Bibliometric mapping as a science policy and research management tool
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8 Assessment of Flemish R&D in the field of Information Technology*

A bibliometric evaluation based on publication and patent data, combined with OECD research input statistics

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Abstract

This paper outlines a method to evaluate a geographic region's performance in a research field. Using bibliometric indicators, an overview is given of Flemish R&D potential in information technology (IT). Flemish IT activity is presented within the context of recent international developments in this field. Both publication, patent data, and OECD input statistics are used in the study. We found that Flanders is quite productive in IT as far as publication activity is concerned. In contrast, the patenting productivity is rather low. Furthermore, the data indicate that Flemish R&D in IT has two strong points: image processing on the patent side, and processing technology on the publication side. Publications in the latter subdomain have an impact which is above world average.

8.1 Introduction

The study presented in this paper was performed for the Ministry for the Flemish Community. Flanders comprises the northern part of Belgium. The whole country used to be a centralized unitary state. To meet the demands for autonomy by both Flanders (Dutch-speaking) and Walonia (French-speaking), the unitary state was converted into a federation by constitutional amendments of 1971, 1980, and 1988. In 1988, the responsibility for education and nearly all competencies relating to science and technology policy were transferred to the regional authorities (Van den Berghe et al., 1998).

The results and details of the study are presented in Noyons et al. (1994). The main objective was to obtain an overview of the position of Flanders in the field of information technology (IT) by using bibliometric indicators. We merged and combined data from several sources in order to make the picture as complete as possible: (1) data from scientific publications as well as patent data are used to represent the output of IT activity; (2) the results for Flanders are analyzed in relation to the international developments in the field; (3) we normalized output data with input data by using OECD statistics[12]; and finally, (4) we calculated the impact of the Flemish publication output in IT and compared it to the world average. In addition to the comparison of Flemish output with worldwide output and impact standards, we included data from Belgium and three European countries in the study. These three

[12] The combination of input and output data is not new. Recent studies (Leydesdorff and Gauthier, 1996, Jacobsson et al., 1996, and Gomez et al., 1995) have shown the use of R&D input figures.

countries (the Netherlands, France, and Germany) are Belgium's neighbors and its most important trade partners. The study covers a period of 10 years (1983 to 1992).

8.2 Data and methods

8.2.1 Bibliographic databases and the delineation of the field

The output data used in this study was retrieved from two international bibliographic databases. The publication data was collected from INSPEC, a worldwide database on Physics, Electronics and Computing, in which all publication are classified with by means of the Physics Abstracts Classification Scheme (PACS). The patent data was extracted from the ESPACE-Bulletin database, a product from the European Patent Office (EPO), in which all published patents are enriched by one or more International Patent Classification (IPC) codes.

Table 8–1 21 subdomains in information technology

Code	*subdomain description*
01	Image Processing
02	Computer Aided Design
03	Computer Integrated Manufacturing & Production Control
04	Communication
05	Computer Architecture
06	Educational Systems
07	Encryption & Security
08	Geographical Information Systems
09	Graphical Information & Computer Graphics
10	Information Processing
11	Micro-electronics & General Electronic Techniques
12	Multi-media Techniques
13	Numerical Analysis & Applied Mathematics
14	Opto-electronics
15	Process Control
16	Peripherals
17	Sensors & Actuators
18	Signal Processing (Analogue, Digital)
19	Software Engineering
20	Language Technology
21	Processing Technology

The INSPEC database has four sections: physics; electrical and electronic engineering; computer technology; and IT. This database is considered to cover the field of IT in its broadest sense. The main types of publications included in this database are journal articles, book chapters, and proceeding papers. The European Patent database contains all patents published by the EPO since 1978. It covers patent data from all possible science and technology fields, including IT, as far as the products and processes are patentable. From both databases, items related to IT were selected and classified in 21 subdomains. These subdomains are listed in Table 8–1.

For the purpose of this study, the Flemish Institute for the Promotion of Scientific-Technological Research in Industry (IWT), which supports industrial R&D in Flanders, provided the description of these 21 subdomains. In an interactive process between IWT and CWTS, publications and patents were assigned to the subdomains[13]. A publication can be assigned to more than one subdomain.

Experts of the Ministry of the Flemish Community were able to assign each publication, on the basis of the address of the first author[14], and each patent, on the basis of the address of the applicant or inventor, either to Flanders or to the other part of Belgium.

Patents were primarily assigned to countries by using the inventors' addresses. It has been argued that the inventor's address is to be preferred over the applicant's when assessing a country's actual R&D activity (Schmoch and Kirsch, 1993).

8.2.2 Combining publication and patent data

An important issue in the study is the combination of publication and patent data. The idea was to generate a picture of Flemish IT which was as complete as possible. This does not mean that we considered a patent and a scientific publication as one of a kind: they do represent different 'worlds'. Still, one may assume some overlap between these two 'worlds'. In both cases, the intellectual properties are being protected. A patent provides financial protection and a publication provides intellectual protection. In most science and technology fields, and not in the least in IT, both aspects of research and development are of great importance: the market-oriented aspect, usually protected by patents, and the more fundamental (intellectual) one, usually protected by scientific publications. As an additional argument to combine both types of data, we note an observed tendency of both 'worlds' to mingle. It has been stated that companies dispense with a patent application and rather publish the result of a development (Grupp and Schmoch, 1992). Nevertheless, 'trends' may be discerned recently in academic organizations to increase their 'patent activity' in order to protect their knowledge in a commercially more interesting way. According to the data from the EPO (ESPACE Bulletin CD-ROM) in the past 10 years, the

[13] The available keywords per subdomain were translated by CWTS into classification codes of INSPEC (Physics Abstracts Classification Scheme codes) and EPO (International Patent Classification codes). Experts from IWT corrected the lists before they were used to select the publications and patents per subdomain.

[14] INSPEC includes the address of the first author only.

percentage of patents with an academic address in a patent description) has increased from around 0.9 to 1.25[15].

Finally, we should note the coverage of some of the subdomains by patents. In IT, a significant part concerns software engineering. However, software is not (yet) patentable as such. This is the main reason why no patent activity is found in some of the subdomains. For these particular subdomains in the study, only the publication output is used.

8.2.3 Bibliometric indicators

As outlined in section 1, the objective was to explore IT developments in general and to obtain the characteristics of the activity of Flanders and of three other European countries in this field. We characterized general developments in the field of IT by counting the publications in the 21 subdomains over the period 1983 to 1992. In addition, the total number of publications in IT worldwide, as well as the total number of publications in the field from Flanders, Belgium as a whole, and three other European countries were calculated.

The characteristics of Flemish IT research can be obtained by calculating activity indices. The activity index is derived from the Revealed Patent Advantage (RPA) indicator [see the work of Engelsman and van Raan (1993) for an extensive description of its history], which is an adjusted version of the Revealed Technology Advantage (RTA) indicator, described by Soete and Wyatt (1983). The index is calculated by the ratio of the number of publications (or patents) of a country in a particular subdomain, divided by the number of total publications in these subdomains, and the number of publications of that country in the whole field, divided by the total number of publications in the field. See Figure 8-1.

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[15] In the applicant field of the patents we searched for addresses with strings like 'UNIV', 'ACAD'.

$$\ln\left(\frac{P_{ij} \Big/ \sum_{l} P_{il}}{\sum_{k} P_{kj} \Big/ \sum_{k}\sum_{l} P_{kl}}\right)$$

where:

P_{ij} = Number of publications/patents of country i in subdomain j

$\sum_{l} P_{il}$ = Number of publications/patents of country i in the whole field

$\sum_{k} P_{kj}$ = Number of publications/patents of all countries in subdomain j

$\sum_{k}\sum_{l} P_{kl}$ = Number of publications/patents of all countries in the whole field

ln = Natural Logarithm

Figure 8-1 Activity Index formula

In each of the 21 subdomains, the activity index per country values between -1 and 1. The range of scores of a country renders its activity profile. Like in the work of Noyons and van Raan (1996), we calculated the standard error bars for each data point of Flanders. By comparing the profile of Flanders with those of the other countries in this study, we were able to view its activity from an international perspective. Moreover, by determining the activity profile of Flanders in two successive 5-year periods, changes in the activity profile during the studied period can be examined.

Furthermore, the overall publication and patenting output of Flanders, Belgium as a whole, and of the three other countries was normalized using several input indicators. These input indicators included the country's population, the gross national (regional) product, and the country's R&D expenditures in the categories of 'higher education and government' (for publications) and 'business and private, non-profit' (for patents), respectively. This data was extracted from the 'OECD - Main Science and Technology Indicators'. For Flanders they were extracted from a database with regional indicators at the Ministry of the Flemish Community. The results provide an indication of the scientific productivity of Flanders and of the studied countries, taking into account the available financial and human resources.

Finally, an advanced citation analysis was performed on the publication output of Flanders during the years 1983 to 1992 in order to assess the impact. This was accomplished by collecting citations received by the publications selected from

INSPEC from publications in journals covered by the Science Citation Index. Details about this methodology are presented in De Bruin et al. (1993).

8.3 Results

In this section, we will discuss the results of the bibliometric evaluation of Flemish IT. The discussion highlights two major points: an exploration of overall developments in IT, and the position of Flemish R&D in this field.

8.3.1 Exploration of the developments in IT

The objective of this section is to present an overview of the main developments in the field from a worldwide perspective. This overview is generated by calculating the average increase or decrease of numbers of publications per subdomain in IT, as represented by publications and patents selected by PACS codes and IPC codes. Per subdomain, a growth index is calculated by the average of relative differences between two successive years during the entire period (1983 to 1992). A relative difference is calculated by dividing the absolute difference between year t and year $t+1$ by the numbers of publications/patents in year t. The results for the publications and the patents are given in Figure 8-2.

The figure shows that there was a significant increase of publication activity in subdomains 07 (Encryption & Security) and 08 (Geographical Information Systems). Unfortunately, technological developments in these subdomains are not patentable, so no comparison can be made with technological developments. In subdomain 16 (Peripherals), we find a decrease in publication activity (particularly in the second part of the studied period), whereas on the patent side, we observe an increased activity. These contrasting trends may be caused by the fact that basic research in this subdomain has reached a certain saturation point, but product R&D, as represented by patents, is still growing. For all other subdomains, an average increase of activity is observed between 0 and 1, which is similar to the growth of the number of publications included in INSPEC during this period. One of the IT scientists who was interviewed to discuss the results of the study, expressed his concern about the use of classification codes to characterize the field. He properly suggested that INSPEC or EPO may have introduced new classification codes at some point during the studied period. A strong activity increase in some of the subdomains may then be a result of the introduction of a new classification code in the scheme, rather than an increase of R&D. We actually observed that new classification codes have been introduced in some of the subdomains with a strongly increasing activity. It is even quite common in new or rapidly developing fields such as IT [see the works of McCain and Whitney (1994), Noyons and Van Raan (1996), and Lawson et al. (1980)]. We argue, however, that this 'artifact' is not strange to the actual developments in the field. The introduction of a new classification code indicates a significant development in that area. As long as we take the most recent scheme as starting point, we will cover such developments. If we would start with a scheme used at the beginning of the period under consideration, we would in fact disregard recent developments in the field. Moreover, publications entered in the database in the most recent years would be left out of the analyses because mainly new classification codes may be assigned to them[16].

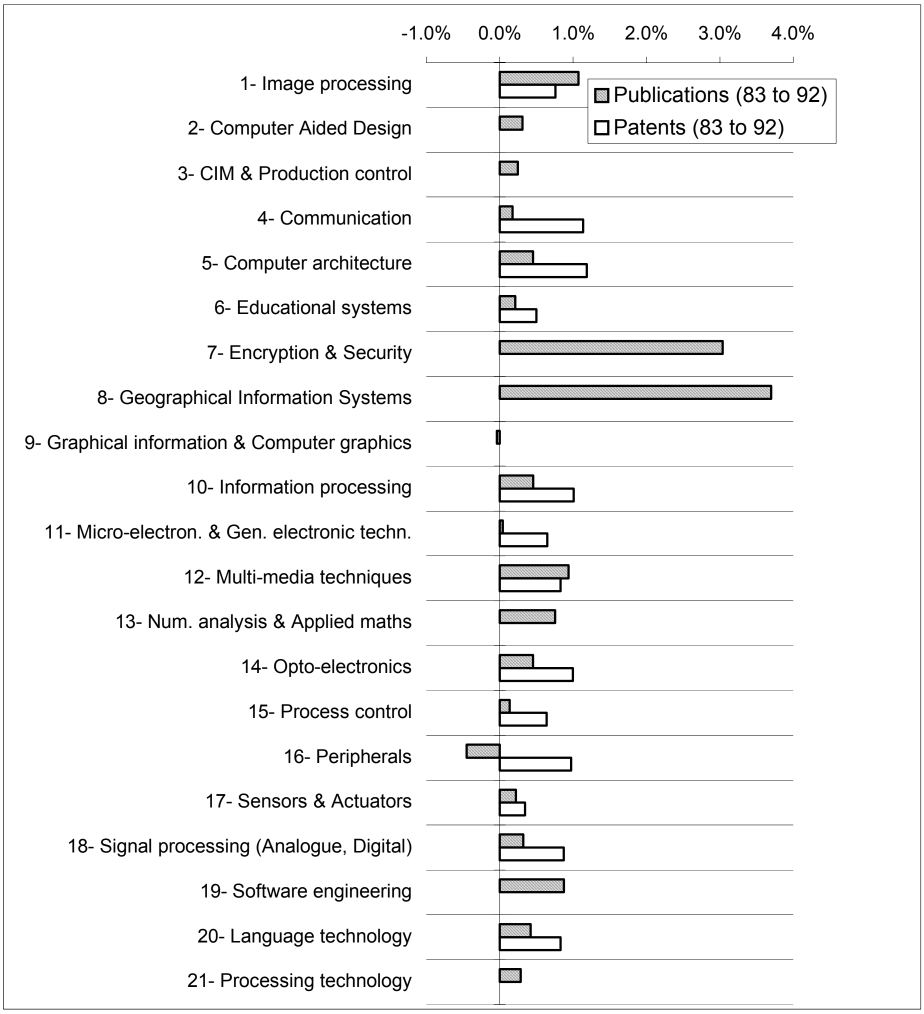


Figure 8-2 Average growth of the number of IT publications/patents from year to year during 1983 to 1992

[16] This viewpoint is extensively discussed in Noyons and Van Raan (1998).

8.3.2 Flemish activity in IT

The identified trends in the different subdomains are used to put the results for Flanders in a wider perspective. In Table 8–2, the numbers of publications and patents per year are given for Flanders, Belgium as a whole, the Netherlands, France, and Germany. The numbers for Flanders are broken down over the subdomains in Table 8–3.

Table 8–2 Numbers of publications (a) and patents (b) in IT in 1983-1992

a Publications

	1983	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
Flanders	238	273	258	291	358	424	476	590	555	582
Belgium	429	433	452	495	579	670	726	885	839	937
Netherlands	823	946	888	1149	1205	1368	1593	1744	1950	1857
France	2031	2279	2660	3113	3466	3626	4121	4453	4437	4827
Germany	4563	4821	4882	5471	5574	6201	6039	7091	7047	6321

b Patents

	1983	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
Flanders	16	20	25	25	38	43	35	48	71	67
Belgium	38	43	43	43	71	68	61	75	105	97
Netherlands	220	257	266	307	345	356	449	442	415	406
France	665	695	703	828	912	926	1053	1096	1237	1216
Germany	1119	1275	1431	1666	1749	1951	2005	2173	2192	2175

A characterization of Flemish activity is obtained by calculating the activity index per subdomain. The profile of scores reflects the focus of Flemish research activity in IT. This Flemish IT activity profile is compared with that of Belgium and three other European countries (Netherlands, Germany, and France). The results are presented in Figure 8-3 (publications) and Figure 8-4 (patents).

Table 8–3 Numbers of Flemish publications (a) and patents (b) in 21 IT subdomains

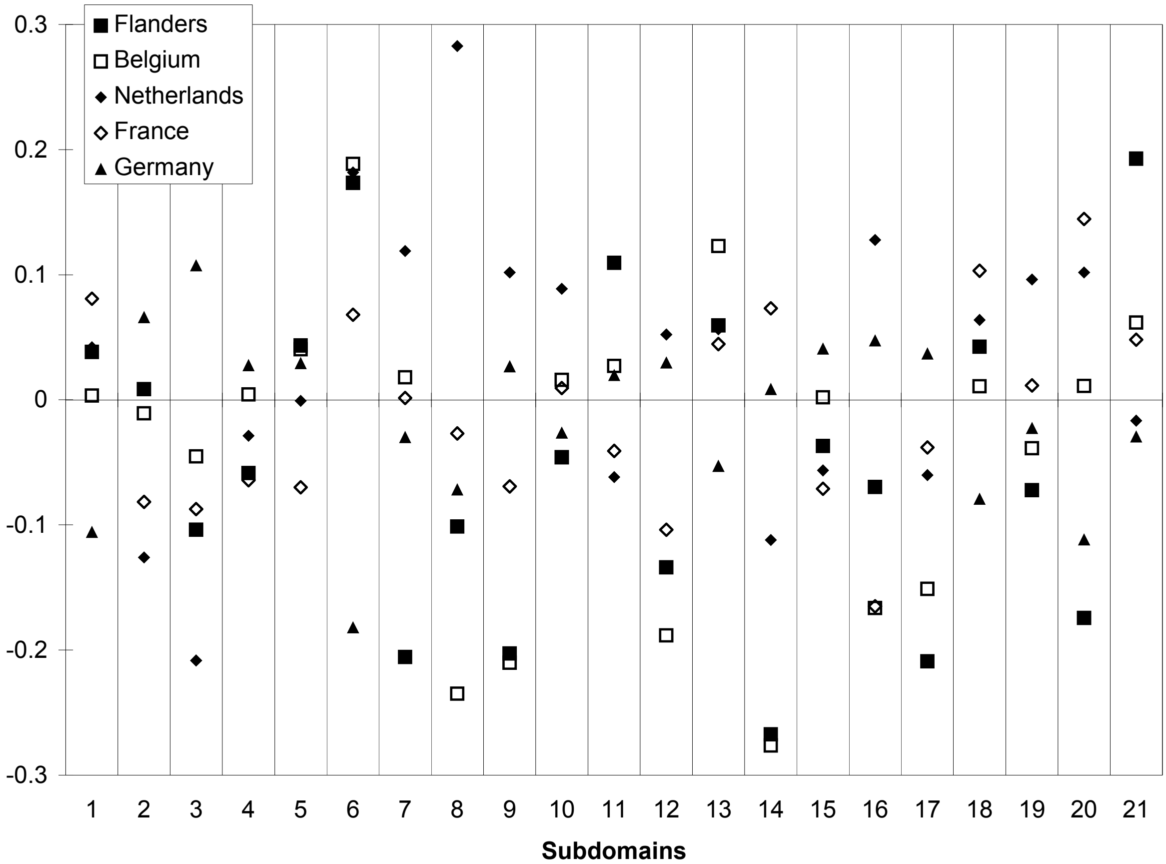
a Publications

Sub	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
01	20	17	19	17	28	35	34	53	42	39
02	36	29	37	35	54	58	88	91	63	74
03	12	14	9	10	23	24	16	34	16	23
04	34	47	35	35	64	55	45	90	59	73
05	11	15	14	30	34	45	52	56	59	58
06	2	5	4	6	3	14	6	9	9	6
07	0	0	0	0	0	0	0	1	2	2
08	0	1	0	0	0	0	0	1	1	4
09	0	0	1	2	1	4	4	8	5	11
10	29	31	33	53	59	73	93	121	97	106
11	54	37	49	49	50	59	82	97	79	92
12	0	1	0	2	1	1	10	11	3	6
13	43	72	46	60	65	86	86	106	127	125
14	12	14	16	11	11	16	22	31	46	39
15	22	30	19	32	36	35	45	43	34	43
16	3	7	4	5	7	12	12	10	14	8
17	23	29	27	24	29	16	36	45	38	36
18	23	36	36	30	41	55	55	70	62	50
19	2	7	6	15	22	37	33	36	46	61
20	3	3	1	8	2	9	13	7	9	8
21	43	50	60	60	82	98	122	143	179	152

b Patents

Sub	*1983*	*1984*	*1985*	*1986*	*1987*	*1988*	*1989*	*1990*	*1991*	*1992*
01	7	4	2	10	11	17	17	14	20	27
02										
03										
04	4	5	13	6	14	17	7	18	31	19
05	0	0	1	3	3	1	1	3	4	6
06	0	0	0	0	0	0	0	0	0	0
07										
08										
09										
10	0	0	1	0	0	0	0	0	1	0
11	6	6	7	6	5	3	6	4	12	7
12	0	0	0	1	0	0	1	1	1	1
13										
14	0	3	4	3	3	4	5	7	5	3
15	0	0	0	1	0	1	2	1	0	0
16	1	2	0	1	4	1	0	4	3	7
17	0	1	0	0	1	2	0	0	0	0
18	0	0	2	0	1	0	0	0	0	1
19										
20	0	0	0	0	0	0	0	0	0	0
21										

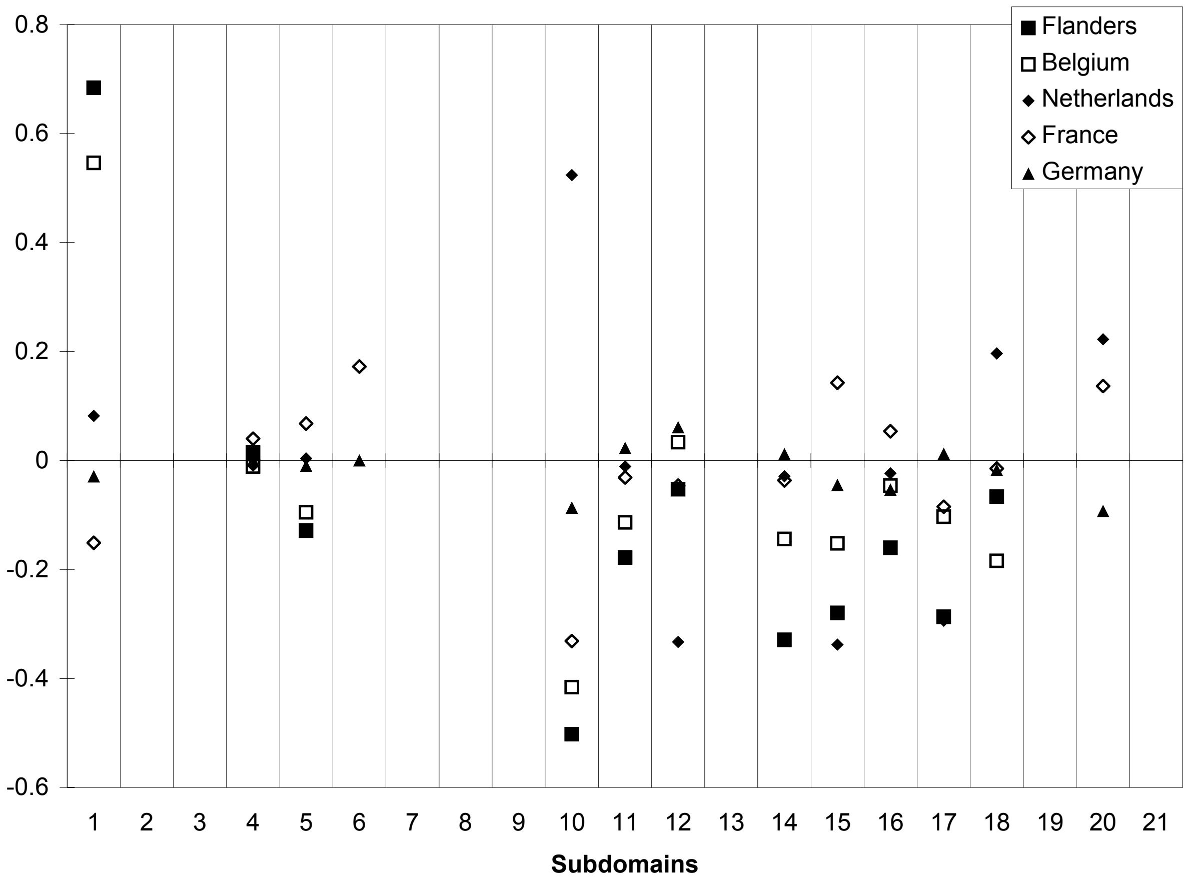
For subdomain names: see Table 1 or Figure 2



Subdomains:

01	Image Processing	11	Micro-electron. & General Electronic Techniques
02	Computer Aided Design	12	Multimedia Techniques
03	CIM & Production Control	13	Numerical Analysis & Applied Mathematics
04	Communication	14	Opto-electronics
05	Computer Architecture	15	Process Control
06	Educational Systems	16	Peripherals
07	Encryption & Security	17	Sensors & Actuators
08	Geographical Information Systems	18	Signal Processing (Analogue, Digital)
09	Graphical Information & Computer Graphics	19	Software Engineering
10	Information Processing	20	Language Technology
		21	Processing Technology

Figure 8-3 Activity index for the publication output of Flanders and of 4 European Countries in all IT subdomains in the period 1983-1992



Subdomains:

01	Image Processing	11	Micro-electron. & General Electronic Techniques
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04	Communication	14	Opto-electronics
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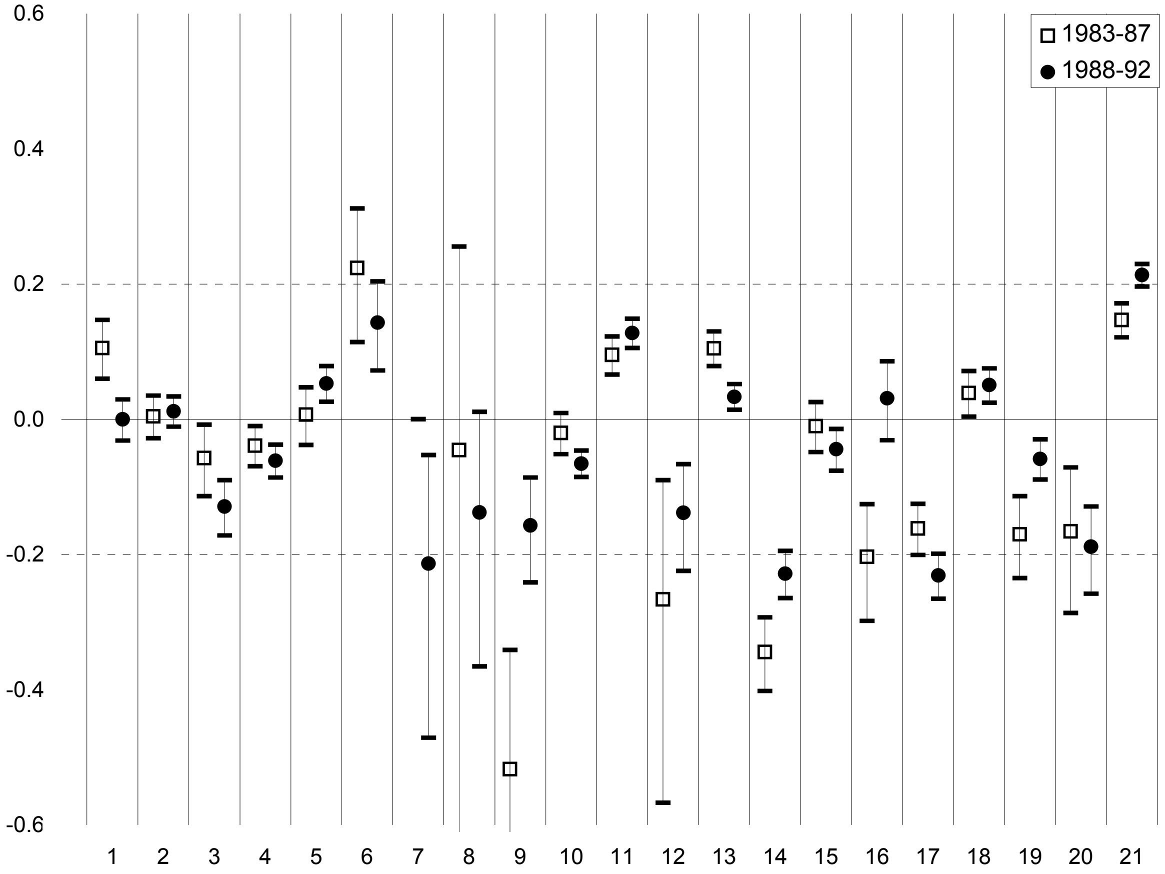
06	Educational Systems	16	Peripherals
07	Encryption & Security	17	Sensors & Actuators
08	Geographical Information Systems	18	Signal Processing (Analogue, Digital)
09	Graphical Information & Computer Graphics	19	Software Engineering
10	Information Processing	20	Language Technology
		21	Processing Technology

Figure 8-4 Activity index for the patenting output of Flanders and of 4 European Countries in all IT subdomains in the period 1983-1992

For reasons of clarity, we did not include error bars in the figure. That would cause the whole figure to become too 'crowded'. Instead, we calculated the average error of the publication activity index (0.004) and for the patent activity index (0.026).

In Figure 8-3, a clear Flemish preference for subdomain 21 (Processing technology) is visible. Also a preference for 06 (Educational systems) is observed. Furthermore, the chart shows a low Flemish interest for 07 (Encryption & Security), 09 (Graphical information & Computer graphics), 14 (Opto-electronics), 17 (Sensors & Actuators), and 20 (Language Technology). The profile of Belgium as a whole is quite similar to that of Flanders. Some of the seemingly large differences (07 and 08) are not statistically significant due to the low number of publications involved. In two other subdomains (20: Language technology and 21: Processing technology) the differences are significant. In language technology, Belgium's overall activity is much higher than in Flanders, and in processing technology it is the other way around. In general, we can observe a clear-cut profile of Flemish IT. In many subdomains, it has either the lowest or the highest activity index. We observe a similar clear-cut activity profile for the Netherlands, albeit with different focuses.

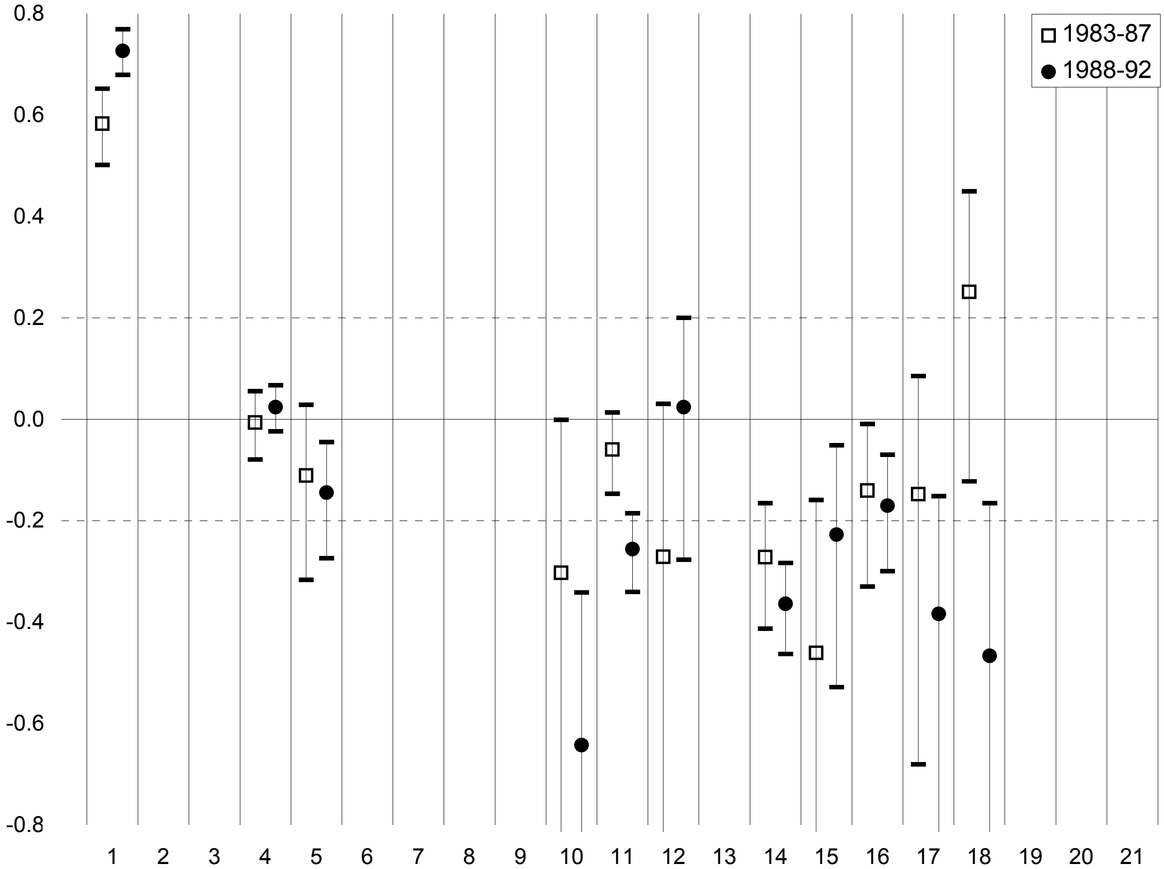
On the patent side (Figure 8-4), we should interpret the results with great care. Firstly, because there are some subdomains for which no patent data is available: 02: Computer Aided Design, 03: CIM & Production Control, 07: Encryption & Security, 08: Geographical Information Systems, 09: Graphical Information & Computer Graphics, 13: Numerical Analysis & Applied Mathematics, 19: Software Engineering, and 21: Processing Technology. The reason for this is primarily that R&D in these subdomains mainly concerns software development which is more difficult to be patented as such under the European patent law. Subdomain 21 was added to the list of subdomains at a later stage in the study without patent data. Furthermore, in two other subdomains, Flanders has no patent activity at all (6: Educational Systems and 20: Language Technology). In these two subdomains, the patent activity index cannot be calculated. In subdomains 10 (Information Processing), 15 (Process Control) and 16 (Peripherals), the Flemish activity index is calculated as being low, but this is not significant (i.e., the absolute number of patents is too small). In subdomain 14 (Opto-electronics), the low activity index is significant. The number of patents in this subdomain is 37 over the whole period, which is less than the average activity of Flanders in the whole field. Among all of the subdomains, the highest activity index for Flanders is measured in subdomain 01 (Image Processing). We conclude that the activity on the patent side of the Flemish IT focuses clearly on this particular subdomain.



Subdomains:

01	Image Processing	11	Micro-electron. & General Electronic Techniques
02	Computer Aided Design	12	Multimedia Techniques
03	CIM & Production Control	13	Numerical Analysis & Applied Mathematics
04	Communication	14	Opto-electronics
05	Computer Architecture	15	Process Control
06	Educational Systems	16	Peripherals
07	Encryption & Security	17	Sensors & Actuators
08	Geographical Information Systems	18	Signal Processing (Analogue, Digital)
09	Graphical Information & Computer Graphics	19	Software Engineering
10	Information Processing	20	Language Technology
		21	Processing Technology

Figure 8-5 Activity index for publication output of Flanders in 1983-1987 and 1988-1992



Subdomains:

01	Image Processing	11	Micro-electron. & General Electronic Techniques
02	Computer Aided Design	12	Multimedia Techniques
03	CIM & Production Control	13	Numerical Analysis & Applied Mathematics
04	Communication	14	Opto-electronics
05	Computer Architecture	15	Process Control
06	Educational Systems	16	Peripherals
07	Encryption & Security	17	Sensors & Actuators
08	Geographical Information Systems	18	Signal Processing (Analogue, Digital)
09	Graphical Information & Computer Graphics	19	Software Engineering
10	Information Processing	20	Language Technology
		21	Processing Technology

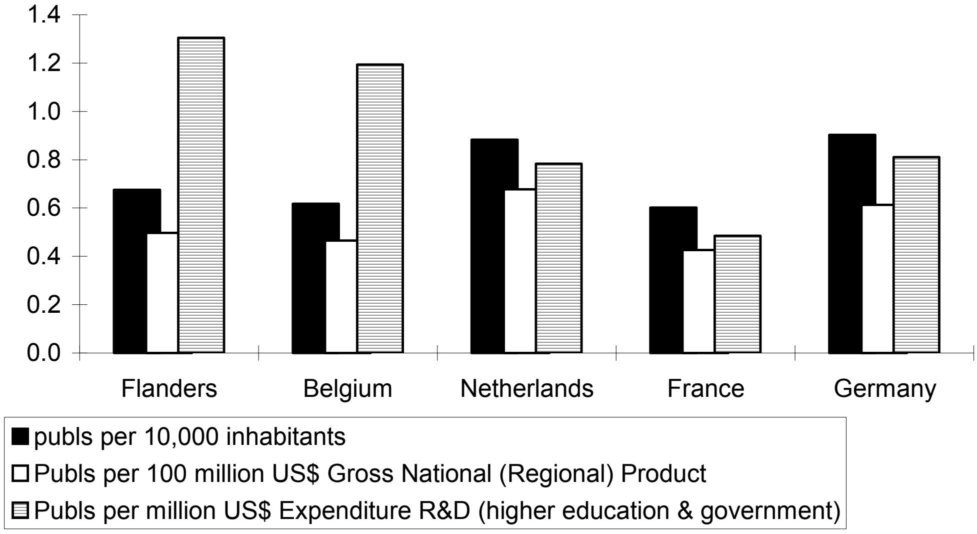
Figure 8-6 Activity index for patenting output of Flanders in 1983-1987 and 1988-1992

To analyze the time evolution, the Flemish activity index, calculated for the first five-year period and for the second 5-year period, is plotted in Figure 8-5 and Figure 8-6. In Figure 8-5, there is a general trend visible. In 11 of the 21 subdomains, the activity index approaches the average during the studied period. In Figure 8-3, we observed that countries with a larger output tend to have an index (in all subdomains) around this average, whereas 'smaller' countries seem to have more outliers. It seems that Flanders changed its IT publication strategy in a direction similar to European countries with a large output. A particular exception to this trend is 21 (Processing Technology). In this subdomain, the number of publications have been doubled to 694, resulting in an activity index over 0.2. It is becoming more and more a spearhead of Flemish IT. On the patent side (Figure 8-6), we observe a similar pattern. The subdomain of Image Processing has become even more important in the last 5 years than it already was in the first five. Activity in subdomain 04 (Communication) remains around average. In all other subdomains, changes are hardly significant, as the numbers of patents applied for by Flanders are low.

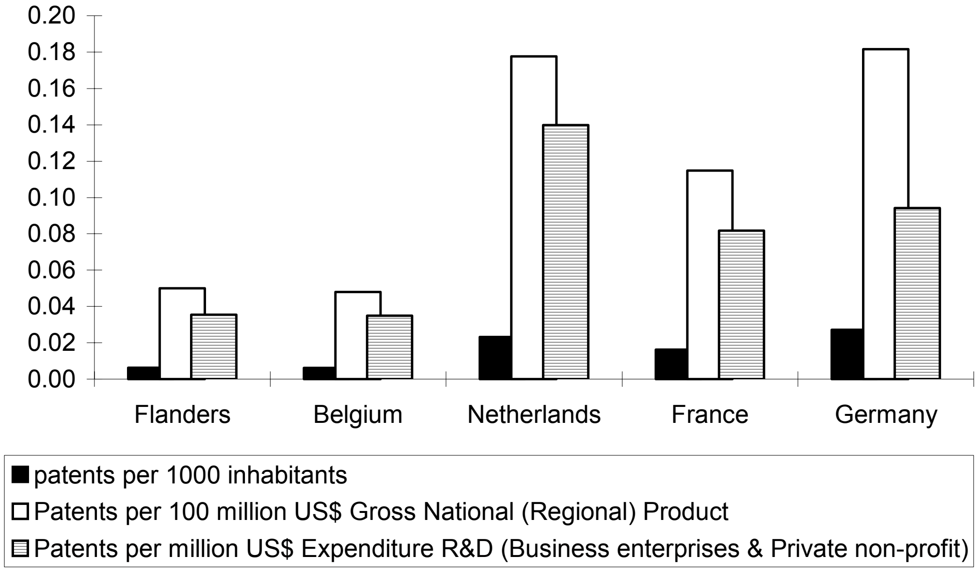
For the overall Flemish IT activity, we may conclude that it seems to focus more and more on two subdomains, Image Processing on the patent side, and Processing Technology on the publication side.

8.3.3 Productivity of Flemish IT

An estimation of the productivity in IT is made by normalizing the output with several input indicators. From the 'OECD - Main Science and Technology Indicators', the input data was obtained for the studied countries (Belgium, France, Germany, and the Netherlands). For Flanders, the data was extracted from the database with regional indicators at the Ministry of the Flemish Community. Both publication and patent data were normalized to the number of inhabitants, the Gross National (Regional) Product, and relevant data on R&D expenditures. The results are presented in Figure 8-7. Most striking in these charts is the observation that on the average, Flanders (and Belgium) perform similarly compared to the other European countries as far as publication output is concerned. On the patent side, however, the productivity is far below that of the other countries. The publication productivity becomes even better in Flanders and Belgium than in three other European countries, when normalized to R&D expenditures in 'higher education and government'. An additional striking observation about Flanders (Belgium) in relation to the other countries, concerns the productivity normalized to the aimed R&D expenditure on the one hand, and productivity normalized to the Gross National Product (GNP) on the other hand. In the other countries, both indicators are at a similar level. In Flanders and Belgium however, the productivity normalized to the aimed R&D expenditure is significantly higher. As the activity (publication output) remains the same, this difference confirms the fact that public R&D expenditures, mainly concentrated in universities and public research institutions, as part of GNP is considerably lower in Flanders and Belgium during the studied period than in the other countries.



(a) Publications



(b) Patents

Figure 8-7 Average productivity measured with three input variables in IT (1983-1992)

8.3.4 Impact of Flemish IT publication output

Finally, we assessed the impact or 'visibility' of Flemish IT publications. The impact is measured by counting citations to these publications and by comparing it with world averages. First we make some remarks about the data. The publications subject to the citation analyses are only those which are covered by the Science Citation Index (SCI). The output analyses in the previous sections were based on data derived from the INSPEC database. The citation-analyzed set of Flemish IT publications, therefore, is a subset of the total Flemish INSPEC output in IT. The applied analyses are described in detail in the work of De Bruin et al. (1993). An overview of the figures for the Flemish IT publication output is given in Table 8–4.

Table 8–4 Bibliometric scores of Flemish IT publications (1983-1991)

Indicator	*Description*	*Score*
P	Number of IT publications in SCI	992
P/Inspec	Percentage of total Flemish IT output covered in SCI citation analysis	28.65
C	Total number of received citations	5,682
CPP	Average number of citations per publication	5.7
CPPex	CPP excluding self-citations	4.1
Self-Cits	Percentage of self-citations	28.5
JCSm	Average journal impact factor	6.9
FCSm	World citation average in IT	5.6
CPP/JCSm	Citation average/journal impact factor	0.8
CPP/FCSm	Citation average/world citation average in IT	1.0
JCSm/FCSm	Journal impact factor/world citation average in IT	1.2

The results in Table 8–4 show that overall Flemish IT performs well: a total of 992 Flemish publications (*P*) in the sector of IT was cited 5,682 times until 1995 (*C*). The average of 5.7 citations per publication (CPP) decreases to 4 (CPPex) if self-citations are excluded. The average number of citations per IT publication is normalized by the citation average of the journal set used by Flemish IT researchers (CPP/JCSm), and by the world average in the subfields (CPP/FCSm, where the subfields are defined through ISI journal categories) in which they are active. The most important ISI categories in our database are: Electrical Engineering, Applied Physics, and Applied Mathematics. The Flemish IT impact is around the world average (CPP/FCSm = 5.6). CPP/JCSm is somewhat lower than the CPP/FCSm because their JCSm is above their FCSm. This means that the Flemish IT researchers publish their work in journals with an impact factor which is above the world average in the field.

In Table 8–5, the data has been broken down over the subdomains. The results show that there are significant differences with respect to numbers of papers included in the citation analysis and with respect to the coverage of numbers included in the citation analysis (SCI) as related to the number included in the production analysis (INSPEC). The covered percentages (*P*/Inspec) range from almost nothing to more than 50.

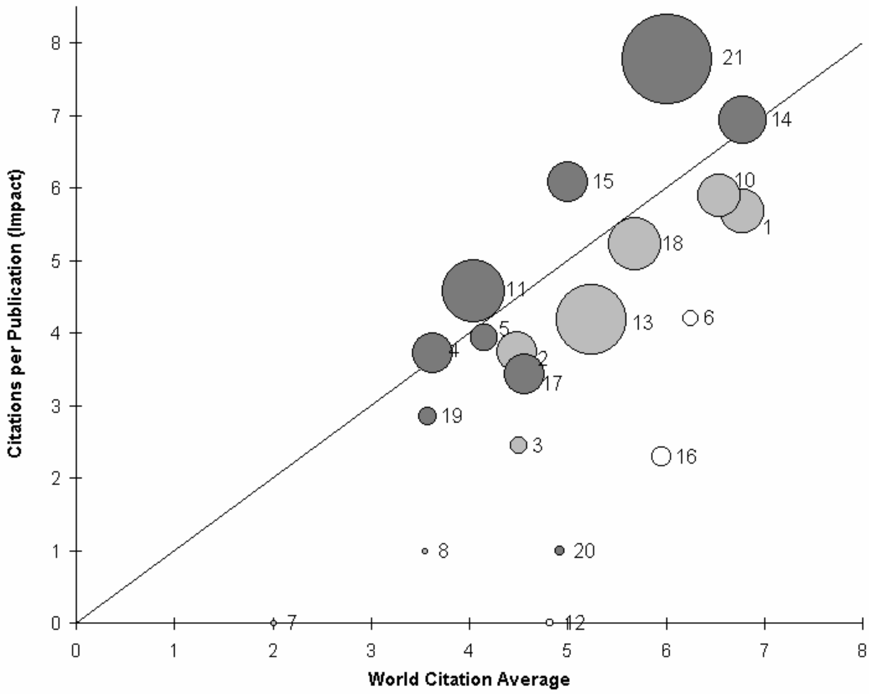
Table 8–5 Bibliometric scores of Flemish IT publications by subdomain (1983-1991)

sub	*P*	*P/ Inspec*	*C*	*CPP*	*CPP ex*	*JCSm*	*FCSm*	*CPP/ JCSm*	*CPP/ FCSm*	*JCSm/ FCSm*	*% Self Cits*
01	84	30.6	477	5.7	4.3	5.8	6.8	1.0	0.8	0.9	24
02	67	13.6	251	3.8	2.4	4.5	4.5	0.8	0.8	1.0	36
03	11	5.1	27	2.5	1.6	4.4	4.5	0.6	0.5	1.0	37
04	71	15.3	265	3.7	2.9	5.8	3.6	0.6	1.0	1.6	23
05	34	10.8	134	3.9	3.0	5.0	4.2	0.8	1.0	1.2	23
06	10	15.5	42	4.2	3.2	2.1	6.3	2.0	0.7	0.3	24
07	1	33.3		0		1.7	2.0	0	0	0.9	
08	1	33.3	1	1.0	1.0	3.2	3.5	0.3	0.3	0.9	0
09	1	4.0		0			13.0				
10	81	13.6	478	5.9	3.9	7.2	6.5	0.8	0.9	1.1	34
11	172	30.8	789	4.6	3.4	5.3	4.0	0.9	1.1	1.3	27
12	2	3.4		0		2.4	4.8			0.5	
13	225	31.8	943	4.2	2.9	6.1	5.2	0.7	0.8	1.2	31
14	100	52.5	694	6.9	5.1	9.1	6.8	0.8	1.0	1.3	27
15	69	23.0	420	6.1	4.2	6.9	5.0	0.9	1.2	1.4	31
16	17	23.0	39	2.3	1.1	4.8	6.0	0.5	0.4	0.8	54
17	67	22.5	230	3.4	2.5	5.9	4.6	0.6	0.8	1.3	28
18	121	27.9	634	5.2	3.4	5.1	5.7	1.0	0.9	0.9	36
19	14	6.9	40	2.9	1.8	4.3	3.6	0.7	0.8	1.2	38
20	3	5.5	3	1.0	0	7.0	4.9	0.1	0.2	1.4	100
21	357	41.7	2781	7.8	5.8	8.0	6.0	1.0	1.3	1.3	26

Subdomains:

01	Image Processing	11	Micro-electron. & General Electronic Techniques
02	Computer Aided Design	12	Multimedia Techniques
03	CIM & Production Control	13	Numerical Analysis & Applied Mathematics
04	Communication	14	Opto-electronics
05	Computer Architecture	15	Process Control
06	Educational Systems	16	Peripherals
07	Encryption & Security	17	Sensors & Actuators
08	Geographical Information Systems	18	Signal Processing (Analogue, Digital)
09	Graphical Information & Computer Graphics	19	Software Engineering
10	Information Processing	20	Language Technology
		21	Processing Technology

In addition, we show part of the data in this table in Figure 8-8 for the 21 subdomains. In the activity analysis, we observed that subdomain 21 (Processing Technology) is a spearhead of Flemish IT research. It is striking to see that this becomes visible here as well. The impact of 21 is above world average (above the diagonal), while the impact of the journals used in 21 is above the impact of the field (indicated in dark Grey). This means that the researchers in this subdomain are quite ambitious. Furthermore, the ambition of Flemish researchers and the impact of their publications in subdomain 15 (Process Control) is above world average.



Source data: Flemish IT publications covered by ISI databases. Citations to publications in a three year citation window. Size of circles (data points) indicate the proportional numbers of Flemish papers included in each subdomain, as related to the total number of Flemish papers in IT. Dark Grey data points are subdomains with a JCSm/FCSm > 1.2, light Grey are subdomains 0.8 < JCSm/FCSm < 1.2, white if < 0.8.

Subdomains:

01	Image Processing	11	Micro-electron. & General Electronic Techniques
02	Computer Aided Design	12	Multimedia Techniques
03	CIM & Production Control	13	Numerical Analysis & Applied Mathematics
04	Communication	14	Opto-electronics
05	Computer Architecture	15	Process Control
06	Educational Systems	16	Peripherals
07	Encryption & Security	17	Sensors & Actuators
08	Geographical Information Systems	18	Signal Processing (Analogue, Digital)
09	Graphical Information & Computer Graphics	19	Software Engineering
10	Information Processing	20	Language Technology
		21	Processing Technology

Figure 8-8 Overview of impact of Flemish IT publications per subdomain (1983-1991)

8.4 Concluding remarks

At this point, we wish to bring forward some aspects to be taken into consideration. The results of this bibliometric study were reported to the authority that commissioned this study in January 1994. Taking into account the duration of the project, the results were up-to-date. Since then, we only updated the citation data (i.e., the citations received by the IT publications from 1983-1992). Therefore, the results are in fact 'history' of IT research in Flanders. One might consider this as a weakness of bibliometric studies. However, it is a problem as far as publications in scientific journals are concerned. It will always take some time before the results of such a study are publicly available as a journal article. Therefore, the conclusions of this study, as far as the results are concerned, are somewhat outdated. The conclusions with regard to the methods are not.

In this study we proposed a procedure to evaluate an R&D field for its scientific and technological side. The study is primarily based on bibliographic data. To an as complete as possible picture, we combined data of scientific publications and citations, and patents. Moreover, we added input data retrieved from the OECD statistics (R&D expenditure, Population, and GNP) in order to compare the results for Flanders with those of Belgium and three neighboring countries. The study also relates this activity profile to overall developments in the field.

In general, the results present a clear picture of Flemish IT activity during 1983-1992. They show Processing Technology as a spearhead of Flemish IT research, as represented by the scientific publications. Furthermore, the results show Image Processing as a spearhead where patenting activity is concerned.

One of the main objectives of the study was to obtain this almost complete picture of the field and of Flemish activity as complete as possible. As a starting point, we took the publication and patenting activity. As mentioned above, the publication side and the patent side have different spearheads with regard to Flemish activity. Moreover, the study shows that Flemish IT researchers were generally very active on the publication side but not on the patenting side. Obviously, this is a choice made by the entire Flemish IT community. Of course, this will not lead us to the conclusion that Flemish IT researchers were not productive. Neither should we conclude that the results for the publication data indicate that Flemish IT researchers were better than scientists in other countries. The overall results, however, do show us that Flemish IT had a very characteristic activity profile during the studied period. The emphasis on publication activity is typical for Flanders, but a shift towards patenting has already been detected. Of course, other aspects have to be considered here in order to interpret these results from the proper perspective: particularly, industrial R&D infrastructure, regional publication/patenting culture. Countries or regions have different 'input' and therefore different 'output' characteristics. As a result, we argue that in studies like this one, patent and publication data should be analyzed together. Combined, they represent a country's output. At a later stage of study, differentiation can be useful to detect subdomains and topics with, for instance, high or low commercial potential.

From a bibliometrician's point of view, the problem arises as to how these different data sources should be combined. If we want to consider both a patent application and a learned publication as one unit of R&D production, we also need to find a way to break down all the 'products' over subdomains. In the present study patents and publications were grouped separately by using IPC and PACS codes. These two classification schemes differ from each other, so that the integrated results depend on the compatibility of the schemes. Moreover, the databases used, namely INSPEC and EPO, have such schemes, whereas others may not. Bibliographic fields (titles, abstracts, and authors/inventors, for instance) available for both data sources should be applied to accomplish this.

Furthermore, it should be noted that the publication and patent data are broken down over different subdomains by experts in the field of IT. Researchers at IWT have made a major effort to accomplish this. Obviously, these expert facilities are not available in every bibliometric analysis. An alternative approach would be to let the data generate its own structure (delimitation of subdomains). Thus, experts will only be needed to evaluate the results afterwards. At present, research is going on at CWTS to investigate the possibilities, advantages, and disadvantages of such an approach.

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