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ORIGINAL ARTICLE

European research in the field of production technology and manufacturing systems: an exploratory analysis through publications and patents

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Abstract This paper develops a structured comparison among a sample of European researchers in the field of *production technology and manufacturing systems* on the basis of two research outputs: scientific publications and patents. Researchers are evaluated and compared by a variegated set of indicators concerning (1) the output of individual researchers and (2) that of groups of researchers from the same country. Whilst not claiming to be exhaustive, the results of this preliminary study provide a rough indication of the publishing and patenting activity of European researchers in the field of interest, identifying (dis)similarities between different countries with regard to their inclination to publishing and patenting. Of particular interest is a proposal for aggregating analysis results by means of maps based on publication and patent indicators. A large amount of empirical data are presented and discussed.

Keywords Research evaluation · Publications · Patents · Technology transfer · Production technology · Manufacturing systems

1 Introduction

Evaluating the performance of a research system is a complex and tricky activity wherein many aspects are involved. At the risk of oversimplifying, there generally are two main pathways of interaction between the research system and its environment [53] (see Fig. 1):

- Incoming resources, which are essential to feed the research system. They usually are human (e.g. staff) and/or economic–financial ones (e.g. public/private research funding)
- Research outputs, which can be divided in two main types: (1) scientific publications (e.g. journals papers, conference proceedings, book chapters, monographs, etc.), addressed to the scientific community, and (2) technology transfer applications (e.g. patents, university spin-offs, consulting services etc.), addressed to the industry and the whole socioeconomic system.

It is worth noting that although the first type of research output (i.e. publications) is commonly recognised, the second (i.e. technology transfer applications, which constitute the so-called third mission for university research systems) has been much discussed only in the last 10–15 years [27, 44]. Nevertheless, technology transfer is particularly important for the applied scientific disciplines since they are closely connected to industry and technology in general [28, 35].

As emerges from Fig. 1, there is a double link between incoming resources and research outputs. Whilst it seems reasonable that more resources are likely to produce more outputs (direct link), on the other hand, the feedback loop denotes that a significant part of the (future) resources may depend on the (past) outputs (reverse link). In this sense, there is no clear distinction between cause and effect. However, it can be said that generating a good output is a necessary (but not sufficient) condition for a research system's life [8]. This is particularly evident during periods of

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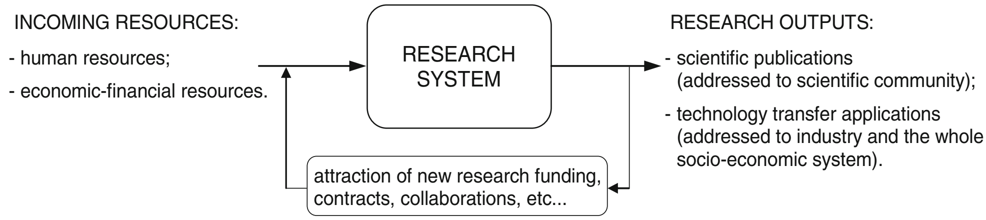

Fig. 1 Simplified representation of a research system and the linkages with its environment

general crisis, with budget cuts and increasingly limited resources.

Indicators based on publications and patents—which are both objective and easily measurable quantities—are the most commonly used proxies for evaluating the previous two types of research outputs. In the literature, there are many cases in which these two typologies of indicators are used in combination, for instance, [2, 3, 7, 10, 17, 18, 30, 57], and many others. From most of these works, interesting results emerge about the potential correlation between the intensity of research activity and patents. Although no consensus has been reached, there is some evidence that industry–science collaboration tends to trigger new basic research and vice versa.

The goal of this paper was to make a preliminary comparison among European researchers in the field of *production technology and manufacturing systems* on the two analysis perspectives of publications and patents. Whilst in this specific field some publication analyses have been recently presented in the literature [24, 25], there is a lack of studies from the perspective of patent analysis [54]. This work should be useful for providing a rough indication on the different inclination of researchers to "classical" research and technology transfer, investigating possible interactions [1].

A homogeneous sample of researchers from several European countries was identified by referring to members of the Collège International pour la Recherche en Productique(CIRP, also known as International Academy for Production Engineering), one of the most important international associations of researchers in the discipline concerned [13]. Specifically, we selected the researchers from the first nine European countries in terms of the number of CIRP members. The resulting sample consists of almost 200 total researchers as follows: Germany (62), United Kingdom (33), Italy (27), France (17), the Netherlands (17), Switzerland (13), Poland (10), Denmark (9) and Sweden (9) [12].

The choice of limiting the analysis to European researchers is aimed at making the comparison as homogeneous as possible, especially regarding patent analysis. Differences between European countries in terms of inclination and incentive to patent are relatively less pronounced than those between European and extra-European countries, such as the USA or Japan [6, 7, 16, 39, 48].

Analysis is carried out by several indicators that are collected using the Scopus database. Input data are publications and patents, with corresponding citations. Publications and patents give a quantitative indication of the research activity respectively in terms of scientific production and technology transfer. Regarding citations, the matter is more subtle. Whilst the fact that the citations received by a scientific publication depict its impact/diffusion within a scientific community is (almost) universally accepted [5], the debate on the role of patent citations is a bit more controversial. According to the majority of authors, they roughly represent the knowledge flow between the scientific community and the industry [1]. For others, patent citations can be indicative of the technological importance of a patent or even the patent (potential) market value and profitability [11, 31, 56].

Input data are used to construct other *derived* indicators so as to better depict the performance of researchers [21]. The prerogatives of these indicators are simplicity and immediate intuitive meaning [25]. Of particular interest is the intensive use of the Hirsch (h) index and other h-based indicators, both at publication and patent levels [25, 29, 34].

Whilst not claiming to be exhaustive and complete, the results of this preliminary study can be useful for many reasons:

- Providing a rough indication on the publishing and patenting activity of European researchers in the field of production technology and manufacturing systems, investigating possible relationships/interactions
- Identifying (dis)similarities between researchers from different countries with regard to their propensity to publish and patent (being aware that it can be strongly influenced by government policies or incentives)

The remainder of this paper is organised into six sections. Section 2 provides a short description of the publication/patent indicators in use and focuses on the analysis methodology, with particular attention to data collection and data cleaning. Section 3 presents and discusses in detail the analysis results. Section 4 contains additional reflections on the proposed analysis. Particularly remarkable is a proposal for aggregating the results of the analysis from the two perspectives of publications and patents. In Section 5, conclusions are given, summarising the original contribution of the paper. Finally, a detailed collection of (publication/patent) statistics relating to the individual researchers is accommodated in the Appendix.

2 Methodology

2.1 Publication and patent indicators

The same set of indicators is used for both the analysis perspectives of publications and patents. In case of potential ambiguity, when presenting the analysis results, these two categories of indicators will be distinguished by means of the superscript "(PUB)", for publication-related indicators, and "(PAT)", for patent-related indicators. Indicators can be in turn divided into: (1) indicators related to individual researchers and (2) indicators related to groups of researchers from the same country. They are summarised in Fig. 2 and described in detail in the following paragraphs. All the indicators are calculated taking into account the publications/patents and the corresponding citations, accumulated up to the moment of the analysis (February 2011).

2.1.1 Indicators for individual researchers

P is the total number of publications/patents and *C* is the total number of citations received by the scientific publications/patents of a researcher. *P* gives quantitative information of the publishing/patenting activity. In the case of publications, *C* is informative of the total impact/diffusion of one researcher's scientific publications, whilst in the case of patents, *C* roughly illustrates the overall knowledge flow generated by one researcher's patents. *P* and *C* are available from the most diffused bibliometric and patent search engines and do not require any calculation [32, 46, 52, 55]. *CPP* is the average number of citations per publication (i.e. *C*/*P*). It provides an indication of the average impact/diffusion and can be used to make comparisons between researchers regardless of the fact that they have a different number of publications/patents. On the other hand, this indicator is not very robust, especially for low *P* values [26].

The *h* index is a relatively recent but very popular indicator that synthetically aggregates two important aspects of the publication output: respectively impact/diffusion, represented by the number of citations of a paper, and productivity, represented by the number of different papers. *h* is defined as the number such that for one author's publications, *h* publications received at least *h* citations whilst the other publications received no more than *h* citations [34]. For more on the advantages/disadvantages of *h* and the large number of proposals for new variants and improvements, we refer the reader to the vast literature and extensive reviews [19, 22, 49]. In general, the larger the *h*, the larger is the diffusion and prestige of one author in the scientific community. The *h* index can also be used to evaluate the technological importance and impact of one researcher's patent portfolio, simply considering the number of different patents and the number of citations of each patent [29].

$Avg_{\text{co-authors}}$ is the average number of co-authors relating to publications/patents of one researcher. This indicator is symptomatic of the tendency towards co-authorship.

Y_{MIN} and Y_{MAX} are respectively the year relating to the oldest publication/patent and the year relating to the latest one. They provide a rough indication of the temporal extension of the publishing or patenting activity of

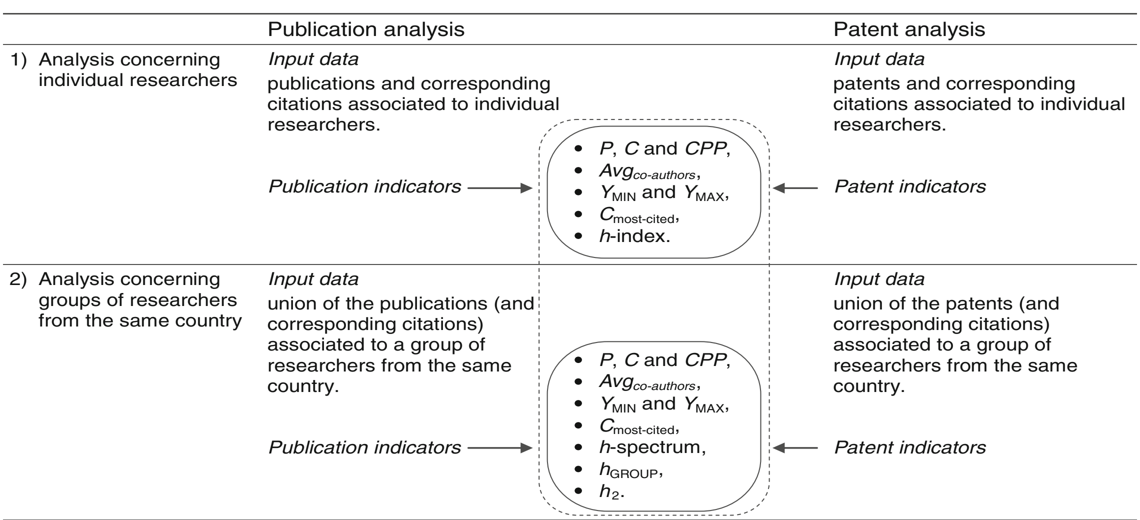

Fig. 2 Summary of the indicators in use. It can be noticed that the same indicators are used for both the analysis based on publications and that based on patents. Indicators can be in turn divided into (*1*) indicators for individual researchers and (*2*) indicators for groups of researchers from the same country

a researcher. We remark that, after a publication or patent submission, there is a physiological time required by the publication to be issued or by the patent to be granted. Regarding publications, it is generally included between a few months and 1–2 years. Regarding patents, it cannot be smaller than 1 year and may even extend up to 6–8 years.

$C_{\text{most-cited}}$ is the number of citations received by the most cited publication/patent of a researcher, representing the "jewel in the crown" in terms of impact/diffusion.

2.1.2 Indicators for groups of researchers from the same country

P, *C* and *CPP*, $Avg_{\text{co-authors}}$, Y_{MIN}, Y_{MAX} and $C_{\text{most-cited}}$ are exactly the same indicators seen in Section 2.1.1. In this case, they are constructed considering the union of the publications/patents associated to the researchers from the same country.

The *h* spectrum is defined as the distribution representing the *h* values associated to a group of researchers. *h* spectrum gives a "snapshot" of the population of a group. Initially, the *h* spectrum was originally used to compare scientific journals on the basis of the bibliometric positioning of their (co-) authors, but its use can be easily extended to groups of researchers on the basis of their publications and patents [23, 37]. We can distinguish between local *h* spectra, i.e. those related to researchers of the same country, and a global *h* spectrum, constructed considering the *h* values of all the researchers at the European level. Several indicators can be associated to the *h* spectrum: the average ($\bar{h}$) and the median (h_{MED}) as indicators of central tendency, the corresponding standard deviation (*s*) and interquartile range (IQR) as indicators of dispersion.

The h_{GROUP} is the *h* index of a group of researchers from the same country, that is to say, the *h* index of the union of the publications or patents associated to the researchers from the same country. The h_{GROUP} depicts the impact of a group of researchers on the scientific community.

The h_2 is the first successive *h* index of a group of researchers. h_2 is defined in this way: a group has index h_2 if it has h_2 members with an *h* index of at least h_2 [50, 51]. h_2 indicates the portion of members that "keep the show going" for one group of researchers, identifying the size of the most productive core of researchers.

2.1.3 Further comments about indicators

The majority of the indicators presented, particularly those derived from the *h* index, are commonly used in the field of bibliometrics. Nevertheless, with the necessary "precautions", they can be extended to the analysis of patents [40, 45]. Probably, the most remarkable difference is that for many scientists, especially the academic ones, patenting is no more than an occasional event in their career—for a number of concauses [27]—whilst they are primarily devoted to the production of scientific publications [9]. As a consequence, the amount of patents of the average scientist is likely to be much lower than the amount of publications.

2.2 Data collection

A first problem, which is only apparently trivial, is identifying a sample of homologous researchers belonging to different European nations but involved in similar research issues. For example, regarding public research institutions, the categorization of scientific fields may vary from country to country [38]. In addition, these categorizations may change even within the same country, depending on academic or non-academic research institutions, e.g. in Italy, as explained in [15].

Besides, one may select a sample of researchers from the authors of scientific journals in the field of interest. But this strategy has some drawbacks. First, identifying a set of reference journals is not so simple due to the fact that the field of production technology and manufacturing systems is very close to other interdisciplinary fields—such as *material science*, *operations research*, *mechanics*, *metrology*, etc.—with the consequent risk of confusing researchers involved in different overlapping disciplines. In this sense, the relative "flexibility" and uncertainty in the journal classification schemes of the most popular bibliometric database (e.g. Web of Science or Scopus) is emblematic [43]. Secondly, using scientific journals to identify homologous researchers would inevitably give more importance to those researchers more inclined to publishing (e.g. academic ones), partially excluding the others.

The expedient used to select a homogeneous sample of researchers from several European countries is to refer to members of the CIRP, one of the major international associations of academic and non-academic researchers in the discipline concerned [13]. The complete list of researchers, including additional data such as affiliation, web site, main research interests, etc., is available in [12]. There are two main categories of CIRP members: *fellows* (honorary and emeritus as well), who are internationally recognised scientists elected to be CIRP members for life, and *associate*, who are well-known scientists elected typically for a period of 3 years with the possibility of renewal [13]. In this study, we selected about 200 total researchers who are distributed among the following countries: Germany (62), United Kingdom (33), Italy (27), France (17), the Netherlands (17), Switzerland (13), Poland (10), Denmark (9) and Sweden (9).

For each of these researchers, publication/patent statistics were collected using the Scopus search engine.

We chose this database for three main reasons: (1) in the field of engineering science, Scopus' coverage is superior to that of Web of Science [4]; (2) Scopus is much more accurate than Google Scholar database [36]; (3) Scopus integrates patent statistics from the major worldwide patent and organisations, i.e. European Patent Office (EPO), United States Patent and Trademark Office (USPTO), Japan Patent Office and World Intellectual Property Organization (WIPO) [52].

A crucial problem encountered in the analysis is represented by disambiguation of researchers. In general, researchers with common names or researchers identified only by the surname and the first name initials—rather than full first name(s)—are subject to this kind of problem. The practical effect is that contributions of different homonym researchers are erroneously added up, with the result of "inflating" one researcher's publication/patent statistics.

Regarding publication statistics, data obtained from Scopus turned out to be accurate since the database makes it possible to quickly "isolate" researchers by their full first name(s) and affiliation. For this reason, a manual check of these data has been performed relatively quickly. Seven researchers were finally excluded from the (publication) analysis because of the risk of ambiguity. The complete list of researchers, indicating those excluded from the analysis, is reported in Table 6 in the Appendix.

Regarding patent statistics, data collection was much more difficult and time-consuming. In fact, the Scopus patent database reports only the first name initials of a generic researcher, increasing the risk of homonymy. In the patent analysis, the number of researchers excluded is doubled (14 researchers, see Table 6 in the Appendix). Results associated with the non-excluded researchers were examined carefully and cleaned. This operation was carried out manually by using all available information, such as: (1) coherence between patents and one individual's research interests, (2) coherence between the date of a patent and the age of a researchers, (3) coherence between the main affiliation of one researcher and the affiliation reported in the patent, etc.

The resulting samples of researchers used in the publication and patent analysis are summarised in Table 1, specifying how they are distributed among the different European countries. Table 1 also contains the abbreviations that will be used hereafter to identify the national groups of researchers.

After identifying the patents of each researcher, we determined the number of citations received. It may happen that sometimes, the same patent may have been deposited in more than one patent office. For example, regarding European researchers, it is quite frequent to deposit a patent at the EPO and WIPO. The latter patent system makes it possible to extend the patent up to 142 worldwide countries and is very often an "expedient" for procrastinating up to 30 months the decision on which countries to apply for patent protection [47]. Duplicate patents were identified quite easily, noting the title of the patent and the name of the inventors, and counted only once, whereas the corresponding citations were cumulated. We are aware that this citation "aggregation" could be questionable since the tendency towards citation may change from one patent office to the other. For example, a substantial difference between the citation attitude of the EPO and the USPTO examiners, due to the different rules governing the citation practices, is documented in the literature [16]. However, we believe that these "aggregated" citations give a reasonable indication of the overall impact/diffusion of a patent [11]. Finally, we remark that most of the patents of the examined researchers were deposited only in EPO; therefore, duplications are not very frequent.

Table 1 Country and staff number of the groups of researchers analysed

Country	Group abbreviation	Staff number		
		Before exclusion	After exclusion	
			Publication analysis	Patent analysis
Germany	DEU	62	61	60
United Kingdom	UK	33	31	26
Italy	ITA	27	25	27
France	FRA	17	16	15
Netherlands	NED	17	16	14
Switzerland	CH	13	13	13
Poland	POL	10	10	10
Denmark	DEN	9	9	9
Sweden	SWE	9	9	9
	Total	197	190	183

In particular, we report the staff number before and after the exclusion of some researchers for publication and patent analysis, respectively. Countries are sorted in descending order according to their staff number before exclusion

Regarding publications, it is worth remarking that a limitation of Scopus is that of excluding books, book chapters, dissertations, working papers, and journal articles published in non-indexed journals and conference proceedings. Another limitation is that citation counts are not accurate for articles published prior to 1997 [52]. In any case, apart from a few *emeritus* members, researchers are not very dissimilar in terms of age; hence, we believe that this limitation does not overly penalize some (i.e. those whose publications were widespread before 1997) rather than others.

3 Analysis results

Indicators (both at publication and patent levels) concerning individual researchers are reported in Table 6 in the Appendix. They are used to determine the indicators related to groups of researchers from the same country, summarised in Table 2. The results are discussed in depth in the following paragraphs.

Figure 3 shows the (global) h spectra related to the whole set of European researchers examined respectively from the publication and patent perspective. As expected, distributions are right-skewed and the average h index relating to publication analysis is significantly higher than that relating to patent analysis (values are reported in the last row of Table 2) [23]. The h indices of the individual researchers, both at publication and patent levels, are reported in Table 6.

The global h spectra may represent a European reference for individual researchers within the area of interest. For example, a researcher with $h^{(PUB)}=3$ will fall on the 28th percentile. Analogous (local) h spectra can be constructed for each of the nine groups of researchers from the same country.

Consistently with Lazaridis [37], $\overline{h}$ is used as a synthetic indicator to perform quick evaluations and comparisons among the local h spectra, even if—from a conceptual point

Table 2 Analysis results concerning groups of researchers from the same country

Group	N	P	C	CPP	$Avg_{co\text{-}authors}$	Y_{MIN}	Y_{MAX}	$C_{most\text{-}cited}$	$\%P_0$	$\overline{h}$	h_{MED}	s	IQR	h_{GROUP}	$h_{GROUP,norm}$	h_2
Indicators relating to publications (PUB)																
DEU	61	4,135	16,266	3.9	3.2	1966	2010	795	0	6.9	6.0	4.2	5.0	48	6.1	11
UK	31	1,412	9,737	6.9	3.0	1961	2011	298	3	8.0	8.0	5.5	7.0	41	7.4	10
ITA	25	617	4,758	7.7	3.5	1965	2010	371	0	6.7	7.0	2.8	3.0	29	5.8	8
FRA	16	496	2,572	5.2	3.2	1974	2011	76	0	6.5	6.5	3.6	4.3	24	6.0	7
NED	16	346	3,885	11.2	3.5	1973	2010	246	0	6.6	6.0	5.3	9.3	32	8.0	6
CH	13	253	1,669	6.6	3.0	1964	2010	139	0	4.1	3.0	4.3	4.0	20	5.5	4
POL	10	372	2,530	6.8	2.7	1967	2010	114	0	6.8	3.5	5.9	8.3	26	8.2	4
DEN	9	431	4,294	10.0	3.4	1966	2010	147	0	10.8	10.0	3.8	4.0	30	10.0	8
SWE	9	126	648	5.1	2.5	1962	2010	132	0	3.8	3.0	1.5	1.0	12	4.0	4
Overall	190	8,188	46,359	5.3	3.2	–	–	–	1	6.8	6.0	4.5	7.0	–	–	–
Indicators relating to patents (PAT)																
DEU	60	206	734	3.6	3.3	1964	2010	110	47	1.1	0.0	1.6	2.0	13	1.7	4
UK	26	31	107	3.5	3.3	1954	2010	31	65	0.6	0.0	1.0	1.0	5	1.0	2
ITA	27	8	8	1.0	4.5	2001	2009	7	89	0.1	0.0	0.3	0.0	1	0.2	1
FRA	15	51	113	2.2	2.3	1978	2010	29	60	0.5	0.0	1.1	0.5	5	1.3	2
NED	14	5	29	5.8	2.2	1971	2008	23	71	0.1	0.0	0.4	0.0	2	0.5	1
CH	13	70	403	5.8	2.6	1972	2009	80	46	1.7	1.0	2.2	2.0	9	2.5	3
POL	10	8	10	1.3	1.3	1970	1988	5	80	0.3	0.0	0.7	0.0	2	0.6	1
DEN	9	10	59	5.9	3.9	1982	2008	55	33	0.3	0.0	0.7	0.0	2	0.7	1
SWE	9	9	118	13.1	3.0	1968	2004	90	56	0.9	0.0	1.2	2.0	4	1.3	2
Overall	183	398	1581	3.9	3.0	–	–	–	60	0.7	0.0	1.3	1.0	–	–	–

For each group, the following indicators are reported, both at publication and patent levels: total publications/patents (P), total citations (C), mean citations per publication/patent (CPP), average number of co-authors ($Avg_{co\text{-}authors}$), year of the oldest publication/patent (Y_{MIN}), year of the most recent publication/patent (Y_{MAX}), citations of the researcher's most cited publication/patent ($C_{most\text{-}cited}$), fraction of researchers with no publication/patent ($\%P_0$), h index average value ($\overline{h}$), h index median value (h_{MED}), h index standard deviation (s), h index interquartile range (IQR), h index of the group (h_{GROUP}), normalised h_{GROUP} ($h_{GROUP,norm}$) and group's successive h index (h_2). Values are calculated using the Scopus database and taking into account the citations accumulated up to the moment of the analysis (February 2011). Groups are sorted consistently with the order in Table 1. For some indicators, overall values concerning the whole set of researchers are reported in the last row of the two tables

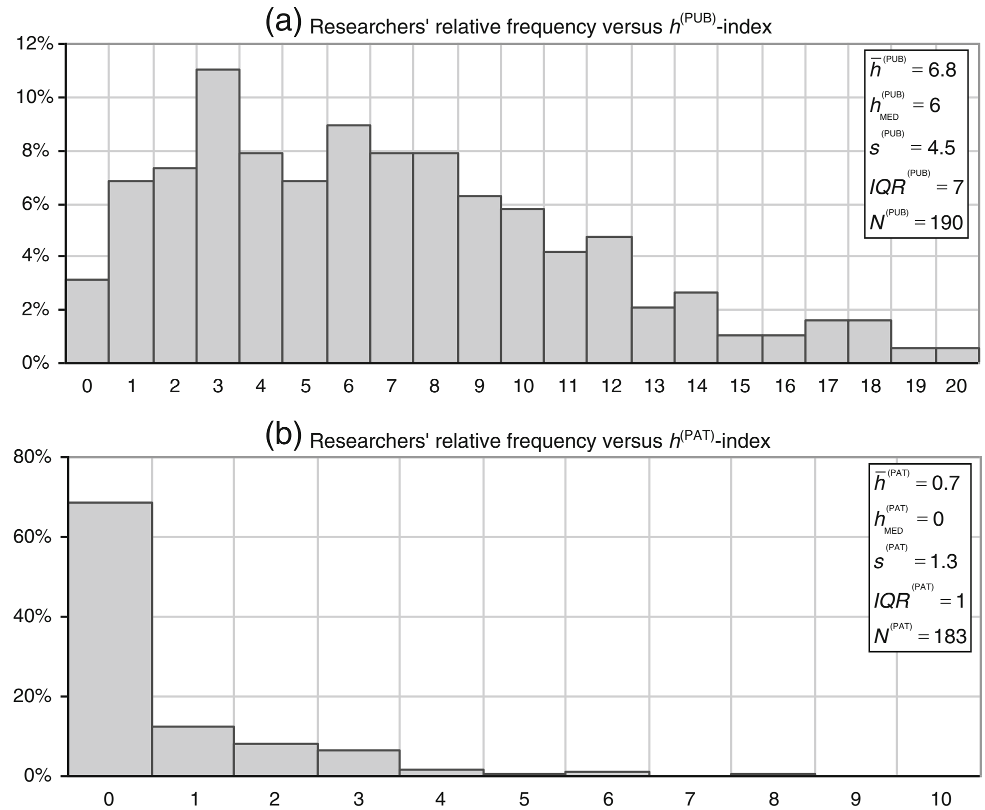

Fig. 3 (Global) h spectra related to the whole set of researchers respectively for publication (**a**) and patent analysis (**b**). The researchers' h index average value ($\bar{h}$), median value (h_{MED}), standard deviation (s), inter-quartile range (IQR), and the total staff number (N) are reported in the *top right corner*

of view—it would be more correct to use h_{MED} [22]. The reason is that h is defined on an ordinal scale [5]. Unfortunately, the fact that h_{MED} is insensitive to extreme values may give results that are not well representative of the group's average performance. This is particularly evident for small-sized groups. For example, the group of Polish researchers (POL) consists of ten scientists with $h^{(PUB)}$ values of 1, 2, 3, 3, 3, 4, 9, 12, 12 and 19. In this case, $\bar{h}^{(PUB)} = 6.8$ is quite twice as large as $h_{MED}^{(PUB)} = 3.5$. Since a significant portion of the groups is small-sized, we decided to use both $\bar{h}$ and h_{MED}.

Particularly interesting is the comparison between the researchers' $h^{(PUB)}$ and $h^{(PAT)}$ values. In general, the latter ones are very low (e.g. almost 70% of the researchers have $h^{(PAT)}$=0) for two main reasons: (1) patenting is a relatively rare event in the career of a researcher, as also confirmed by the very large portion of researchers with no patent ($\%P_0^{(PAT)}$, see Table 2); (2) only very few patents are cited heavily, also because it takes time for a patent to accumulate a large number of citations from later patents [29]. In this sense, for individual researchers, $h^{(PAT)}$ is significantly less effective than $h^{(PUB)}$ due to the lower discriminatory power.

h_{GROUP} gives an indication of the impact of a group of researchers on the scientific community. As shown in Table 2, and confirmed by [29], $h_{GROUP}{}^{(PAT)}$ does not suffer from the low discriminatory power of $h^{(PAT)}$, being based on a larger number of patents (and corresponding citations). Of course, large groups are favoured since they generally have a larger number of publications and patents. For example, the group of German researchers (DEU) has the highest h_{GROUP} value, both at publication and patent levels. Thus, this indicator cannot be used to make direct comparisons among groups with different size. Another problem is that h_{GROUP} can be dominated by the contribution of one very productive group member. This is particularly evident when there is a great difference between the researcher with the highest h and the remaining ones [37]. In our specific case, this condition does not frequently occur since researchers of the same group do not have very dissimilar h values (see Table 6 in the Appendix).

To make h_{GROUP} values comparable and obtain an indication on the average performance of a group of researcher, complementary to the one provided by $\bar{h}$, a normalisation has to be introduced. A possible way is to multiply the h_{GROUP} values by the inverse of the square root of the group size ($\sqrt{N}$). This normalisation is quite consistent with other models in the literature in which the relationship between h_{GROUP} and N is governed by the power law $h_{GROUP} \propto N^{\beta}$, with exponent β around 0.4–0.5 [25, 42].

The normalised h_{GROUP} (i.e. $h_{GROUP,norm} = h_{GROUP}/\sqrt{N}$) is therefore reasonably insensitive to N. The advantage of $h_{GROUP,norm}$ with respect to $\bar{h}$ is that it cannot be inflated by the co-authorship among members of the same group. For example, in case of systematic co-authorship, the h indices of the individual researchers would artificially increase, with a resulting increase in $\bar{h}$. However, it can be seen that in our analysis, the positioning of the groups according to $h_{GROUP,norm}$ is not so different from that one according to $\bar{h}$, both at publication and patent levels. This is probably due to the relatively homogeneous distribution of co-authorship among researchers of the same group (see Table 2). Also, there is not any "critical mass" effect, meaning that big groups do not necessarily perform better than small ones [41].

P and C are two other indicators influenced by N; unsurprisingly, the highest values of these indicators are associated with the group of German researchers. A simple way to enable comparisons among groups on the basis of the members' "average efficiency" is to use the normalised indicators P/N and C/N (see Fig. 4). Analysing these and other indicators that are not influenced by N—such as $\bar{h}$ and $h_{GROUP,norm}$—some interesting results emerge.

Regarding publications, Germans are overcome in terms of impact/diffusion (depicted by $C^{(PUB)}/N^{(PUB)}$ values) by the group of Danish and that of British researchers. This is due to the fact that, on average, publications of DEU are less cited than those of other groups. A confirmation is represented by the relatively small $CPP^{(PUB)}$ and $h_{GROUP,norm}{}^{(PUB)}$ with respect to other groups (see Table 2).

Regarding patents, Swiss researchers dominates since their productivity and impact/diffusion is much higher than the other researchers', as evidenced by the very high $P^{(PAT)}/N^{(PAT)}$, $C^{(PAT)}/N^{(PAT)}$, $h_{GROUP,norm}{}^{(PAT)}$ and $CPP^{(PAT)}$ values (see Fig. 4 and Table 2). Conversely, Italian researchers perform very badly. The fact that they have $\%P_0{}^{(PAT)}=$ 89% is emblematic and denotes a very low propensity to patent.

A number of issues that deserve further study arise from these specific considerations:

- Are the different trends in publishing and patenting the results of a conscious decision by researchers?
- Are there external influences in the publishing/patenting behaviour, such as government regulations or (dis) incentives?
- Are researchers with poor patent output really unable to realize technology transfer?

These questions have been abundantly discussed in the literature [38, 57, 58], although not specifically within the scientific field of interest. Probably a combination of the above factors contributes to generate the differences, and this type of investigation deserves attention for future research.

Finally, the groups' h_2 values are reported in Table 2. Two problems can arise with this indicator: (1) it is influenced by N and (2) it is low discerning when N values are quite small. Generally, the synthesis provided by h_2 becomes relevant when the number of the group members and the corresponding h values have roughly the same order of magnitude; so, despite their different nature, they can be compared [22]. For this reason, in the case of patents, we note that h_2 is not as discriminatory as in the case of publications.

4 Further remarks

4.1 Publishing and patenting: any relationship?

The most interesting aspect that emerges when comparing the results of the publication and patent analysis is the lack

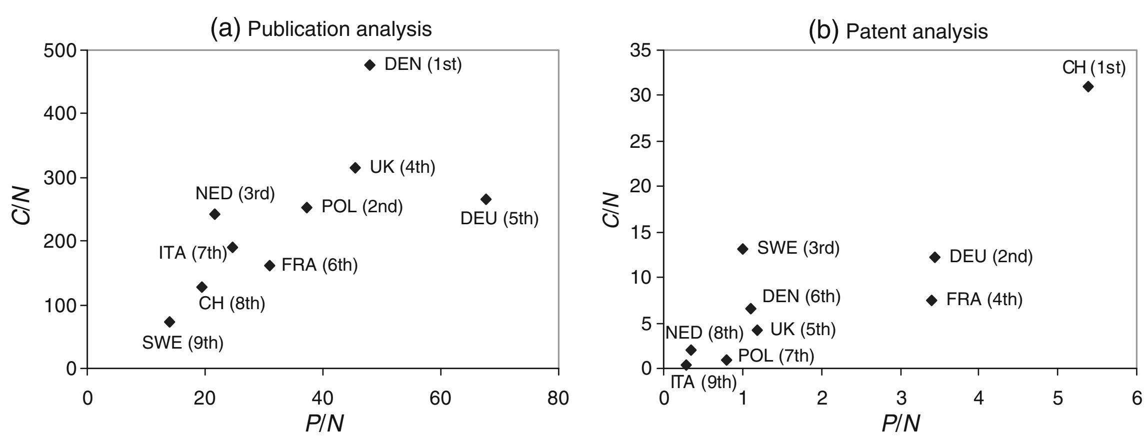

Fig. 4 C/N versus P/N for the groups of researchers from the same country both at publication (**a**) and patent levels (**b**). Reported in *brackets* are the ranks obtained on the basis of the groups' $h_{GROUP,norm}$ value, which aggregates the information relating to publications/patents of a group and corresponding citations (see Table 2 and Fig. 4)

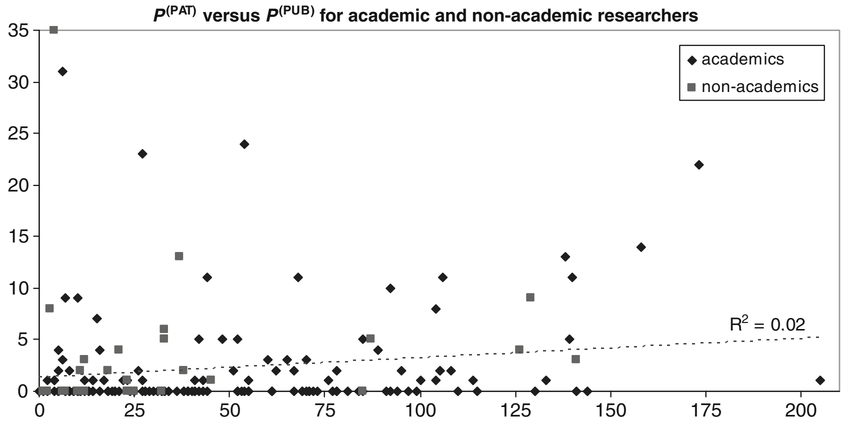

Fig. 5 Relationship between the $P^{(PAT)}$ and $P^{(PUB)}$ for individual researchers distinguishing between academic and non-academic (data are reported in Table 6 in the Appendix). The lack of correlation ($R^2 \approx 0$) denotes that, for a quite relevant sample of researchers in the field of production technology and manufacturing systems, publishing and patenting are independent activities. The graph considers only those (182) researchers for which both publication and patent analyses were performed

of correlation between these two kinds of research outputs. Precisely, Fig. 5 shows that there is no correlation ($R^2 \approx 0$) between the $P^{(PAT)}$ and $P^{(PUB)}$ values of individual researchers (data are reported in Table 6 in the Appendix). We are aware that in other scientific fields, a general positive relation, supporting the thesis that these activities may actually reinforce one another, was found. The mechanism sounds like a Matthew effect: scientifically prolific scientists tend to be more up-to-date, committed to research and likely to achieve technology transfer than others, thus benefiting from more resources from the collaboration with industry to be reinvested in basic research and so on [2, 7, 57, 58].

Also, we analysed possible differences between academic and non-academic researchers. In accordance with Fig. 5, points associated with academics and non-academics look both randomly distributed; thus, there is no apparent correlation among publication and patent productivity. However, it is interesting to notice some differences in terms of the average amount of production. Precisely, the average total production of publications per capita (represented by the mean $P^{(PUB)}$ in Table 3) of academics is higher than the one for non-academics. This means that academics tends to be more inclined to publish even if—regarding the average impact/diffusion (represented by the mean *CPP*)—the difference is very little. With regard to patents, we notice the opposite situation: productivity (represented by the mean $P^{(PAT)}$ in Table 3) of non-academics is significantly higher than that of academics. This is also confirmed by the high percentage of academics with no patents ($\%P_0^{(PAT)}$). Regarding the mean $CPP^{(PAT)}$, academics are predominant. However, this rather surprising result is given by the fact that the mean $CPP^{(PAT)}$ of academics is strongly influenced by the contribution of two researchers (precisely DEU20 and CH10 in Table 6), with an astonishingly high *C* values. It is worth remembering that, being a not very robust indicator, *CPP* and similar indicators can be strongly influenced by outliers [26].

4.2 Which types of technology?

Previous analysis shows substantial differences between researchers from several European countries in terms of propensity to publish/patent, although it gives no information on the predominant types of technologies and how they vary from country to country. To obtain a rough indication of the latter aspect, we analysed the most frequent keywords associated with the publications and patents of each group of researchers. For simplicity, keywords have been reworded in

Table 3 Comparison among academic and non-academic researchers with respect to their propensity to publish or patent

Affiliation type	Publications				Patents			
	mean *P*	mean *C*	mean *CPP*	$\%P_0$	mean *P*	mean *C*	mean *CPP*	$\%P_0$
Academic	49.1	259.0	5.3	0.6	2.0	8.6	4.3	62.7
Non-academic	32.7	167.0	5.1	0.0	3.4	8.8	2.6	46.7

For each of the two categories of researchers, the following indicators are reported: mean total publications/patents per capita (mean *P*), mean total citations per capita (mean *C*), mean *CPP* and percentage of researchers with no publications or patents ($\%P_0$). Indicators are obtained using data reported in Table 6 in the Appendix

Table 4 List of keywords and relevant frequencies, i.e. absolute (f_a) and relative frequency (f_r), concerning the Pubs and Pats of groups of researchers from the same country

	Keyword(s)	f_a	f_r (%)	Keyword(s)	f_a	f_r (%)	Keyword(s)	f_a	f_r (%)	Keyword(s)	f_a	f_r (%)
DEU												
Pubs	Machine tool	13	7.3	Machining	6	3.4	Assembly	3	1.7	Gear	2	1.1
	Control	11	6.2	Metrology	6	3.4	Design	3	1.7	Life cycle	2	1.1
	Simulation	11	6.2	Modelling	6	3.4	Machine	3	1.7	Micromachining	2	1.1
	Automation	10	5.6	Ops mgmt	5	2.8	Management	3	1.7	Tolerancing	2	1.1
	Grinding	8	4.5	Production	5	2.8	Material	3	1.7	Handling	1	0.6
	Coating	7	4.0	Cutting	4	2.3	Metal forming	3	1.7	mfg system	1	0.6
	Laser	7	4.0	Fluid	4	2.3	Optical	3	1.7	Prod. planning	1	0.6
	Moulding	7	4.0	Monitoring	4	2.3	Quality	3	1.7	Rolling	1	0.6
	precision	7	4.0	Optimization	4	2.3	Robot	3	1.7	Uncertainty	1	0.6
	Forming	6	3.4	Sensor	4	2.3	CMM	2	1.1			
Pats	Forming	65	11.4	Grinding	14	2.5	Quality	10	1.8	Interferometry	4	0.7
	Machine tool	53	9.3	Micromachining	14	2.5	Robot	10	1.8	Monitoring	3	0.5
	Sheet metal	46	8.1	Handling	13	2.3	Laser	9	1.6	Sensor	3	0.5
	Simulation	29	5.1	Machine	13	2.3	Material	9	1.6	Assembly	2	0.4
	Metrology	27	4.7	CMM	11	1.9	Cutting	8	1.4	Residual stress	2	0.4
	Hydroforming	25	4.4	Machining	11	1.9	mfg system	8	1.4	Coating	1	0.2
	Precision	23	4.0	Management	11	1.9	CNC	5	0.9	Moulding	1	0.2
	Rolling	22	3.9	Production	11	1.9	Design	5	0.9	Roughness	1	0.2
	Automation	21	3.7	Tolerancing	11	1.9	Modelling	5	0.9			
	Control	20	3.5	Optical	10	1.8	Uncertainty	5	0.9			
	Metal forming	15	2.6	Optimization	10	1.8	Gear	4	0.7			
UK												
Pubs	Machining	16	11.2	Cutting	5	3.5	Optimization	2	1.4	Rapid prototyping	1	0.7
	Nanotechnology	13	9.1	Machine tool	5	3.5	Chip	1	0.7	Robot	1	0.7
	Metrology	12	8.4	Optical	5	3.5	Cooling	1	0.7	Simulation	1	0.7
	Grinding	10	7.0	Tribology	5	3.5	Cost	1	0.7	Sustainable development	1	0.7
	Material	10	7.0	Micromachining	4	2.8	Environment(al)	1	0.7	Thermal effects	1	0.7
	EDM	9	6.3	Sintering	4	2.8	Machine	1	0.7	Wear	1	0.7
	Precision	9	6.3	Biomedical	3	2.1	mfg system	1	0.7			
	Surface	8	5.6	Design	2	1.4	Metal forming	1	0.7			
	CMM	5	3.5	Monitoring	2	1.4	Modelling	1	0.7			
Pats	Surface	23	18.9	Nano technology	11	9.0	Material	4	3.3	Automation	1	0.8
	Monitoring	15	12.3	EDM	5	4.1	Optimization	4	3.3	Sintering	1	0.8
	Cutting	12	9.8	Grinding	5	4.1	Biomedical	3	2.5			
	Metrology	12	9.8	machining	5	4.1	Micromachining	3	2.5			
	Precision	12	9.8	cooling	4	3.3	robot	2	1.6			
ITA												
Pubs	FMS	7	7.1	Sensor	5	5.1	Monitoring	3	3.0	Laser	1	1.0
	mfg system	7	7.1	Material	4	4.0	Assembly	2	2.0	Measurement	1	1.0
	Simulation	7	7.1	Surface	4	4.0	Miniaturization	2	2.0	ops mgmt	1	1.0
	Friction stir Welding	6	6.1	Conceptual design	3	3.0	Quality	2	2.0	Optical	1	1.0
	Joining	6	6.1	EDM	3	3.0	Rapid prototyping	2	2.0	Optimization	1	1.0
	Machining	6	6.1	FEM	3	3.0	Coating	1	1.0	Precision	1	1.0
	Metal forming	5	5.1	Forming	3	3.0	CAPP	1	1.0	Production	1	1.0
	Metrology	5	5.1	Hydroforming	3	3.0	Cutting	1	1.0	Reverse engg	1	1.0
Pats	Automation	4	15.4	Metrology	4	15.4	Error	2	7.7			
	Factory	4	15.4	CMM	2	7.7	Measurement	2	7.7			
	mfg system	4	15.4	Cutting	2	7.7	Uncertainty	2	7.7			
FRA												
Pubs	Chip	9	11.5	Energy	6	7.7	FEM	3	3.8	Life cycle	1	1.3

Table 4 (continued)

	Keyword(s)	f_a	f_r (%)	Keyword(s)	f_a	f_r (%)	Keyword(s)	f_a	f_r (%)	Keyword(s)	f_a	f_r (%)
	Material	9	11.5	EDM	5	6.4	Forming	3	3.8	Performance	1	1.3
	Modelling	9	11.5	Decision making	4	5.1	Processing	3	3.8	Production	1	1.3
	Machining	7	9.0	Maintenance	4	5.1	Design	2	2.6			
	Cutting	6	7.7	mfg system	4	5.1	Knowledge mgmt	1	1.3			
Pats	Machining	35	21.1	Knowledge mgmt	13	7.8	CNC	1	0.6	Mechatronic	1	0.6
	Rapid tooling	35	21.1	Performance	13	7.8	FEM	1	0.6	Robot	1	0.6
	Surface	35	21.1	Production	13	7.8	Machine	1	0.6	Tolerancing	1	0.6
	Design	13	7.8	Chip	1	0.6	Material	1	0.6	Uncertainty	1	0.6
NED												
Pubs	CAPP	15	12.2	Life cycle	9	7.3	Production	4	3.3	Grinding	1	0.8
	Design	13	10.6	Chip	6	4.9	Sensor	3	2.4	Machine tool	1	0.8
	Abrasion	11	8.9	Control	6	4.9	Uncertainty	3	2.4	Wear	1	0.8
	Modelling	11	8.9	Metrology	6	4.9	Automation	1	0.8			
	Sheet metal	11	8.9	Precision	5	4.1	CMM	1	0.8			
	Integration	10	8.1	Management	4	3.3	Cutting	1	0.8			
Pats	Metrology	3	21.4	Automation	1	7.1	Laser	1	7.1	Wear	1	7.1
	Sensor	2	14.3	Cutting	1	7.1	Machine tool	1	7.1			
	Uncertainty	2	14.3	Grinding	1	7.1	Precision	1	7.1			
CH												
Pubs	Nanotechnology	13	25.0	Grinding	3	5.8	Laser	2	3.8	Rapid prototyping	1	1.9
	Surface	13	25.0	Composite	2	3.8	Conceptual design	1	1.9	Rapid tooling	1	1.9
	Tribology	13	25.0	EDM	2	3.8	Machine tool	1	1.9			
Pats	Laser	34	15.2	Nanotechnology	14	6.3	Metrology	13	5.8	EDM	3	1.3
	Composite	31	13.8	Surface	14	6.3	CMM	9	4.0			
	Conceptual design	31	13.8	Tribology	14	6.3	Error	9	4.0			
	Rapid prototyping	31	13.8	Machine tool	13	5.8	Grinding	8	3.6			
POL												
Pubs	Assembly	17	18.1	Quality	17	18.1	Machining	4	4.3	Surface	4	4.3
	Control	17	18.1	Cutting	4	4.3	Modelling	4	4.3	Forming	1	1.1
	Design	17	18.1	Machine tool	4	4.3	Monitoring	4	4.3	Thermal effects	1	1.1
Pats	Forming	7	41.2	Design	1	5.9	Precision	1	5.9			
	Thermal effects	7	41.2	Machine tool	1	5.9						
DEN												
Pubs	Tribology	16	16.0	mfg system	8	8.0	Friction	4	4.0	Nano mfg	2	2.0
	Metal forming	10	10.0	Cutting	6	6.0	Hydroforming	4	4.0	Prod. planning	2	2.0
	Welding	10	10.0	Metrology	6	6.0	Sheet metal	4	4.0			
	Design	8	8.0	Forging	4	4.0	Management	2	2.0			
	Life cycle	8	8.0	Forming	4	4.0	Micromachining	2	2.0			
Pats	Tribology	5	14.3	Metrology	3	8.6	Micromachining	2	5.7	Welding	2	5.7
	Forging	4	11.4	Forming	2	5.7	Nano mfg	2	5.7			
	Metal forming	4	11.4	Friction	2	5.7	Optimization	2	5.7			
	Cutting	3	8.6	Hydroforming	2	5.7	Sheet metal	2	5.7			
SWE												
Pubs	Assembly	6	19.4	Cutting	4	12.9	Conceptual design	1	3.2	System	1	3.2
	Simulation	5	16.1	Wear	4	12.9	Concurrent engg	1	3.2			
	Tolerancing	5	16.1	Modelling	3	9.7	Engineering	1	3.2			
Pats	Cutting	4	19.0	Machining	4	19.0	Assembly	2	9.5	Modelling	1	4.8
	Grinding	4	19.0	Wear	4	19.0	Conceptual design	2	9.5			

For uniformity, keywords have been reworded according to the Unified CIRP Keyword List [14]. Among the total group publications, we considered only those of greatest impact, namely the first h_{GROUP} ones in terms of citations (see Table 2). Instead, as regards patents, we considered them all

Pubs publications, *Pats* patents, *CMM* coordinate measuring machine, *CNC* computer numerical control, *EDM* electrical discharge machining, *FMS* flexible manufacturing system, *FEM* finite element method, *CAPP* computer automated process planning

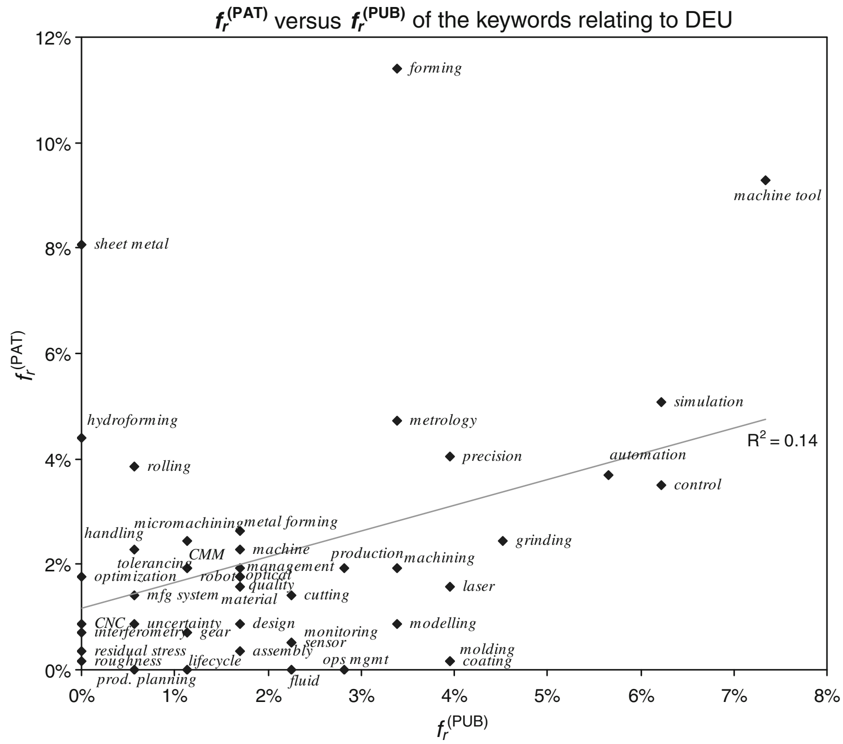

Fig. 6 Relationship between the keywords associated with patents and publications for the group of German researchers. For each keyword, the relative frequency relating to patents ($f_r^{(PAT)}$) against that relating to publications ($f_r^{(PAT)}$) is represented (see numerical data in Table 4)

accordance with the Unified CIRP Keyword List [14]. In doing this task, we also checked the consistency with the information on the specific research interests of each CIRP member, available in [12].

Given the relatively large number of publications of each group of researchers and the large variability in terms of citation impact, it was decided to restrict the study to the publications of greatest impact, namely those belonging to the so-called h_{GROUP} core, i.e. the h_{GROUP} most cited publications in each group (see Table 2). Instead, with regard to patents, we considered them all. The results of this analysis are shown in Table 4.

It can be noticed that the popularity of the different research topics may vary widely from country to country. For example, *nanotechnologies* and *nanomanufacturing* seem to be very popular among the group of Swiss scientists (both in terms of patents and publications), but totally ignored by the group of French and Italians. It can also be observed that the publication and patent topics are generally unrelated. As an example, consider the diagram in Fig. 6 which illustrates—for each keyword—the relative frequency regarding patents ($f_r^{(PAT)}$) and publications ($f_r^{(PAT)}$) for the group of DEU. The correlation is virtually nonexistent (R^2= 0.14), and the same applies to the other groups.

Table 5 GERD, i.e. per cent share of GDP, for the countries of interest in the period 1998–2008 [20]

Country	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Mean
DEU	2.27	2.4	2.45	2.46	2.49	2.52	2.49	2.49	2.53	2.53	2.63	2.48
UK	1.76	1.82	1.81	1.79	1.79	1.75	1.68	1.7	1.75	1.82	1.88	1.78
ITA	1.05	1.02	1.05	1.09	1.13	1.11	1.1	1.09	1.13	1.18	1.18	1.10
FRA	2.14	2.16	2.15	2.2	2.23	2.17	2.15	2.1	2.1	2.04	2.02	2.13
HOL	1.9	1.96	1.82	1.8	1.72	1.76	1.81	1.79	1.78	1.71	1.63	1.79
CH	–	–	2.53	–	–	–	2.9	–	–	–	–	2.72
POL	0.67	0.69	0.64	0.62	0.56	0.54	0.56	0.57	0.56	0.57	0.61	0.60
DEN	2.04	2.18	2.24	2.39	2.51	2.58	2.48	2.46	2.48	2.55	2.72	2.42
SWE	–	3.61	–	4.17	–	3.85	3.62	3.6	3.74	3.61	3.75	3.74
EU-27	1.79	1.83	1.85	1.86	1.87	1.86	1.82	1.82	1.85	1.85	1.90	1.85

The diagrams in Fig. 7 illustrate the relationship between one group's productivity per head (P/N)—both in terms of publications and patents—and the relevant average GERD of the country in 1998–2008 (see numerical data in the last column of Table 5)

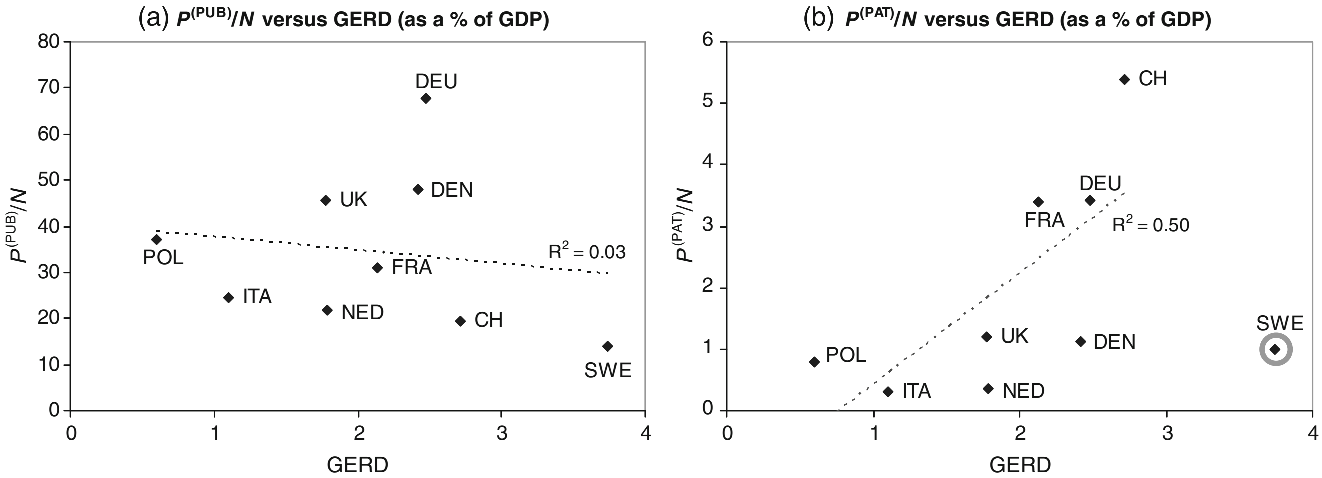

Fig. 7 Relationship between one group's productivity per head (*P*/*N*)—respectively in terms of publications (**a**) and patents (**b**)—and the relevant average GERD of the country in 1998–2008 (see Table 5). In the diagram (**b**), SWE (*circled in grey*) was excluded when determining the trend line; the reason of this exclusion is reported in the text

4.3 Relationship between research output and funding

Another interesting point concerns the presence of a possible correlation between the number of publications/patents and funding received. This study would require detailed information on the precise amount of funding received by each of the researchers during the years of activity. Given the great difficulty in obtaining this information, we limit ourselves to a preliminary study in which the average publication/patent productivity of a group of researchers is connected to an indicator of overall research investment at the national level. The simplifying assumptions underlying this study are that (1) the total national investment in research is evenly distributed among the scientific fields and (2) the average scientific output per head of each of the groups of researchers investigated approximately reflects that of the totality of national researchers in the discipline of interest.

As an indicator of research investment, we use the so-called R&D intensity, or gross domestic expenditure on R&D (GERD), calculated as a percentage of GDP. The annual data relating to the nine countries of interest, for the period 1998–2008, are reported in Table 5 [20]. Despite one of the key objectives of the EU during the last decade having been to encourage increasing levels of investment in order to provide a stimulus to the EU's competitiveness, it can be noticed that national investments look generally stable over time, with just a very slight tendency to increase.

In the case of publications, there is no apparent correlation, whilst in the case of patents, the link with investments looks clearer, although based on a very approximate study,

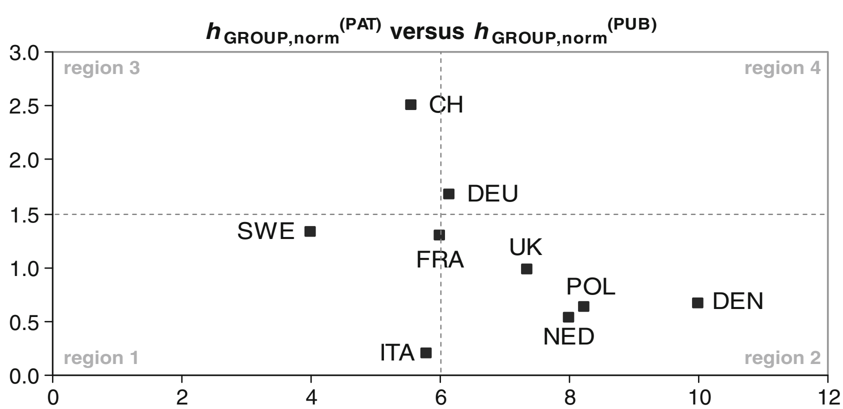

Fig. 8 h_{GROUP} map illustrating the relationship between the $h_{\text{GROUP,norm}}^{(PAT)}$ and $h_{\text{GROUP,norm}}^{(PUB)}$ for groups of researchers from the same country. The apparent lack of correlation confirms that, in the field of production technology and manufacturing systems, publishing and patenting are independent activities. The map makes it possible to (qualitatively) identify different regions: (*1*) groups with relatively low performance in terms of patents and publications; (*2*) groups relatively efficient in terms of publications but not in terms of patents; (*3*) groups with medium-high performance in terms of patents but relatively poor performance in terms of publications and (*4*) groups with a remarkable performance both in terms of publications and patents

this result confirms what has been observed by other more detailed studies on the relationship between funding and patents [53].

In the second diagram (Fig. 7b), we point out the position of SWE: despite being the only country among those studied with a GERD larger than 3% of the GDP (see Table 5), the number of patents per head of CIRP members is suspiciously low. This result contrasts with the fact that Sweden is one of the first European countries in terms of patents per researcher [20]. For this reason, SWE was excluded when determining the trend line and the corresponding R^2 value. A more in-depth analysis has to be performed to explore the reasons of this anomalous behaviour.

4.4 Aggregation of the two analysis perspectives

Researchers have been analysed from the two (separate) perspectives of publications and patents. Their aggregation remains an open issue, albeit it can be partially overcome by introducing some maps which depict the research output positioning of the researchers on the basis of two indicators associated with the perspectives of interest. For example, the map in Fig. 8 plots the $h_{\mathrm{GROUP,norm}}$ values concerning publications and patents respectively for each of the nine groups of researchers from the same country.

$h_{\mathrm{GROUP,norm}}$ was chosen as a synthetic indicator for three reasons: (1) it is able to synthesise the two aspects of productivity and impact/diffusion into a single number; (2) in the case of patents, this indicator does not suffer from the low discriminatory power of the h index when associated with the patents of an individual researchers (see Section 3); and (3) this indicator is intrinsically robust and not influenced by the group staff number [33]. The (h_{GROUP}) map shows an apparent lack of correlation between the indicators of interest, confirming that, in the field of production technology and manufacturing systems, publishing and patenting are quite independent activities.

4.5 Limitations of the analysis

The analysis proposed is based on a limited sample of individuals; thus, it is wild to extend the results associated with national groups of researchers to the whole national communities of scientists in the field of production technology and manufacturing systems. Nevertheless, our study represents a starting point for a future wider research. The preliminary results are interesting, also taking into account the fact that CIRP is recognised as a qualified and prestigious association with restricted membership based on demonstrated excellence in research [13].

Another limitation is that—being based on h index—most of the indicators in use could be subjected not only to the benefits but also criticisms made to the h index itself (e.g. they are sensitive to co-authorship, age of publications/patents, type of publications/patent, self citations, etc.) [22].

Also, h-based indicators are not perfectly suitable to compare scholars with different seniority, being in favour of those with long careers [34]. To focus on the impact of recent work and thus on current research performance, the same analysis could be repeated restricting citation period to a 5- to 10-year window instead of "lifetime counts".

5 Conclusions

This paper proposed a structured comparison between groups of researchers from nine European countries in the area of production technology and manufacturing systems. Almost 200 researchers were analysed on the basis of two perspectives: publications (indicator of scientific productivity) and patents (indicator of technology transfer). Data were collected by the Scopus database and their manual cleaning was fundamental for the accuracy of analysis, especially regarding patents. Many remarkable results emerge from the analysis:

- The study has highlighted some interesting differences in the tendency to publish and patent of European researchers. For the purpose of example, we remark on the difference between Swiss and Italian researchers. Despite coming from two geographically adjacent countries, their behaviour is, on average, curiously different. In terms of publications, there is a slight superiority of Italians, but from the point of view of patents, the situation is diametrically opposite: Swiss researchers have a very strong propensity to patent, which distinguishes them from the other groups, whilst Italian scientists are "lagging behind".
- In this scientific area, there is no apparent correlation between the publishing and patenting activity of researchers either in terms of amount of research output or in terms of specific research topics.
- Of particular interest is the construction of a h_{GROUP} map for depicting the positioning of researchers on the basis of their publication and patent output.

Due to the limited sample used, the results of this analysis are far from being generalized to the national research communities in the field of interest. Nevertheless, this work provides some cues for future research, such as: (1) extending the study to a larger sample (both in terms of researchers and examined countries) to find a confirmation of the results presented before; (2) studying the time evolution of the attitude to patent/publish by researchers from different countries; and (3) providing an interpretation to the differences among national groups of researchers in their publishing/patenting behaviour.

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1 Appendix

Table 6 Analysis results concerning individual researchers

Abbreviations	Membership[a]	Affiliation[b]	Indicators relating to PUB								Indicators relating to PAT							
			P	C	CPP	h	$Avg_{co\text{-}authors}$	Y_{MIN}	Y_{MAX}	$C_{most\text{-}cited}$	P	C	CPP	h	$Avg_{co\text{-}authors}$	Y_{MIN}	Y_{MAX}	$C_{most\text{-}cited}$
DEU1	H	A	133	197	1.5	8	2.6	1973	2004	41	1	0	0.0	0	1.0	1969	1969	0
DEU2	H	A	97	269	2.8	8	2.6	1973	2003	80	0	–	–	–	–	–	–	–
DEU3	H	A	140	644	4.6	12	3.0	1974	2006	98	11	34	3.1	3	4.3	1982	2007	12
DEU4	F	A	52	174	3.3	7	3.6	1996	2010	31	0	–	–	–	–	–	–	–
DEU5	F	A	141	905	6.4	17	3.5	1980	2010	113	0	–	–	–	–	–	–	–
DEU6	F	A	138	231	1.7	6	3.6	1989	2010	76	13	7	0.5	1	2.6	1997	2010	5
DEU7	F	A	139	971	7.0	16	3.1	1973	2010	155	5	10	2.0	2	3.8	1992	2006	6
DEU8	F	A	78	327	4.2	10	4.2	1990	2010	48	2	0	0.0	0	4.0	1996	2008	0
DEU9	F	A	48	446	9.3	5	3.3	1981	2010	371	5	53	10.6	3	2.2	1987	1998	35
DEU10	F	A	42	257	6.1	10	3.5	1992	2010	38	0	–	–	–	–	–	–	–
DEU11	F	N	87	520	6.0	9	3.8	1983	2010	157	5	22	4.4	2	3.0	1996	2008	14
DEU12	F	A	205	1330	6.5	18	4.0	1980	2010	150	1	4	4.0	1	9.0	1997	1997	4
DEU13	F	N	129	278	2.2	9	3.7	1996	2010	42	9	14	1.6	2	4.0	1998	2006	7
DEU14	F	A	94	264	2.8	7	3.6	1995	2010	98	0	–	–	–	–	–	–	–
DEU15	F	A	92	492	5.3	12	3.4	1983	2010	103	0	–	–	–	–	–	–	–
DEU16	F	A	104	257	2.5	9	3.5	1993	2010	31	8	24	3.0	2	3.0	1994	2010	19
DEU17	F	A	85	89	1.0	6	3.4	1986	2010	12.0	0	–	–	–	–	–	–	–
DEU18	F	A	68	68	1.0	4	3.1	1982	2009	14	11	30	2.7	3	2.1	1986	1994	9
DEU19	F	N	126	732	5.8	14	3.4	1989	2010	123	4	6	1.5	2	4.8	2005	2010	3
DEU20	F	A	92	276	3.0	7	3.0	1973	2010	51	10	249	24.9	8	2.7	1977	1992	110
DEU21	F	A	11	3	0.3	1	2.3	1975	2010	1	0	–	–	–	–	–	–	–
DEU22	A	A	84	111	1.3	6	3.3	1978	2010	26	0	–	–	–	–	–	–	–
DEU23	A	A	85	95	1.1	6	4.1	1997	2010	12	5	0	0.0	0	3.2	2006	2010	0
DEU24	A	A	69	28	0.4	3	3.6	1992	2010	8	0	–	–	–	–	–	–	–
DEU25	A	A	105	137	1.3	5	3.7	2001	2010	44	2	0	0.0	0	3.5	2007	2010	0
DEU26[c,d]	A	N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
DEU27	A	A	61	78	1.3	4	4.1	1997	2009	40	0	–	–	–	–	–	–	–
DEU28	A	A	52	129	2.5	7	3.2	2000	2010	19	5	2	0.4	1	2.0	2001	2008	2
DEU29	A	A	95	238	2.5	8	4.1	1989	2009	18	2	0	0.0	0	5.5	2003	2009	0
DEU30	A	A	81	428	5.3	11	3.9	1989	2010	83	0	–	–	–	–	–	–	–
DEU31	A	A	27	19	0.7	3	2.9	1974	2010	8	23	32	1.4	3	3.8	1981	2003	11
DEU32	A	A	13	73	5.6	3	3.9	1993	2010	23	0	–	–	–	–	–	–	–

Table 6 (continued)

Abbreviations	Membership[a]	Affiliation[b]	Indicators relating to PUB								Indicators relating to PAT							
			P	C	CPP	h	$Avg_{co\text{-}authors}$	Y_{MIN}	Y_{MAX}	$C_{most\text{-}cited}$	P	C	CPP	h	$Avg_{co\text{-}authors}$	Y_{MIN}	Y_{MAX}	$C_{most\text{-}cited}$
DEU33	A	A	32	15	0.5	3	3.1	1998	2010	4	0	–	–	–	–	–	–	–
DEU34	A	A	70	132	1.9	5	3.2	1994	2010	40	0	–	–	–	–	–	–	–
DEU35[d]	A	A	66	77	1.2	3	4.0	1991	2010	48	–	–	–	–	–	–	–	–
DEU36	A	A	43	92	2.1	5	3.0	1996	2010	26	0	–	–	–	–	–	–	–
DEU37	A	N	33	255	7.7	9	3.5	1977	2009	41	5	18	3.6	3	3.2	1998	2005	7
DEU38	A	A	42	24	0.6	2	3.6	1998	2010	18	5	6	1.2	1	2.4	1999	2009	6
DEU39	A	A	55	108	2.0	5	3.9	2003	2010	22	0	–	–	–	–	–	–	–
DEU40	E	A	30	60	2.0	5	2.9	1978	2007	10	0	–	–	–	–	–	–	–
DEU41	E	A	7	3	0.4	1	2.3	1977	1992	1	0	–	–	–	–	–	–	–
DEU42	E	A	33	38	1.2	3	2.8	1972	1997	14	0	–	–	–	–	–	–	–
DEU43	E	A	99	246	2.5	9	3.1	1975	2004	92	0	–	–	–	–	–	–	–
DEU44	E	A	110	369	3.4	10	2.9	1974	2010	92	0	–	–	–	–	–	–	–
DEU45	E	A	14	28	2.0	2	3.1	1981	1998	17	0	–	–	–	–	–	–	–
DEU46	E	N	1	0	0.0	0	1.0	1981	1981	0	0	–	–	–	–	–	–	–
DEU47	E	A	173	733	4.2	15	3.5	1974	2009	70	22	36	1.6	4	3.7	1982	2009	7
DEU48	E	N	85	145	1.7	6	3.0	1979	2007	17	0	–	–	–	–	–	–	–
DEU49	E	N	33	1136	34.4	12	3.6	1966	2010	795	6	62	10.3	5	3.5	1983	1989	17
DEU50	E	A	16	53	3.3	3	2.5	1980	2007	30	0	–	–	–	–	–	–	–
DEU51	E	N	25	72	2.9	4	2.6	1984	2009	29	0	–	–	-	–	–	–	–
DEU52	E	A	89	196	2.2	8	3.0	1981	2010	31	4	20	5.0	3	2.5	1988	1996	7
DEU53	E	A	65	813	12.5	12	2.8	1986	2006	371	3	9	3.0	2	3.0	1997	2009	6
DEU54	E	A	43	136	3.2	7	2.2	1966	2003	32	1	0	0.0	0	5.0	1997	1997	0
DEU55	E	A	10	5	0.5	1	1.8	1981	2002	4	9	23	2.6	3	3.3	1972	2000	10
DEU56	E	A	54	177	3.3	6	2.7	1973	2006	35	24	49	2.0	4	3.7	1977	2006	14
DEU57	E	A	14	89	6.4	4	4.0	1975	2001	38	1	5	5.0	1	5.0	1995	1995	5
DEU58	E	N	141	220	1.6	7	2.5	1972	2002	69	3	8	2.7	2	1.7	1992	1997	5
DEU59	E	A	5	0	0.0	0	3.2	1976	1986	0	2	6	3.0	1	3.5	1964	1976	6
DEU60	E	A	105	530	5.0	11	3.6	1973	2009	94	2	0	0.0	0	3.5	2006	2006	0
DEU61	E	A	22	112	5.1	3	2.3	1973	2003	91	1	5	5.0	1	2.0	1989	1989	5
DEU62	E	A	77	336	4.4	10	2.3	1981	2010	63	0	–	–	–	–	–	–	–
UK1	H	A	18	30	1.7	4	4.2	1972	1992	6	0	–	–	–	–	–	–	–
UK2	H	A	28	104	3.7	4	2.1	1974	2008	71	0	–	–	–	–	–	–	–
UK3[d]	F	A	33	187	5.7	8	2.8	1984	2010	63	–	–	–	–	–	–	–	–
UK4	F	A	76	1064	14.0	18	3.4	1984	2010	98	1	1	1.0	1	9.0	2005	2005	1
UK5	F	A	71	475	6.7	13	3.0	1972	2010	34	0	–	–	–	–	–	–	–

Table 6 (continued)

Abbreviations	Membership[a]	Affiliation[b]	Indicators relating to PUB								Indicators relating to PAT							
			P	*C*	*CPP*	*h*	$Avg_{co\text{-}authors}$	Y_{MIN}	Y_{MAX}	$C_{most\text{-}cited}$	*P*	*C*	*CPP*	*h*	$Avg_{co\text{-}authors}$	Y_{MIN}	Y_{MAX}	$C_{most\text{-}cited}$
UK6	F	A	44	359	8.2	12	2.4	1976	2008	49	0	–	–	–	–	–	–	–
UK7[c,d]	F	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
UK8	F	A	78	411	5.3	11	3.3	1989	2010	27	0	–	–	–	–	–	–	–
UK9	F	A	70	511	7.3	11	3.1	1973	2010	95	3	24	8.0	2	3.0	1984	1994	13
UK10	F	A	73	261	3.6	8	3.5	1999	2010	49	0	–	–	–	–	–	–	–
UK11	F	A	71	544	7.7	13	3.2	1976	2007	109	0	–	–	–	–	–	–	–
UK12[d]	F	N	27	122	4.5	5	2.7	1990	2008	37	–	–	–	–	–	–	–	–
UK13	F	A	106	1126	10.6	16	2.3	1972	2009	298	11	58	5.3	4	2.5	1954	2003	31
UK14[c,d]	F	A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
UK15	A	A	52	272	5.2	8	2.8	1996	2010	83	0	–	–	–	–	–	–	–
UK16	A	A	44	159	3.6	8	3.0	2001	2010	37	11	12	1.1	3	4.1	2002	2010	4
UK17	A	A	1	1	1.0	1	1.0	2009	2009	1	0	–	–	–	–	–	–	–
UK18	A	A	100	274	2.7	9	4.1	1996	2011	31	1	1	1.0	1	4.0	2007	2007	1
UK19	A	A	61	577	9.5	11	3.3	1986	2010	127	0	–	–	–	–	–	–	–
UK20[d]	A	A	5	1	0.2	1	4.8	2004	2010	1	–	–	–	–	–	–	–	–
UK21	E	A	34	294	8.6	10	3.4	1966	2007	45	0	–	–	–	–	–	–	–
UK22	E	A	67	316	4.7	9	2.9	1965	2008	83	0	–	–	–	–	–	–	–
UK23	E	A	114	988	8.7	20	3.1	1969	2009	132	1	4	4.0	1	4.0	1995	1995	4
UK24[d]	E	A	23	157	6.8	5	3.3	1983	2008	37	–	–	–	–	–	–	–	–
UK25	E	A	0	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–
UK26	E	A	27	39	1.4	4	2.9	1972	2002	9	1	5	5.0	1	3.0	1982	1982	5
UK27[d]	E	A	52	98	1.9	6	2.6	1981	2005	18	–	–	–	–	–	–	–	–
UK28	E	N	45	73	1.6	2	3.2	1972	1986	63	1	1	1.0	1	2.0	1967	1967	1
UK29	E	N	23	255	11.1	8	2.8	1973	2009	48	0	–	–	–	–	–	–	–
UK30	E	A	115	1014	8.8	18	3.0	1966	2008	54	0	–	–	–	–	–	–	–
UK31	E	N	6	13	2.2	2	3.5	1961	1984	11	0	–	–	–	–	–	–	–
UK32	E	A	4	5	1.3	1	2.3	1983	1986	4	1	1	1.0	1	1.0	1968	1968	1
UK33	E	A	2	7	3.5	1	2.5	1977	1984	6	0	–	–	–	–	–	–	–
ITA1	H	A	20	593	29.7	7	3.9	1978	2008	371	0	–	–	–	–	–	–	–
ITA2	H	A	51	89	1.7	6	3.2	1965	2009	31	2	0	0.0	0	3.0	2006	2007	0
ITA3	F	N	11	58	5.3	4	3.6	1995	2009	17	2	7	3.5	1	3.5	2001	2008	7
ITA4	F	A	29	130	4.5	7	3.3	1982	2010	20	0	–	–	–	–	–	–	–
ITA5	F	A	8	74	9.3	4	2.6	1999	2010	21	0	–	–	–	–	–	–	–
ITA6	F	A	38	174	4.6	8	3.9	1986	2010	25	0	–	–	–	–	–	–	–
ITA7	F	A	32	221	6.9	8	3.1	1974	2010	38	0	–	–	–	–	–	–	–

Table 6 (continued)

Abbreviations	Membership[a]	Affiliation[b]	Indicators relating to PUB								Indicators relating to PAT							
			P	C	CPP	h	$Avg_{\text{co-authors}}$	Y_{MIN}	Y_{MAX}	$C_{\text{most-cited}}$	P	C	CPP	h	$Avg_{\text{co-authors}}$	Y_{MIN}	Y_{MAX}	$C_{\text{most-cited}}$
ITA8	F	A	71	478	6.7	11	4.0	1989	2010	82	0	–	–	–	–	–	–	–
ITA9	F	A	21	96	4.6	6	3.4	1981	2006	16	0	–	–	–	–	–	–	–
ITA10	F	A	24	255	10.6	10	2.7	1982	2010	62	0	–	–	–	–	–	–	–
ITA11	F	A	41	415	10.1	7	3.0	1980	2010	243	0	–	–	–	–	–	–	–
ITA12	F	A	39	232	5.9	10	3.3	1994	2010	36	0	–	–	–	–	–	–	–
ITA13	A	A	33	165	5.0	8	3.6	2000	2010	35	0	–	–	–	–	–	–	–
ITA14	A	A	5	13	2.6	2	3.6	1996	2010	8	0	–	–	–	–	–	–	–
ITA15	A	N	21	70	3.3	5	2.7	1998	2010	15	4	1	0.3	1	5.8	2007	2009	1
ITA16	A	A	39	263	6.7	7	4.5	1992	2010	84	0	–	–	–	–	–	–	–
ITA17	A	A	7	16	2.3	3	2.6	1999	2009	5	0	–	–	–	–	–	–	–
ITA18	A	A	55	293	5.3	8	4.1	2002	2010	44	0	–	–	–	–	–	–	–
ITA19	A	A	91	536	5.9	14	3.6	1995	2010	49	0	–	–	–	–	–	–	–
ITA20[c]	A	A	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–
ITA21	A	A	9	72	8.0	4	2.4	1999	2010	31	0	–	–	–	–	–	–	–
ITA22	A	A	33	187	5.7	8	3.5	1994	2010	29	0	–	–	–	–	–	–	–
ITA23	A	A	20	123	6.2	7	4.0	2001	2010	43	0	–	–	–	–	–	–	–
ITA24	A	A	24	124	5.2	7	3.3	1994	2010	28	0	–	–	–	–	–	–	–
ITA25	E	A	12	69	5.8	5	4.2	1972	2004	21	0	–	–	–	–	–	–	–
ITA26	E	A	9	12	1.3	2	2.6	1967	1999	6	0	–	–	–	–	–	–	–
ITA27[c]	E	N	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–
FRA1	H	N	12	20	1.7	2	2.7	1974	1996	17	0	–	–	–	–	–	–	–
FRA2	H	N	1	0	0.0	0	1.5	2002	2002	0	0	–	–	–	–	–	–	–
FRA3	F	N	37	110	3.0	5	2.8	1986	2011	26	13	65	5.0	3	1.8	1982	2005	29
FRA4	F	A	40	217	5.4	11	2.9	1996	2010	22	0	–	–	–	–	–	–	–
FRA5	F	A	104	168	1.6	7	3.3	1990	2010	15	1	2	2.0	1	3.0	1992	1992	2
FRA6	F	A	130	593	4.6	13	3.3	1981	2010	34	0	–	–	–	–	–	–	–
FRA7	F	A	10	39	3.9	4	3.3	2001	2010	11	0	–	–	–	–	–	–	–
FRA8	F	N	32	138	4.3	7	2.5	1982	2010	20	0	–	–	–	–	–	–	–
FRA9	A	A	55	104	1.9	5	3.2	1976	2010	15	1	2	2.0	1	3.0	1992	1992	2
FRA10	A	A	28	222	7.9	9	3.7	1993	2010	32	0	–	–	–	–	–	–	–
FRA11	A	N	23	222	9.7	9	3.7	1998	2010	49	1	0	0.0	0	3.0	2009	2009	0
FRA12[d]	A	N	20	96	4.8	6	3.2	1997	2009	20	–	–	–	–	–	–	–	–
FRA13	A	A	25	228	9.1	9	3.7	1998	2010	38	0	–	–	–	–	–	–	–
FRA14	E	A	12	81	6.8	6	3.7	1998	2009	21	1	0	0.0	0	4.0	2010	2010	0
FRA15[c,d]	E	N	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table 6 (continued)

Abbreviations	Membership[a]	Affiliation[b]	Indicators relating to PUB								Indicators relating to PAT							
			P	C	CPP	h	$Avg_{co\text{-}authors}$	Y_{MIN}	Y_{MAX}	$C_{most\text{-}cited}$	P	C	CPP	h	$Avg_{co\text{-}authors}$	Y_{MIN}	Y_{MAX}	$C_{most\text{-}cited}$
FRA16	E	A	36	331	9.2	10	3.7	1981	2007	52	0	–	–	–	–	–	–	–
FRA17	E	N	4	3	0.8	1	3.0	2003	2007	2	35	44	1.3	3	2.4	1978	2010	14
NED1	H	A	69	928	13.4	15	3.6	1975	2004	123	0	–	–	–	–	–	–	–
NED2	H	A	17	123	7.2	6	2.6	1973	1984	41	1	0	0.0	0	1.0	1971	1971	0
NED3	H	N	1	0	0.0	0	0.5	1984	1984	0	0	–	–	–	–	–	–	–
NED4	F	A	2	0	0.0	0	4.0	2007	2010	0	1	23	23.0	1	2.0	1984	1984	23
NED5	F	A	41	365	8.9	10	3.6	1981	2009	104	0	–	–	–	–	–	–	–
NED6[d]	F	A	100	714	7.1	14	3.4	1984	2010	135	–	–	–	–	–	–	–	–
NED7	A	A	18	115	6.4	6	4.1	1990	2010	29	0	–	–	–	–	–	–	–
NED8	A	N	38	277	7.3	11	3.3	1996	2010	45	2	0	0.0	0	2.5	2006	2008	0
NED9	A	A	4	25	6.3	3	4.0	2000	2004	15	0	–	–	–	–	–	–	–
NED10	A	A	5	5	1.0	2	3.2	2004	2010	3	0	–	–	–	–	–	–	–
NED11[d]	E	A	4	27	6.8	2	4.3	2005	2008	16	–	–	–	–	–	–	–	–
NED12[c]	E	A	–	–	–	–	–	–	–	–	0	–	–	–	–	–	–	–
NED13	E	A	14	48	3.4	3	2.8	1981	1992	24	0	–	–	–	–	–	–	–
NED14	E	A	1	4	4.0	1	1.5	1990	1990	4	0	–	–	–	–	–	–	–
NED15	E	A	41	436	10.6	14	3.5	1978	2008	56	1	6	6.0	1	4.0	1993	1993	6
NED16[d]	E	A	24	91	3.8	6	3.8	1973	1996	19	–	–	–	–	–	–	–	–
NED17	E	A	38	727	19.1	12	4.3	1974	2005	132	0	–	–	–	–	–	–	–
CH1	F	A	33	88	2.7	6	3.4	1981	2008	17	0	–	–	–	–	–	–	–
CH2	F	N	12	155	12.9	6	3.1	1983	1998	80	3	9	3.0	2	3.0	1987	2008	7
CH3	F	N	2	77	38.5	2	3.5	1990	1998	63	0	–	–	–	–	–	–	–
CH4	F	A	7	28	4.0	2	1.6	1985	2004	18.0	9	34	3.8	3	3.4	1984	2009	20
CH5	F	A	6	86	14.3	3	2.2	1985	2009	76	31	97	3.1	6	2.8	1977	2007	10
CH6	F	N	1	6	6.0	1	1.5	1990	1990	6	0	–	–	–	–	–	–	–
CH7	A	N	7	23	3.3	3	2.4	2005	2009	12	0	–	–	–	–	–	–	–
CH8	A	N	3	25	8.3	2	2.7	1999	2002	14	8	6	0.8	2	1.0	1999	2009	3
CH9	A	A	11	41	3.7	3	2.5	2000	2010	19	0	–	–	–	–	–	–	–
CH10	E	A	158	1007	6.4	17	3.3	1964	2005	139	14	235	16.8	6	2.6	1972	1994	80
CH11	E	A	7	105	15.0	6	3.1	1993	2002	28	0	–	–	–	–	–	–	–
CH12	E	A	5	1	0.2	1	1.0	1973	2004	1	4	9	2.3	2	2.3	1983	1985	4
CH13	E	A	4	27	6.8	1	1.0	1983	2004	27	1	13	13.0	1	3.0	1976	1976	13
POL1	H	N	10	30	3.0	3	3.2	1981	2001	20	0	–	–	–	–	–	–	–
POL2	F	A	78	1116	14.3	19	3.2	1993	2010	114	0	–	–	–	–	–	–	–
POL3	F	A	23	73	3.2	4	2.3	1975	2010	19	1	5	5.0	1	1.0	1988	1988	5

Table 6 (continued)

Abbreviations	Membership[a]	Affiliation[b]	Indicators relating to PUB								Indicators relating to PAT							
			P	C	CPP	h	$Avg_{co\text{-}authors}$	Y_{MIN}	Y_{MAX}	$C_{most\text{-}cited}$	P	C	CPP	h	$Avg_{co\text{-}authors}$	Y_{MIN}	Y_{MAX}	$C_{most\text{-}cited}$
POL4	F	A	27	236	8.7	9	2.6	1976	2010	39	0	–	–	–	–	–	–	–
POL5	F	A	10	32	3.2	3	2.1	1979	2006	14	0	–	–	–	–	–	–	–
POL6	A	A	54	409	7.6	12	1.9	1980	2010	39	0	–	–	–	–	–	–	–
POL7	A	A	144	495	3.4	12	3.1	1976	2010	22	0	–	–	–	–	–	–	–
POL8	E	A	15	114	7.6	3	1.9	1967	1987	95	7	5	0.7	2	1.3	1970	1978	2
POL9	E	A	8	14	1.8	2	2.1	1980	1987	8	0	–	–	–	–	–	–	–
POL10	E	A	8	11	1.4	1	2.1	1973	2003	11	0	–	–	–	–	–	–	–
DEN1	H	A	53	888	16.8	13	2.9	1980	2008	147	0	–	–	–	–	–	–	–
DEN2	F	A	108	807	7.5	14	3.1	1966	2010	60	2	0	0.0	0	9.0	2008	2008	0
DEN3	F	A	62	390	6.3	10	3.6	1970	2010	59	2	0	0.0	0	1.0	2003	2004	0
DEN4	F	A	60	503	8.4	12	2.6	1976	2010	38	3	2	0.7	1	2.3	1988	2005	2
DEN5	F	A	26	237	9.1	8	3.6	1996	2008	68	2	0	0.0	0	6.0	2005	2008	0
DEN6	A	N	18	46	2.6	4	4.0	1994	2010	13	2	0	0.0	0	9.0	2008	2008	0
DEN7	A	A	31	207	6.7	9	3.1	1995	2010	35	0	–	–	–	–	–	–	–
DEN8	A	A	72	834	11.6	17	5.0	1992	2010	105	0	–	–	–	–	–	–	–
DEN9	E	A	67	382	5.7	10	2.6	1966	2006	60	2	57	28.5	2	3.0	1982	1994	55
SWE1	H	A	19	137	7.2	4	2.2	1981	2005	112	0	–	–	–	–	–	–	–
SWE2	F	A	10	46	4.6	5	3.0	1975	2005	14	0	–	–	–	–	–	–	–
SWE3	A	A	5	22	4.4	3	2.2	1993	2000	7	0	–	–	–	–	–	–	–
SWE4	A	A	39	143	3.7	7	2.9	1992	2010	19	0	–	–	–	–	–	–	–
SWE5	E	A	16	8	0.5	2	1.4	1962	2004	2	4	60	15.0	3	2.0	1968	1978	45
SWE6	E	A	13	16	1.2	3	2.0	1975	2005	4	0	–	–	–	–	–	–	–
SWE7	E	A	14	194	13.9	3	3.8	1981	2006	132	1	1	1.0	1	4.0	1999	1999	1
SWE8	E	A	6	26	4.3	3	1.7	1982	2002	17	3	50	16.7	2	2.0	1976	1977	45
SWE9	E	A	8	56	7.0	4	2.8	1990	2006	28	2	7	3.5	2	6.5	2002	2004	4

For each researcher, the following indicators are reported, both at PUB and PAT levels: total publications/patents (*P*), total citations (*C*), mean citations per publication/patent (*CPP*), *h* index (*h*), average number of co-authors ($Avg_{co\text{-}authors}$), year of the oldest publication/patent (Y_{MIN}), year of the most recent publication/patent (Y_{MAX}), and citations of the researcher's most-cited publication/patent ($C_{most\text{-}cited}$). Values are calculated using the Scopus database and taking into account the citations accumulated up to the moment of the analysis (February 2011). Researchers are sorted according to their country abbreviation (see Table 1) and the ordering with which they are reported in [12]

Pubs publications, *Pats* patents

[a] We distinguish between four CIRP membership types: fellow (*F*), honorary fellow (*H*), fellow emeritus (*E*) and associate member (*A*) [12]

[b] We distinguish between two affiliation types: academic (*A*) and non-academic (*N*). Typical NA affiliations are national laboratories, research centres and industry

[c] These (seven) researchers were excluded from the analysis based on publications because of disambiguation issues. Therefore, it was not possible to determine the relevant (PUB) indicators

[d] These (14) researchers were excluded from the analysis based on patents because of disambiguation issues. Therefore, it was not possible to determine the relevant (PAT) indicators

References

1. Agrawal A, Henderson R (2002) Putting patents in context: exploring knowledge transfer from MIT. Management Science—Special Issue on University Entrepreneurship and Technology Transfer 48(1):44–60
2. Balconi M, Laboranti A (2006) University–industry interactions in applied research: the case of microelectronics. Res Policy 35 (10):1616–1630
3. Baldini N (2006) Negative effects of university patenting: myths and grounded evidence. Scientometrics 75(2):289–311
4. Bar-Ilan J (2010) Citations to the 'introduction to informetrics' indexed by WOS, Scopus and Google Scholar. Scientometrics 82 (3):495–506
5. Bornmann L, Mutz R, Neuhaus C, Daniel HD (2008) Citation counts for research evaluation: standards of good practice for analyzing bibliometric data and presenting and interpreting results. Ethics Sci Environ Polit 8(1):93–102
6. Bozeman B (2000) Technology transfer and public policy: a review of research and theory. Res Policy 29(4–5):627–655
7. Breschi S, Catalini C (2010) Tracing the links between science and technology: an exploratory analysis of scientists' and inventors' networks. Res Policy 39(1):14–26
8. Breschi S, Lissoni F, Montobbio F (2007) The scientific productivity of academic inventors: new evidence from Italian data. Econ Innovat New Tech 16(2):101–118
9. Breschi S, Lissoni F, Montobbio F (2010) University patenting and scientific productivity: a quantitative study of Italian academic inventors. Eur Manag Rev 5(2):91–109
10. Calderini M, Franzoni C, Vezzulli A (2009) The unequal benefits of academic patenting for science and engineering research. IEEE Trans Eng Manag 56(1):16–30
11. Cheng YH, Kuan FY, Chuang SC (2010) Profitability decided by patent quality? An empirical study of the U.S. semiconductor industry. Scientometrics 82(1):175–183
12. CIRP (2010) Annual CIRP Directory 2010 (non-public document, exclusively for members). Paris, France
13. CIRP (2011a) Organization web site. http://www.cirp.net Accessed 10 April 2011
14. CIRP (2011b) CIRP Unified Keyword List (updated August 2011). http://www.cirp.net/images/cirpfichiers/publicfiles/Annals/keyword_list.pdf. Accessed 20 October 2011
15. CNR (2007) Il sistema di classificazione delle competenze disciplinari al CNR. http://www.cnr.it. Accessed 10 April 2011
16. Criscuolo P, Verspagen B (2008) Does it matter where patent citations come from? Inventor vs. examiner citations in European patents. Res Pol 37(10):1892–1908
17. Czarnitzki D, Glänzel W, Hussinger K (2007) Patent and publication activities of german professors: an empirical assessment of their co-activity. Res Eval 16(4):311–319
18. Daim TU, Rueda G, Martin H, Gerdsri P (2006) Forecasting emerging technologies: use of bibliometrics and patent analysis. Technol Forecast Soc Chang 73(8):981–1012
19. Egghe L (2010) The hirsch-index and related impact measures. Annual Review of Information Science and Technology (ARIST), 44 (edited by B. Cronin). ISBN 978-1-57387-371-0
20. Eurostat (2011) Science, technology and innovation in Europe (yearly editions from 2001 to 2011). Publications Office of the European Union, Luxembourg. http://epp.eurostat.ec.europa.eu Accessed 20 October 2011
21. Franceschini F, Galetto M, Maisano D (2007) Management by measurement: designing key indicators and performance measurement systems. Springer, Berlin
22. Franceschini F, Maisano D (2010) Analysis of the Hirsch index's operational properties. Eur J Oper Res 203(2):494–504
23. Franceschini F, Maisano D (2010) The Hirsch spectrum: a novel tool for analysing scientific journals. Journal of Informetrics 4 (1):64–73
24. Franceschini F, Maisano D (2011) Bibliometric positioning of scientific manufacturing journals: a comparative analysis. Scientometrics 86(2):463–485
25. Franceschini F, Maisano D (2011) Structured evaluation of the scientific output of academic research groups by recent *h*-based indicators. Journal of Informetrics 5(1):64–74
26. Franceschini F, Maisano D (2011) Influence of database mistakes on journal citation analysis: remarks on the paper by Franceschini and Maisano, QREI (2010). Qual Reliab Eng Int 27(7):969–976
27. Geuna A, Nesta lJJ (2006) University patenting and its effects on academic research: the emerging European evidence. Res Policy 35(6):790–807
28. Greenough RM, Williams D (2007) Investigating the transfer of techniques for electronic technical support documentation from aerospace to machine tools. Int J Adv Manuf Technol 32(7–8):774–779
29. Guan JC, Gao X (2009) Exploring the *h*-index at patent level. J Am Soc Inf Sci Technol 60(1):35–40
30. Guan J, He Y (2007) Patent-bibliometric analysis on the Chinese science–technology linkages. Scientometrics 72(3):403–425
31. Hall BH, Ziedonis RH (2001) The patent paradox revisited: an empirical study of patenting in the U.S. semiconductor industry, 1979–1995. RAND J Econ 32(1):102–128
32. Harzing AW, van der Wal R (2008) Google scholar as a new source for citation analysis. Ethics Sci Environ Polit 8(11):61–73
33. Henzinger M, Sunol J, Weber I (2010) The stability of the *h*-index. Scientometrics 84(2):465–479
34. Hirsch JE (2005) An index to quantify an individual's scientific research output. Proc Natl Acad Sci U S A 102:16569–16572
35. Kuczynski A, Stokic D, Kirchhoff U (2006) Set-up and maintenance of ontologies for innovation support in extended enterprises. Int J Adv Manuf Technol 29(3–4):398–407
36. Labbé C (2010) Ike Antkare, one of the great stars in the scientific firmament. ISSI Newsletter 6(2):48–52
37. Lazaridis T (2010) Ranking university departments using the mean *h*-index. Scientometrics 82(2):211–216
38. Mattson P, Laget P, Nilsson A, Sundberg CJ (2008) Intra-EU vs. extra-EU scientific co-publication patterns in EU. Scientometrics 75(3):555–574
39. Maurseth B, Verspagen B (2002) Knowledge spillovers in Europe: a patent citations analysis. Scand J Econ 104(4):531–545
40. Meyer M (2000) What is special about patent citations? Differences between scientific and patent citations. Scientometrics 49 (1):93–123
41. Moed HF (2006) Bibliometric rankings of world universities. CWTS Report 2006-01. http://www.cwts.nl/hm/bibl_rnk_wrld_univ_full.pdf. Accessed 10 April 2011
42. Molinari A, Molinari JF (2008) A new methodology for ranking scientific institutions. Scientometrics 75(1):163–174
43. Morillo F, Bordons M, Gomez I (2003) Interdisciplinarity in science: a tentative typology of disciplines and research areas. J Am Soc Inf Sci Technol 54(13):1237–1249
44. Nagpaul PS, Roy S (2003) Constructing multi-objective measure of research performance. Scientometrics 56(3):383–402
45. Narin F (1994) Patent bibliometrics. Scientometrics 30(1):147–155
46. Orbit (2011) Web site of the patent database. http://www.orbit.com. Accessed 10 April 2011
47. PCT (Patent Cooperation Treaty) (2011) The PCT applicant's guide. www.wipo.int. Accessed 10 April 2011
48. Ramos-Vielba I, Fernandez-Esquinas M, Espinosa-de-los-Monteros E (2010) Measuring university-industry collaboration in a regional innovation system. Scientometrics 84(3):649–667

49. Rousseau R (2010) New developments related to the Hirsch index. E-prints in Library and Information Science (ELIS). www.eprints.rclis.org. Accessed 10 April 2011
50. Ruanea F, Tol RSJ (2008) Rational (successive) *h*-indices: an application to economics in the Republic of Ireland. Scientometrics 75(2):395–405
51. Schubert A (2007) Successive *h*-indices. Scientometrics 70 (1):201–205
52. Scopus—Elsevier (2011). www.info.scopus.com. Accessed 10 April 2011
53. Shelton RD, Leydesdorff L (2011) Publish or patent: bibliometric evidence for empirical trade-offs in national funding strategies. 13th Conference of International Society for Scientometrics and Informetrics, Durban, 4–8 July 2011
54. Suh NP (1990) University–industry interaction for the innovation of new products and processes: A U.S. model. Robot Comput Integrated Manuf 7(1–2):15–25
55. Thomson Reuters (2011). www.thomsonreuters.com. Accessed 10 April 2011
56. Trajtenberg M (1990) A penny for your quotes: patent citations and the value of innovations. RAND J Econ 21(1):172–187
57. Van Looy B, Callaert J, Debackere K (2006) Publication and patent behavior of academic researchers: conflicting, reinforcing or merely co-existing? Res Policy 35(4):596–608
58. Wong PK, Singh A (2010) University patenting activities and their link to the quantity and quality of scientific publications. Scientometrics 83 (1):271–294