Using a Bibliometric Approach to Support Research Policy Making: The Case of the Flemish BOF-key

K. Debackere and W. Glänzel,
K.U. Leuven, Steunpunt O&O Statistieken
Dekenstraat 2, B-3000 Leuven

Koenraad.Debackere@econ.kuleuven.ac.be
Wolfgang.Glanzel@econ.kuleuven.ac.be

Abstract

In this paper, we describe the development of a methodology and an instrument to support a major research funding allocation decision by the Flemish government. Over the last decade, and in parallel with the decentralization and the devolution of the Belgian federal policy authority towards the various regions and communities in the country, science and technology policy have become a major component of regional policy making. In the Flemish region, there has been an increasing focus on basing the funding allocation decisions that originate from this policy decentralization on "objective, quantifiable and repeatable" decision parameters. One of the data sources and indicator bases that have received ample attention in this evolution is the use of bibliometric data and indicators. This has now led to the creation of a dedicated research and policy support staff, called "Steunpunt O&O Statistieken," and the first time application of bibliometric data and methods to support a major inter-university funding allocation decision. In this paper, we analyze this evolution. We show how bibliometric data have for the first time been used to allocate 93 million Euro of public research money between 6 Flemish universities for the fiscal year 2003, based on Web-of-Science SCI data provided to "Steunpunt O&O Statistieken" via a license agreement with Thomson-ISI. We also discuss the limitations of the current approach that was based on inter-university publication and citation counts. More specifically, we hypothesize that the allocation method now developed and under further improvement will become more criticized if it turns out that it (1) also starts influencing intra-university research allocation decisions and, as a consequence (2) introduces adverse publication and citation behaviors at the universities involved.

Putting R&D allocation in context

Over the last decade, the R&D function has seen the continuous advent of "new" instruments that should enable decision-makers to better control and monitor the evaluation, the selection and the follow-up of R&D activities (see Vinck (ed.) 1991 or Brockhoff 1994). These concerns are not new, though (Villers 1964 or Roman 1968). As the U.S. were already spending around 3% of their GNP on R&D in the mid-1960s (see NSF Report 67-7), concerns on the effectiveness of R&D allocation decisions and their outcomes started figuring on the agenda of policy-makers and managers already in the 1960s and 1970s (see Roberts 1964 or Seiler 1965). Ever since, a continuous stream of insights and methods on this subject has been generated (e.g. EIRMA 1970, Griliches 1984, Brockhoff 1994, Tidd et al. 2001). One of the outcomes of this continuous stream of insights and methods has been a better understanding of the complexity of the modern R&D enterprise. Its effectiveness thereby depends on a complex web of factors ranging from sufficient levels of funding (see European Innovation Scoreboard 2002), over the access to and the availability of human talent, to the interactions and interfaces between the various actors operating within the R&D enterprise (OECD 2000 & 2001). In addition, an important diversity of activities occurs within the R&D enterprise, ranging from basic research over applied research to engineering-technology development and product innovation (Tidd et al. 2001). This diversity, coupled to the myriad of factors influencing R&D effectiveness, necessitates the development and the deployment of context specific allocation and monitoring methods and instruments.

Although policy-makers have since long recognized the need for the informed decision-making on and the systematic follow-up of public R&D funding allocations (e.g. NSF 1961 & 1976, Gibbons & Georghiou 1986), it is within the realm of industrial R&D funding allocations that a wide

Koenraad Debackere and Wolfgang Glänzel, *Using a bibliometric approach to support research policy making: the case of the Flemish BOF-key*, In: Guohua Jiang, Ronald Rousseau, Yishan Wu (Eds), Proceedings of the 9th International Conference on Scientometrics and Informetrics – ISSI 2003, Dalian University of Technology, Dalian, China, 2003, 33-46.

variety of methodological approaches was developed and deployed over the last decade. Business management jumped on a "value for money" or "return on investment" bandwagon, also with regard to its R&D investments (e.g. Amram 2002, Boer 2002, Paxson 2001). This has resulted in the design of management systems that challenge the accountability of R&D within the company. A major paradigm that has originated from these endeavors is the R&D portfolio management framework that has become widely adopted by the corporate world through the 1991 publication "Third Generation R&D." The central concept in the "Third Generation R&D" paradigm (Roussel et al. 1991) is the so-called partnership between business and technology. The R&D function is accountable to reach pre-defined standards of excellence and relevance. It has to assist the ongoing problem-solving processes related to existing products and markets as well as to contribute to the genesis of new business opportunities through advanced technology development. This paradigm shift has not been limited to private sector R&D allocation and monitoring decisions, though.

Also within the public sector, the need for more accountability on behalf of the various beneficiaries of public R&D money has become a high priority on the agenda of policy-makers (Gibbons et al. 1994). As "knowledge" is now generally accepted as the "third" economic production factor in the economy (Audretsch et al. 2002), policy-makers have increased their attention to the management of their science, technology and innovation bases. Public money provides an important stimulus (in most OECD countries, public money provides 20%-to-40% of the total financial support for R&D) to the development of new knowledge.

As a consequence, the need for methods and instruments to evaluate, to select and to monitor public R&D spending has dramatically increased over the last decade. As mentioned above, public R&D activities support a wide portfolio of objectives and actors. Most policy-makers are still wrestling with the ways in which to manage this diverse portfolio of objectives and actors. Some are related to the development of scientific infrastructure, while others focus on the education and the training of high-level experts and scientists. Besides these objectives, however, a major other one is to support the creation of new, fundamental scientific knowledge. One of the areas that have received a lot of attention is the area of public funding for science activities. In most OECD countries, the major institutional actors in this area are universities and large (public) research institutes. Policy-makers have become increasingly aware of the need to monitor and to evaluate the performance standards of these actors as a way to assess the output of their scientific activities. And, because of the evolution towards more accountability, also on behalf of the policy-makers themselves, this need has been reinforced over the last decade. In the U.K., for instance, this has led to the well-known five-yearly research assessment exercises (see for example, Katz & Hicks 1996).

The rich array of insights, methods and indicators developed by the field of bibliometric research over the last 30 years (Glänzel 1996, Moed et al. 1992, Verbeek et al. 2002) has been avidly used by policy-makers in their quest for "objective, reliable and valid" methodologies to assess the performance of basic science. Of course, this avid use raises many questions as to the problems and the pitfalls associated with bibliometric methods and indicators (Debackere et al. 2002). But, notwithstanding the many caveats, the need for more accountability *ex ante* and *ex post* regarding the public R&D funding allocation decisions has led to many an experiment over the last decade. The regional government of the Flemish region in Belgium has just conducted a major experiment. This experiment calls for the allocation of a significant amount of public money (93 million Euro in 2003) for the support of basic science at Flemish universities on the basis of the bibliometric "output" of those same universities over the ten-year period 1992-2001. This experiment is the subject of the next sections of this paper.

The Belgian and Flemish institutional context for R&D

Belgium is a complex country politically. The ongoing structural reforms of the Belgian State have led to the creation of regions and communities as pivotal entities in the Belgian State structure. The Federal State has devolved major amounts of political authority towards three economic regions (Flemish, Walloon and Brussels) and towards three socio-cultural communities (Flemish, French and German). This has led to a complex structural organization of the country. This complexity has also been reflected in the still ongoing decentralization of public R&D policy in Belgium. For the subject of this paper, we focus on the evolution of public R&D policy between the Flemish region and community and the Federal State of Belgium. The Flemish region consists of the five Flemish provinces. The Flemish community also takes into account the Flemish speaking community in the Brussels region. As a consequence, the Flemish community consists of the Flemish region augmented with the Flemish presence in Brussels. Since 1991, R&D policy in Belgium has gradually been decentralized towards the regional policy level. In 2002, this decentralization movement has led to a situation where 67% of the total Belgian public R&D budget now resides under the umbrella of the regional policy level. The remaining 33% still remain under the authority of the Federal policy level (VRWB 2002). In 2001, some major Federal R&D policy areas (aerospace and agriculture) have also been included in the ongoing the process of regional decentralization.

This evolving decentralization amounted to a total public budget to support the science and technology policy "in a broad sense" for the Flemish region of 1.270 million Euro in the budget year 2002 (HBPWB 2003). This amount also includes the operational and investment subsidies to the Flemish universities that account for about 50% of this total, hence the qualifier "in a broad sense." If we assume that 25% of these operational and investment subsidies are directly related to R&D activities (VRWB 2002), then the total amount of public R&D funding amounted to 703 million Euro in 2002. This amounts to 0.65% of the Flemish Gross Regional Product (GRP). The public R&D money is allocated to the various public and private actors in the Flemish regional R&D system using a myriad of mechanisms and funding channels. Hereafter, we briefly review the major actors and their roles in the Flemish regional R&D system. We do not refer to the multitude of "small" public R&D interventions that only account for a few percentages of the 703 million Euro referred to above.

Economically relevant public R&D support

The Flemish agency IWT manages and monitors all public R&D subsidies to support industrial R&D activities in Flanders. IWT bases its selection and monitoring mechanisms on detailed (external) expert reviews (written and oral) of the projects submitted to the agency, supported by a well-developed in-house group of scientific advisors (IWT 2002). In 2002, the total IWT budget to support industrial R&D was 131 million Euro. Besides this budget, IWT also has a number of budget items that allow it to support industrially relevant research projects in universities and technical schools as well as technological Ph.D. projects at universities. These additional budget items amounted to 41 million Euro in fiscal year 2002. The selection and the allocation of those budget items are based on peer- and expert-reviews of the proposals submitted, coupled to project defenses by the groups or individuals involved.

Public R&D support for major (applied) research centers

Three major "(applied) research" institutes conduct R&D in specific technology domains, aimed at industrial exploitation and application. They receive a public R&D subsidy that has to serve as an "engine" to generate extra R&D income via European programs, direct industry funding and the endogenous exploitation of their research results via patenting, licensing and the creation of spin-off companies. Although their activities are geared towards the more application-oriented end of the R&D-spectrum, this does not mean that they do not engage in more fundamental or basic research activities as well. This is the reason why a significant part of these centers' research portfolio is often referred to as "basic oriented research" or "strategic basic research." The three institutes are: (1) IMEC, the Flemish Inter-University Microelectronics Center, (2) VIB, the Flemish Institute for Biotechnology, and (3) VITO, the Flemish Institute for Applied Technological Research focusing mainly on applied research for Flanders' large SME-base.

Public R&D support for various initiatives

About 53 million Euro in public money (of which 31 million direct R&D subsidy) went to a variety of Flemish institutional actors and public sector departments (environment, family studies, archeology, public radio and television, etc.). While 82 million Euro in public money (of which 43 million in direct R&D subsidy) went to policy relevant programs and studies. Selection and allocation is based either on policy priorities as set by the acting government or on open calls for proposals to be evaluated and assessed by independent experts.

Public R&D support for universities

The major actors in the Flemish scientific research system are without doubt the Flemish universities. Six Flemish universities (K.U. Brussel, K.U. Leuven, Limburgs Universitair Centrum, U. Antwerpen, U. Gent and V.U. Brussel) account for the majority of the scientific research output in Flanders. This is shown in Figure 1: about 85% of the total Flemish scientific paper output (as obtained from the WoS-SCI) resides within the Flemish academic system. As mentioned before, Flemish universities absorb about 50% of the 1.270 million Euro total budget for Flemish science and technology policy, since this budget also contains the operational and the investment subsidies to the Flemish academic world. This “about 50%” amounted to 642 million Euro in fiscal year 2002, of which about 25% is classified as R&D money, or 161 million Euro in 2002. The allocation of these budget items is based on numbers of students enrolled at the respective institutions. Of course, universities in Flanders have access to more public R&D money than the amount just listed. As mentioned, also IWT does support technologically and economically relevant research at universities. Two major additional funding sources and mechanisms are FWO-Vlaanderen en “Bijzonder Onderzoeksfonds” or “BOF.”

FWO-Vlaanderen: public support for small-scale basic research projects at universities

FWO-Vlaanderen, the Fund for Scientific Research in Flanders, monitors a large portfolio of basic research grants and projects to individual researchers (including Ph.D. students and post-doctoral grants) and academic promotors at Flemish universities. The selection and monitoring mechanism is conducted by scientific commissions that base their decisions on a peer-review system, consistently involving foreign experts in evaluating the proposals submitted to the agency (FWO 2002). For the fiscal year 2002, the FWO budget amounted to 82.4 million Euro. Typical interventions vary from 100.000 to 250.000 Euro for 2-to-4 year projects while the individual grants cover up to 6 years of funding (both at the Ph.D. and the postdoc level). Grant applications and project submissions are on a competitive basis.

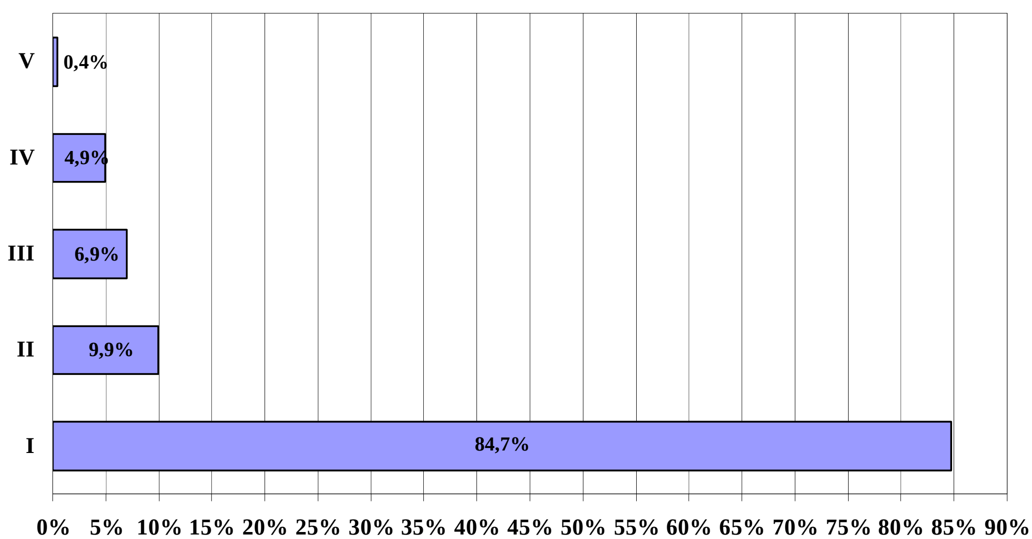

Figure 1: Distribution of Flemish WoS-SCI publications for the period 1992-2001
(I: Higher Education Institution, <1% non-university, II: Public Research Institute or Public Sector Administration, III: Private Sector, IV: (Non-academic) Hospitals, V: Others)

BOF: public support for large-scale basic research projects at universities

Besides the public R&D funding via FWO-Vlaanderen, which is distributed on a project-per-project base or on an individual base, the Flemish government created a mechanism that allows for supporting more large-scale basic research at universities. Moreover, the government decided that apart from “calculating” an inter-university distribution key, the mechanism should allow individual universities to distribute the money they receive internally based on an intra-university competition for grants and projects monitored by the Research Council of the university. Except for setting certain quality guidelines and performance expectations, the government does not intervene in the internal selection and monitoring process for the grants. The mechanism thus created has been called "Bijzonder Onderzoeksfonds" or "BOF" and had a total budget of 90 million Euro to distribute across the 6 Flemish universities for fiscal year 2002. The intra-university selection and monitoring mechanism can differ between the universities involved. It is not the subject of this paper. However, it is obvious that there are certain commonalities between the universities. Selection within a particular university will often be based on a combination of the proven (publication and citation) track record of the group submitting the proposal and a peer-review of the proposal itself.

A major issue with the BOF, though, is the computation of the inter-university distribution key, the so-called BOF-key. Up to 2002, the BOF-key was based on three inputs. First, the number of Ph.D.'s produced by the universities over the four academic years preceding the year during which the computation is executed accounted for 50% of the distribution key. The Ph.D.'s are weighted using a (1,2,3)-weighting criterion depending on the discipline in which the Ph.D. occurs. For instance, a Ph.D. in physics will receive a weight of 3 whereas a Ph.D. in economics will receive a weight of 1. These weights are based on the differential cost estimates of doing doctoral work in the various disciplines as covered and listed by the Flemish Inter-University Council. Second, 35% of the BOF-key was accounted for by the number of graduates at each university during the four academic years preceding the year during which the computation is done. Finally, 15% of the BOF-key was based on the amount of public operational and investment money received by the universities over the four years that precede the year during which the computation is done. Thus we obtain the following formula:

Share of University *x* in BOF-funding for year j+1 computed in year j = 0.50 (Univ. *x* share in Ph.D.'s) + 0.35 (Univ. *x* share in graduates) + 0.15 (Univ. *x* share in money) All shares aggregated and computed over the years *j-4*, *j-3*, *j-2*, *j-1*

(Eq. 1)

Towards more rationalized public R&D funding allocation criteria and mechanisms

As mentioned before, decision-makers have since long recognized the use and the usefulness of bibliometric data for the evaluation of research proposals on both an individual and a project basis, also in Flemish R&D policy circles. Over the last decade, the Flemish government has consistently been paying more attention to include bibliometric output indicators as an allocation parameter for public R&D funding decisions (Luwel et al. 1999). As a consequence, bibliometric indicators have been used to assess and to monitor the performance of the major applied research centers mentioned in the previous paragraphs. In addition, major areas of scientific enquiry, such as biomedical research and natural sciences, have been subject to regular bibliometric assessments (Van Den Berghe et al. 1998). The need for assessment of scientific output at the level of national research systems is certainly not new (Tijssen et al. 2001). However, the use of bibliometric data to directly support a regional inter-university funding allocation decision has seldom been seen.

It is against this policy-oriented background that we can explain the decision of the Flemish government to allocate the BOF-funding described above on the basis of an inclusion of bibliometric data into the allocation rule described in Eq. 1. Ever since the advent of a more independent Flemish science policy, a significant emphasis has been on "performance" assessment (Luwel et al. 1999). Bibliometric data have been the preferred avenue to support and to accompany these performance assessments. In a recent move, the Flemish government thus decided to extend this bibliometric approach to include the distribution mechanism of the BOF-funding via the so-called BOF-key. This decision has been subject to many debates amongst the different actors involved in the assessment exercise since the validity of bibliometric data to determine science productivity and quality is quite criticized. One of the results of this process has been the creation of a dedicated institute, "Steunpunt O&O Statistieken" (further abbreviated as SOOS). This institute should assist the Flemish government and its various science and technology policy advising and policy-making bodies and agencies in generating the necessary bibliometric indicators and data to support this more quantitative approach towards science policy.

SOOS was created in January 2002 after open calls for proposals that were held in May 2001. After a peer-based evaluation and selection round, SOOS was established to support Flemish public science and technology policy-makers with recurrently available and reliable data, constructed indicators and exploratory studies on three "key" areas: (1) bibliometric research, (2) technometric research, and (3) innovation research. Nine researchers and support staff are employed at SOOS. In each of the key knowledge areas, SOOS has to develop a recurrent and accessible database with relevant data and indicators to support Flemish R&D policy. In addition, it is expected that SOOS develop an original research program in each of the three knowledge domains. The year 2002 was the start-up year for those activities. The structural data sources on which SOOS relies for the execution of these tasks are:

(1) Annual plain-text backups of the Web-of-Science that are available to SOOS via a license agreement with ISI (encompassing SCI, SSCI and A&HCI);
(2) the USPTO, EPO (including the REFI-files) and WIPO patent data licensed in from the various patent offices, and;
(3) the innovation data as collected and analyzed by SOOS in the context of the CIS-Eurostat (i.e. the Community Innovation Survey) and the OECD R&D surveys.

The activities just described have initially been contracted out to SOOS for the period 2002-2006. In the context of this paper, we further focus on the support provided by SOOS over the period March – October 2002 with respect to a refinement of the BOF-key computation as described in Eq. 1. This refinement should make the BOF-key more output-oriented and output-dependent by including publication and citation data at the level of the Flemish universities. The approach taken and implemented to achieve this objective is now outlined in the next section of this paper.

Quantification and inclusion of publication and citation output in the BOF-key

As mentioned previously, the Flemish government has for many years been interested in the use of bibliometric indicators as an instrument to assess and to monitor its R&D policy. Marc Luwel has been the pioneer of this approach in Flanders. CWTS (U. Leiden), and in particular Henk Moed, played a crucial role in setting up the necessary studies and experiments to support the endeavors of the Flemish government to better quantify and monitor the research output of its publicly funded R&D system components. This has led to many analyses and exercises that used bibliometric data to monitor the output of the Flemish R&D system. These pioneering efforts during the 1990s have led to the recognition that the Flemish government needed a more permanent structure to support these activities. The creation of SOOS was a direct consequence of this awareness and recognition.

A major issue that has been on the agenda of the Flemish government for many years was the BOF-key. Up till fiscal year 2002, the BOF-key was based on three components as listed in Eq. 1. For fiscal year 2003, the Flemish government had decreed that the BOF-key should also include output-related performance data. Given the previous experiences by Luwel and Moed, bibliometric data were judged to be the best available, reliable and accessible data to engage in this process. More specific, since the Flemish government already collectively supported a license on the Web-of-Science for all Flemish universities, it was deemed appropriate that SOOS obtained an additional license giving it access to the underlying SCI, SSCI and A&HCI data structures. This license was obtained in March 2002 and allowed SOOS to actively engage in the revised and refined computation of the BOF-key.

It has been the explicit objective of the Flemish government and its policy-makers that the inclusion of bibliometric data in the BOF-key should stimulate Flemish academic researchers to aim for better performance in their research activities. Of course, the qualification "better" is interpretable and value-laden. Should "better" mean "more," or should it mean "higher impact," or should it be a combination of both. This issue has been dealt with extensively by the VLIR. The VLIR is the Flemish Inter-University Council (in Dutch: <u>VL</u>aamse <u>I</u>nteruniversitaire <u>R</u>aad) that is responsible for the preparation and the advise to the Minister concerning policy issues that pertain to the mission, the funding, the structure and the organization of the Flemish academic landscape. During 2002, the ideas and the approaches proposed by the VLIR were validated and if necessary adapted by the Steering Group of SOOS. This needed to be done in order to enable SOOS to compute a first Revised Version of Eq. 1 by October 2002. This would allow the Minister to base the BOF-funding for 2003 already in part on bibliometric output of the universities involved. The major items that occurred during this process and their outcomes can be summarized as follows:

(1) It was decided that any refinement of the BOF-key would be based on ISI Web-of-Science (further abbreviated as WoS) data. Although the use of WoS data for evaluative and distributive purposes is not without controversy (e.g. Luwel 1999), they were considered the "best available, recurrently accessible, transparent and controllable" data on which to base a refinement of the BOF-key;
(2) The starting point for a refined BOF-key would be publication and citation data. However, it was obvious that this point of departure required further refinement as well. *First of all*, it was decided that university affiliation would be the starting point for any bibliometric measurement to be included in an inter-university distribution key. *Second*, given the many controversies surrounding the use of WoS data to measure the scientific output in Arts & Humanities, it was decided that these disciplines would not be taken into account until reliable data sources and indicators could be derived for them. *Third*, since no explicit link is made between author fields and affiliation fields in the WoS data sources, a problem arose when co-authors with different institutional affiliations occurred on a paper. This issue was solved by accepting that each publication with multiple Flemish academic affiliations would be allocated and counted as one "full" publication for each institution. Hence, no fractional counting scheme would be implemented. *Fourth*, the same point of departure was subsequently taken with regard to the citation counts. *Fifth*, this stance further raised the issue of self-citations. As no link exists in the WoS data sources between individual author data and affiliation data, it is impossible to aggregate individual self-citation data to an institutional level. As a consequence, it was decided that self-citations would be left out in the computation of the BOF-key, but that the intersection between cited and citing papers would be computed in order to obtain an insight into the magnitude of the "institutional" self-citations;
(3) Given the stances taken towards the publication counts and the citation counts, a time window for the computations had to be chosen. After many deliberations, it was decided to use a moving ten-year time window for both counts, starting with the period 1992-2001;
(4) Although impact measures and relative citation rates might be a useful complement to the points of departure just listed, it was decided not to take them into account for the first round of the BOF-key computation. However, as of 2004, possible further refinements of the BOF-key based on impact measures should be taken into account and elaborated, as decided by the Minister.

This approach led to an adaptation of the BOF-key as listed in equation 2:

Share of University *x* in BOF-funding for year j+1 computed in year j =

w_1 . {0.50 (Univ. *x* share in Ph.D.'s) + 0.35 (Univ. *x* share in graduates) + 0.15 (Univ. *x* share in money)} (Part I)
+
w_2 . {0.50 (Univ. *x* share in publications) + 0.50 (Univ. *x* share in citations)} (Part II)

with:
All shares aggregated and computed over the years *j-4, j-3, j-2, j-1* for Part I of the equation;
All publication and citation shares computed over the years *j-10 … j-1* for Part II of the equation;

Weights w_1 and w_2 will evolve over a three-year period as follows to reach a steady-state in 2005:

Weight	BOF-2003	BOF-2004	BOF-2005	BOF-2006
w_1	0.90	0.80	0.70	0.70
w_2	0.10	0.20	0.30	0.30

(Eq. 2)

As is obvious from Eq. 2, the final outcome of the BOF-key negotiations has led to a complicated inter-university allocation rule in which research output, in terms of Ph.D.s, publications and citations, is gradually increasing until it reaches a steady-state of 65% of the allocation rule. The key listed in Eq. 2 can still be refined with regard to Part II in order to include (1) more impact-based measures and (2) SSCI and A&HCI data besides the SCI data used for the 2003 computation.

Starting from these assumptions and the now adjusted allocation rule, SOOS started to delineate the Flemish WoS-SCI publication universe over the ten-year time window. This was done according to the following steps, leading to the results shown in Tables 1 & 2:

(1) First, all Belgian SCI publications were downloaded into separate, yearly publication sets for the time-period considered. This yielded a total database of approximately 119.000 original source documents. These documents contained approximately 186.000 separate affiliations that now had to be cleaned up for synonyms and (where relevant) had to be uniquely allocated to the 6 Flemish universities;

(2) The allocation of publications to universities was done in a controlled, step-by-step process. First of all, a complete set of the 6 university names including all possible synonyms and spelling variations was made in order to match publications to institutional affiliation with each of the 6 universities. Second, to further automate the filtering and assignment process, all street and city addresses at which research groups of any of the aforementioned universities were located (over the ten-year time window) were included. Third, in case the two first filters did not prove to be sufficient to allocate papers, we used the listings with personnel names obtained from each university for a final (most often manual) check of the papers that could not be assigned based on the previous filters and indices;

(3) During the period April-July 2002 the publications were thus filtered. By the end of July, a first exhaustive download of all university assigned Flemish WoS-SCI publications for the period 1992-2001 was available for validation by each university. The validation period lasted for two months (till end of September 2002) and resulted in a validated publication and citation set. No systematic errors were detected in the filtering and download procedures and results as deployed by SOOS. The final and validated results are shown in Table 1 & 2;

(4) As one university was very small in terms of SCI-publication output (since it only organizes the first years of undergraduate education and has no science nor biomedical faculty at all), the Flemish government decided that this institution (Univ. A in Tables 1 & 2) would obtain 0.23% of the BOF-money without taking into account publication output.

Table 1: Distribution of publication counts among Flemish universities (no fractional count)

	Total publications 1992-2001					
Year	**Univ. A**	**Univ. B**	**Univ. C**	**Univ. D**	**Univ. E**	**Univ. F**
1992	0	1495	69	840	592	495
1993	1	1452	82	914	612	508
1994	0	1738	104	975	605	538
1995	0	1851	109	1135	708	567
1996	0	2095	123	1214	790	602
1997	2	2200	114	1210	796	656
1998	1	2534	111	1335	834	762
1999	2	2546	157	1459	944	736
2000	1	2582	145	1567	891	664
2001	1	2728	160	1680	925	712
Total	**8**	**21221**	**1174**	**12329**	**7697**	**6240**

In addition, an estimation of self-citation scores was made using the intersection of cited versus citing paper approach as outlined above. This analysis showed that, except for Univ. C with a self-citation rate of 45%, all other universities in the sample (B, D, E & F) had self-citation rates ranging from 38.1% up to 39.6%, with Univ. B having the lowest self-citation score.

Table 2: Distribution of citation counts among Flemish universities (no fractional count)

	Total citations 1992-2002					
Year	**Univ. A**	**Univ. B**	**Univ. C**	**Univ. D**	**Univ. E**	**Univ. F**
1992	0	27135	977	12795	10341	9595
1993	0	25783	1015	13233	10108	8415
1994	0	28161	1259	12246	9311	7770
1995	0	28867	1298	13390	10053	9097
1996	0	23406	1190	12240	9261	7720
1997	7	23333	776	10683	8020	7054
1998	0	19580	399	8866	6766	5099
1999	1	14910	472	6751	4700	3910
2000	0	6499	209	3241	2118	1387
2001	0	1071	64	597	332	307
Total	**8**	**198745**	**7659**	**94042**	**71010**	**60354**

The revised BOF-key: comments, speculations and conclusions

It is obvious that this experiment has raised major questions and discussions in Flemish academic and policy circles alike. It may drastically change the way in which universities view, assess and monitor their own science base. We therefore conclude with some reflections on what the future might bring for a science system once it implements this approach. These reflections pertain to the validity of the decisions taken and to the competition that is engendered within the regional science system. Some of their consequences may be intended and beneficial, others may be unintended or even harmful. Anyway, they cannot leave an academic, a policy maker or a university administrator unaffected.

First of all, it is clear that the current BOF-key as listed by Eq. 2 is a significant step in an evolutionary process as to how Flemish science policy might and will include research output and performance data into its allocation rules. The present version of the BOF-key is innovative in the sense that it explicitly recognizes and rewards publication performance within the Flemish university system. However, in order to further recognize and reward this performance, additional refinements to the current Part II of the allocation rule are desired. In order to avoid publication behavior to take on a “more is better” character, it is advisable that some correction based on impact measures is applied to the “first-order” publication counts that have now been obtained. Currently, a working group at the VLIR, in collaboration with SOOS, is developing the corrections needed. This could be achieved by weighting individual publications with the Journal Impact Factors. These weighting procedures can be more or less sophisticated as one decides to take inter-disciplinary differences into account or not. This is a major judgment call. Do we accept that the differential impact values of journals in different disciplines reflect inter-disciplinary differences (and as a consequence, not all disciplines are equal)? Or, do we want to correct for that by re-scaling the impact scores across disciplines so that the higher- and lower-ranked impact journals in each discipline receive equal weights? This is a judgment call that obviously implies a choice that cannot be solved by bibliometric insights alone. In addition, if one decides to weight publications, then the question arises as to what to do with regard to the citation counts. Should they be weighted as well? And, if one decides to do so, what is the underlying rationale for doing so? During the recent debate on this issue, it has also become a point as to whether to include Relative Citation Rates as an indicator of research performance. This Relative Citation Rate (RCR) is the ratio of Mean Observed Citation Rate (MOCR) to Mean Expected Citation Rate (MECR) for the papers identified over a fixed time-window (e.g. four years). Finally, the issue of including Social Sciences and Arts & Humanities in future calculations of Eq. 2 remains standing. Preliminary analyses have demonstrated that this may be useful and relevant for certain subfields of the Social

Sciences and for the fields Economy, Business and Management as well as for Psychology and Behavioral Sciences. However, fields like Law and Literature are more difficult to capture in Eq. 2. It should also be noted that as long as publication and citation counts remain the basis for Part II in Eq. 2, alternative data sources are not readily available. Only the WoS provides the policy-researcher with a recurrently available, traceable and controllable set of data (including citations) to support decisions as the ones advocated by the revised BOF-rule.

Second, the issue arises as to whether and how the changes (both current and future) in allocation rules might affect publication (and ultimately research) behavior of the academic scientists involved. The original rationale to stimulate academic researchers to strive for "higher levels" of publication output with "better, higher impact" publications is understandable, though not without potential pitfalls. A first one is related to the fact that the BOF-key has been conceived as an inter-university R&D allocation rule. Thus, it should hence not affect intra-university funding allocation decisions, and as a consequence, it should have a minor impact on the problem choice and publication choice behavior by individual scientists. Indeed, the only stimulus should be (for each researcher, irrespective of his or her discipline) to aim for higher impact publications within his or her discipline. Of course, we all know that higher impact does not necessarily reflect higher quality, more still, that it is illegitimate to equate impact with quality. However, one must realize that these types of linear extrapolations will inevitably be made. This is a potential pitfall behind the current system. One might still be able to live with a degree of "naïveté" that, because of the large numbers involved, the overall result of the revised allocation rule should thus be a change for the better in each discipline. This may prove to be a noble but naive assumption if not monitored properly. Given the competitive character of R&D funding as stimulated by Eq. 2, it is indeed reasonable to expect that universities might orient their internal funding decisions towards those disciplines where they anticipate higher levels of higher impact publications. This would inevitably lead to a new Matthew effect within the academic institutions themselves, with the disciplines more prone to generate "wealth" in terms of publications, citations and impact scores becoming more favored to receive a larger part of the BOF-money distributed to each university. Hence, the implementation of a publication-based allocation rule calls for a close monitoring as to how this rule might affect the internal funding allocation mechanisms as deployed within each university. A search for internal selection biases might hence be warranted.

Third, one might wonder whether other adverse effects could occur. The "multiple" counts of publications, assigning them to each university affiliated with the paper, might in the longer run also affect promotion and collaboration policies at and between particular institutions. For instance, it might be possible to inflate one's publication output by systematically stimulating inter-university promotion and collaboration policies. This may as yet be a farfetched hypothesis, but it might become reality when "dominant" coalitions would emerge within the Flemish academic landscape, allowing the coalition partners to better "steer" their share in the BOF-key. If such behavior would occur, then it would greatly undermine the acceptance of publication and citation data as parameters in the allocation rule.

It is obvious that some of the biases just mentioned are highly speculative and will probably be proven false as the adjusted BOF-key becomes a generally accepted and legitimate allocation mechanism for public R&D funding. If successful, it is not illogical to assume that other public R&D funding decisions might ultimately adopt similar criteria. Contacts with other European countries moreover do show that the current Flemish BOF-experiment is being watched with careful attention. Hence, if successful, it is also logical to assume that public R&D policy in other European countries might adopt similar allocation rules. In order for these evolutions to happen, though, a burden of proof is on our shoulders. We should indeed prove that the approach taken and described in this paper leads to improvements in the way the academic research system operates and performs. Or at least, we should be able to demonstrate that negative effects and selection biases as mentioned in the previous paragraphs do not occur. To this end, we will have to develop appropriate monitoring parameters that enable a meta-evaluation, i.e. an evaluation of our proper evaluation rules as depicted in Eq. 2.

Acknowledgements

This research was possible thanks to the availability of the ISI-WoS data as provided by ISI under the license agreement with "Steunpunt O&O Statistieken."

References

Amram, M. (2002) Value Sweep: Mapping Corporate Growth Opportunities, Harvard Business School Press, Boston.

Audretsch, D.B., Bozeman, B., Combs, K.L., Feldman, M., Link, A.N., Siegel, D.S., Stephan, P., Tassey, G. and C. Wessner (2002) "The Economics of Science and Technology," *The Journal of Technology Transfer*, Vol. 27 (2): 155-203.

Boer, F.P. (2002) "Financial Management of R&D 2002," *Research Technology Management*, July – August Issue: 23-35.

Brockhoff, K. (1994) Forschung und Entwicklung: Planung und Kontrolle (4. Auflage), R. Oldenbourg Verlag, München.

CORDIS Focus (2002) European Innovation Scoreboard 2002, E.C. Luxembourg.

Debackere, K., Glänzel, W. and M. Meyer (2002) "A Reflection on the Opportunities and Limitations in Using Publication and Patent Based Indicators," Working Paper, Steunpunt O&O Statistieken, K.U. Leuven.

EIRMA (1970) Methods for the Evaluation of R&D Projects, Vol. I, Paris.

FWO-Vlaanderen (2002) Jaarverslag.

Gibbons, M. and L. Georghiou (1986) Research Evaluation, OECD, Paris.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P. and M. Trow (1994) The New Production of Knowledge, Sage Publications, London.

Glänzel, W. (1996) "The need for standards in bibliometric research and technology," *Scientometrics*, 35 (1): 167-176.

Glänzel, W. and A. Schubert (2002) "A new classification scheme of science fields and subfields designed for scientometric evaluation purposes," forthcoming in *Scientometrics*, 56 (3).

Griliches, Z. (1984) R&D, Patents and Productivity, Chicago University Press, Chicago.

HBPWB (2003) Horizontaal Begrotingsprogramma Wetenschapsbeleid, AWI Publication, Ministery of the Flemish Community, Brussels.

IWT-Vlaanderen (2002), Jaarverslag.

Katz, J.S. and D.M. Hicks (1996) "A Systemic View of British Science", *Scientometrics*, 35 (1): 133 – 154.

Luwel, M. (1999) "Is The Science Citation Index US-Biased", *Scientometrics*, 46 (3): 549-562.

Luwel, M., Noyons, E.C.M. and H.F. Moed (1999), "Bibliometric assessment of research performance in Flanders: Policy background and implications", *R & D Management*, 29 (2): 133-141.

Moed, H. F. M., de Bruin, R.E., Nederhof, A.J., van Raan, A.F.J. and R.J.W. Tijssen (1992), State of art bibliometric macro-indicators. An overview of demand and supply, Office for Official Publications of the European Community, Luxembourg.

NSF (1961) Investing in Scientific Progress, National Science Foundation Report 61-27, Washington.

NSF (1967) "Patterns of National R&D Resources, 1953 – 1968," Reviews of Data on Science Resources, National science Foundation Report 67-7, Washington.

NSF (1976) Indicators of International Trends in Technological Innovation, National Science Foundation, Washington.

OECD (2000) Knowledge, technology and economic growth: Recent evidence from OECD countries.

OECD (2001) Benchmarking Industry-Science Relationships, Science, Technology and Industry Outlook 2000.

Paxson, D.A. (2001) "Introduction to real R&D options," Special Issue of the *R&D Management Journal*, Vol. 31 (2): 109-248.

Roberts, E.B. (1964) The Dynamics of Research and Development, Harper & Row Publishers, New York.

Roman, D.D. (1968) Research and Development Management: The Economics and Administration of Technology, Prentice-Hall, Englewood Cliffs, New Jersey.

Roussel, P.A., Saad, K.N. and T.J. Erickson (1991) Third Generation R&D, Harvard Business School Press, Boston.

Seiler, R.E. (1965) Improving the Effectiveness of Research and Development, McGraw-Hill Book Company, New York.

Tidd, J., Bessant, J. and K. Pavitt (2001) Managing Innovation, John Wiley & Sons, Chichester.

Tijssen, R.J.W., Visser, M.S. and T.N. van Leeuwen (2001) "Searching for Scientific Excellence: Scientometric Measurements and Citation Analyses of National research Systems," Proceedings of the 8th International Conference on Scientometrics & Informetrics: 675-689.

Van Den Berghe, H., Houben, J.A., De Bruin, R.E., Moed H.F., Kint, A., Luwel, M. and E.H.J. Spruyt (1998) "Bibliometric Indicators of University Research Performance in Flanders", *Journal of the American Society for Information Science* (JASIS), 49 (1): 59-67.

Villers, R. (1964) Research and Development: Planning and Control, Financial Executives Institute, New York.

Vinck, D. (ed.) (1991) Gestion de la Recherche, De Boeck Publishing, Brussels.
VRWB (2002) Het ‘grote’ begrotingsadvies wetenschaps- en technologisch innovatiebeleid 2002, Brussel.

A revised version of this contribution has been published as:

Koenraad Debackere and Wolfgang Glänzel (2004). Using a bibliometric approach to support research policy making: The case of the Flemish BOF-key. Scientometrics, 59(2), 253-276.