1	0.0	0	0.0	323	26.1
Belgium	1,435	1044	72.8	77	5.4	11	0.7	303	21.1
Canada	3,491	2367	67.8	253	7.3	158	4.5	713	20.4
China			18.8		5.8		0.3		75.1
Denmark	1,773	1433	80.8	4	0.2	3	0.2	332	18.8
Finland	2,478	2148	86.7	17	0.7	1	0.0	312	12.6
France	7,783	4835	62.1	203	2.6	423	5.4	2322	29.8
Germany	22,489	18681	83.1	64	0.3	15	0.1	3729	16.6
Ireland	341	260	76.2	9	2.8	3	0.9	69	20.2
Italy	2,814	1931	68.6	25	0.9	38	1.3	820	29.1
Japan	13,106	12210	93.2	11	0.1	55	0.4	830	6.3
Korea	878	545	62.0	6	0.6	62	7.0	266	30.3
Netherlands	4,678	4226	90.3	89	1.9	5	0.1	358	7.6
New Zealand	498	309	62.1	8	1.6	5	0.9	176	35.4
Norway	1,156	851	73.6	3	0.3	1	0.1	302	26.1
Spain	1,015	450	44.4	53	5.2	9	0.9	502	49.5
Sweden	5,926	5163	87.1	1	0.0	2	0.0	760	12.8
Switzerland	2,676	2249	84.1	31	1.2	4	0.2	392	14.6
United Kingdom	10,538	7871	74.7	537	5.1	747	7.1	1383	13.1
United States	66,784	52925	79.2	4508	6.7	1202	1.8	8149	12.2
EU 27	63,575	49666	78.1	1028	1.6	1210	1.9	11671	18.4
World Total	160,252	125754	78.5	6308	3.9	2849	1.8	25340	15.8

Country	2003-05								
	Total	Industry		Universities		Government		Individuals, NPI,?	
	Abs	Abs	Pct.	Abs	Pct.	Abs	Pct.	Abs	Pct.
Australia	6010	4028	67.0	288	4.8	133	2.2	1561	26.0
Austria	3143	2397	76.3	82	2.6	1	0.0	662	21.1
Belgium	2778	2156	77.6	182	6.6	15	0.5	425	15.3
Canada	7485	5460	72.9	407	5.4	231	3.1	1387	18.5
China			58.2		4.8		0.2		36.8
Denmark	3268	2505	76.7	99	3.0	14	0.4	649	19.9
Finland	4229	3943	93.2	7	0.2	2	0.0	278	6.6
France	17275	10686	61.9	754	4.4	922	5.3	4912	28.4
Germany	47133	39582	84.0	818	1.7	21	0.0	6711	14.2
Ireland	847	610	72.0	81	9.5	11	1.2	146	17.2
Italy	7837	5760	73.5	257	3.3	93	1.2	1726	22.0
Japan	62986	57024	90.5	1640	2.6	1403	2.2	2919	4.6
Korea	12755	8408	65.9	299	2.3	194	1.5	3853	30.2
Netherlands	9345	8621	92.3	126	1.3	3	0.0	595	6.4
New Zealand	1089	784	72.0	19	1.7	4	0.3	283	25.9
Norway	1716	1366	79.6	19	1.1	0	0.0	330	19.3
Spain	3162	1653	52.3	271	8.6	29	0.9	1209	38.2
Sweden	6756	6229	92.2	1	0.0	2	0.0	525	7.8
Switzerland	5673	5036	88.8	116	2.0	6	0.1	515	9.1
United Kingdom	17548	13129	74.8	1153	6.6	537	3.1	2730	15.6
United States	133871	106977	79.9	7973	6.0	2622	2.0	16299	12.2
EU 27	125807	99635	79.2	3636	2.9	1513	1.2	21023	16.7
World Total	389894	310092	79.5	15624	4.0	6854	1.8	57324	14.7

Source: OECD(2008b)



Annex 2: Performance indicators for allocating research funds to universities
1 Weighted no. of Publications
2 National + university databases
4 Indicators for publications
5 WebOfScience, Scopus, other
3 University-Industry: Publicat. cooperation
Bibliometrics: publications & citations
6 Combined indicators publication/citat.
9 Science Citation Indexes
7,8 Indicators for bib. citations
10 Google Scholar
&
12 Search engines, web portals
11 Web publications & citations
13 Usage, networks
Webometrics
14 PATSTAT, NBER, REGSTAT, TRIAD
&
16 National patent offices
15 Indicators: No. and value of patents
17 Uni-industry network: cooperation/citations
Patentometrics
18 Surveys of universities/PRO's
Commercialisation; Uni/industry coop.; HR-upgrade
Surveys
19 Survey of faculties (e.g. QS/T.H.E)
Academic peer reviews
Peer Reviews
20 Appointed experts (e.g. RAE, HEFCE, UK)
Expert peer reviews
Last year's External Funds
Last year's GUF-Funding
FUNDING
General University Funding (OECD: G.U.F.)
Funding subject to competition
universities
Uni-ver-sity 1
Uni-ver-sity u
Faculty 1 1
Faculty f 1
Faculty 1 u
Faculty f u
Research group 1 11
Research group r 11
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