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Research quality and diversity of funding: A model for relating research money to output of research

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We analyze the relation between funding and output using bibliometric methods with field normalized data. Our approach is to connect individual researcher data on funding from Swedish university databases to data on incoming grants using the specific personal ID-number. Data on funding include the person responsible for the grant. All types of research income are considered in the analysis yielding a project database with a high level of precision. Results show that productivity can be explained by background variables, but that quality of research is more or less un-related to background variables.

Introduction

Reviewing the literature on careers and innovation DIETZ & BOZEMAN [2005] remark that there are two almost separated literatures on these issues – the management of innovation studies on the one hand and the study of productivity by economists and sociologist on the other hand. There are by tradition a number of studies that focus on a single sector, either the industrial track or the academic. Many studies with an academic focus have a tendency to favor measures of institutional and personal prestige (the Mertonian tradition), the industrial track favors management aspects and innovative capabilities (the innovation tradition). Some more integrative approaches like that of STEPHAN & LEVIN [1992] have asked for a change in the discussion, but with few exceptions [DIETZ & AL., 2000] theoretical and empirical discussions on this subject are woefully compartmentalized.

Already the literature on faculty research productivity is voluminous. We refer to articles by FOX [1983, 1992], TOUTKOUSHIAN & AL. [2003] and LEE & BOZEMAN [2005] for overviews of the main research issues. Whatever type of research the focus on productivity counted as number of articles or number of citations has created methodological problems. Even if these studies are based on summative indices

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counting different output they all have disadvantages and are open for criticism. The period of time chosen has to be adjusted for, the prestige of the different publications channels and prestige within the respective channels have to be accounted for, and this leads to methodological insecurity and weaknesses. Variations across disciplines due to the nature of work being performed and conventions for communicating research are at the heart of this debate. Quality of the research has been one of the issues since BRAXTON & BAYER [1986], but to some extent straight count of citations add more to the problems than the solutions [PRINT & HATTIE, 1997].

Another vital issue is the level of data gathering and analysis. The institutional or departmental level is often used for these studies [FOX, 1992; PORTER & UMBACH, 2001; TOUTKOUSINAN & AL., 1998]. Often departments are ranked on the basis of their total publications [DUNDAR & LEWIS, 1995]. Our understanding is that the departmental level is an aggregation of several research groups of very different sizes and composition. In practice, some of the groups might consist of people at other departments and other institutions. This creates a summation problem, at least for those who are content with sheer counting of publications

Nowadays, bibliometrics offer more advanced methods and we will rely on the developments in the field over the last decade. Instead of figures based on Journal Citation Reports (e.g. Journal Impact Factor) we employ data concerning actual citations with a benchmark against world figures – so called field normalization. The procedure of field normalization of citation scores developed by CWTS and ISSRU, (CPP/FCSm according to CWTS nomenclature, e.g., [MOED & AL., 1995] or the field Normalized Mean Citation Rate NMCR by ISSRU, see BRAUN & GLÄNZEL, [1990]), relating the citation rates of one article to other articles within that journal category, is preferred by most bibliometricians and is supported by the bibliometric research community (see e.g. [SCHUBERT & GLÄNZEL, 1996; VAN RAAN, 2004; MOED, 2005]) as a proxy for research quality. Thereby, we come around a number of problems regarding the validity of measures, the level of analysis, etc. The analytical advantage of field normalization is that number of publications, publication strategy, and channels of publication becomes more or less irrelevant for the results. By the journals a researchers publishes in he or she points out who are the actual colleagues. Accordingly, the most specific feature with the field normalization method is that a researcher is compared to reference values that are relevant for the actual research done. Another feature of the method is that it is scale-independent, the numbers of publications are necessarily of low importance as long as it is above a certain threshold.

The use of field normalized methods makes it possible to gather data on research leaders or grant holders only, and using them as quality indicators for their respective groups (even if they are not the formal leaders of the group). Here, in this paper, we build on data regarding publication output and relate that to input data from the university databases. In Sweden, as in many other countries, the university administrations have built large data sets on each department and in some cases, on the level of individual researcher.

Data and methods

This Swedish university (made anonymous to the reader) has a personnel database that covers all researchers (and all other staff) during the period 2000–2006. Data given is personal ID-code, status (professor, researcher, associate professor etc.) and department. In some cases, but not all, it is indicated to which research group the person is assigned. This is a service that will be introduced in 2007 for all researchers.

This specific university also has a database for all grants received during the same period of time. Now, remember that the personal ID-code is used also in this database. Among other things this gives information on gender. Every grant that is received goes to a specific researcher responsible for the project. Consequently, it is possible to track all research money coming in to the university to a specific researcher (and his or her group) by matching via the ID-code.

The financial database also covers who is financing the project (grant giver), project number, title of the project, funding body, starting year, length of project in time (yrs), and department of the researcher. There is also a classification of the financiers in the university database in 17 classes according to type of organization (foundation, research council, governmental authority etc.).

From these data it is possible to be more precise on different aspects of funding that goes together with grants. Types of financing and differences between organizations in Sweden are quite well researched. SANDSTRÖM & AL. [2005] have suggested a complete classification of Swedish funding bodies according to the theoretical analyses found in Donald Stokes famous book *Pasteur's Quadrant* (1997). The Swedish team introduced the idea of splitting the financing landscape into three broad categories:

1. Organizations focused mainly on basic research, (fundamental and no obvious application)
2. Organizations focused mainly on strategic research (fundamental but with applications for industry in the future
3. Organizations focused mainly on user-need research (applied and with applications).

The categorization of individual contracts should not be done in a mechanical manner according to this categorization. It is obvious that some of the larger granting bodies have contracts of several types. Therefore, every contract has to be considered by its own and conclusions should not to be automatically drawn from the classification scheme. It gives a hint on the position of the funding body, but each contract can be of a very different type. Figure 1 illustrates the Swedish research landscape in FY 2003 using this categorization.

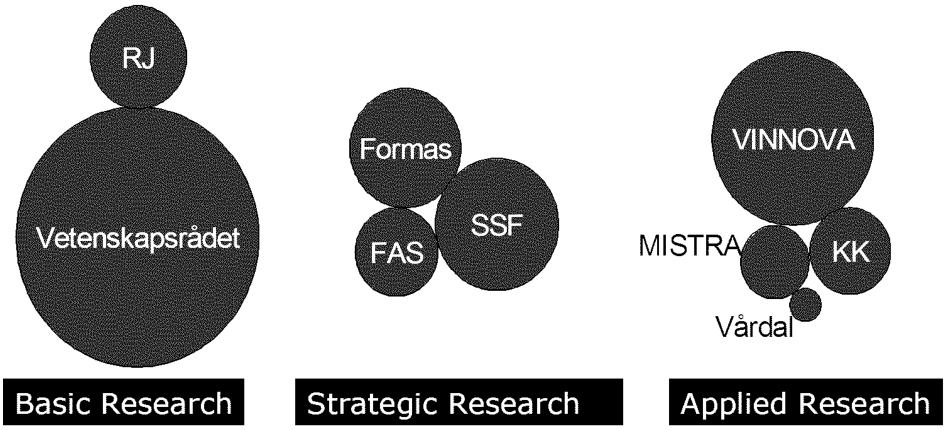

Figure 1. The Swedish Research Landscape (2003). Main financiers of research according to their general orientation. Size of each funding body is proportional to budget in 2003

Inspired by this scheme we have classified all financing bodies to one of these three categories. In all, there are 1 135 contracts in the database covering the period of 2001–2005. The distribution of contracts was quite uneven: 13 per cent from basic research bodies, 43 per cent from strategic and 44 percent of contracts from user-need funding bodies. Counted as proportion of research money per year the basic funds accounted for 14 percent, strategic for 54 percent and user-need for 31 percent. One first remark is that this university is to a large extent dependent on contracts with strategic research bodies, and to a less extent dependent of research money from basic research councils.

The third type of data that we will use in this paper is collected from the Thomson/ISI Internet Web of Science database. All papers from the selected 151 research leaders from four different departments were downloaded using techniques for bibliometric identification based on CVs from the Internet. No matching techniques between CVs and ISI-data were performed. Additionally, in order to build up reference values all journals in all subject categories where these researchers are publishing were downloaded. Data were then gathered in a SQL database and PHP programming techniques were applied. Using the ISI UT-number as identifier we managed, to connect the personal ID-code, name and department to author names in the downloaded ISI-data. This made it possible to get analytical results from the SQL-database in the form of exactly the author part of articles that were identified as belonging to the 151 university researchers. Included in these data is information about number of authors, number of addresses, author fraction of article, first/middle/last author etc. As mentioned, the author gender follows with the personal ID-code.

The bibliometric methods put forward by the Leiden and Leuven groups is one of the most important methodological contributions to the productivity literature. Methods for normalization take all the relevant information that follows with the bibliometric data into account. Each journal in the Thomson/ISI database is assigned to one or several subject codes (e.g. microbiology, biochemistry & molecular biology etc.). Our analysis focuses on Citations per Paper (CPP) in relation to Journal Citation Score (JCS) and CPP in relation to Field Citation Score (FCS). In both cases the *mean* citation score for the journal set is the point of reference for the calculations [VAN RAAN, 2004]. Self-citations are included in the data and we apply an open citation window. NEDERHOF & VISSER [2005] have shown that an open citation window, or at least a citation window which is longer than two or three years, gives an advantage. The bibliometric part is based on data for 1 857 articles (full count).

Via the personal ID-code these results were coupled to financial data. All together this information (personnel data, financial data and output data) were analysed by means of OLS-regression. Results should be able to answer questions like these: Is it good to have grants and contracts from many types of granting/contracting bodies (factor: broadness) or is it better to have a more concentrated and more narrow strategy with fewer agencies? Is there any difference concerning the impact that follows from the share given from different funding sources (factors: sharebas, sharestra, shareuse)? Furthermore, we can answer the important question of whether there are significant differences between male and female researchers.

Findings

Out of 151 researchers 124 are publishing in international journals. We have decided to include all 151 researchers in the analyses as we are studying publishing behaviors and quality of publications. Descriptives are given in Table 1.

Gender is one of the central dimensions of this paper and we will open this section with descriptive statistics on the results concerning differences between male and female researchers. The average sums of total grants collected during 2000–2005 for females are about half the size of the sum collected by male researchers. Females are at larger departments, but in general they have the same ratio between full professors and other personnel. Females are slightly narrow than their male colleagues regarding the number of financing bodies awarding them grants, 1.9 for females and 2.1 for males. Shares from different types of funding sources are about the same, but although differences are not significant it is indicated that females have higher proportion of strategic research than males, likewise females are less dependent on basic science resources. All in all, we can conclude that male researchers receive a higher number of grants per time period.

The average number of publications from this group is 15.0 during the period of eight years (1998–2005). Female researchers in general have a lower productivity performance per person, 11.3 publications. Male researchers produce 17.2 publications in general. Evidently, productivity is lower, but counted as quality of publications (crown indicator CPP/FCSm) female researchers are doing better than their male colleagues. While females are 34 percent better than the world average, males are 27 per cent better only. The gender gap in productivity then is transformed into an efficiency gap where female researchers are better off, cf. SANDSTRÖM & HÄLLSTEN [2008]. With twentyfive per cent higher quality on their papers they seem to produce a bit more interesting results for their colleagues. As very well known this should not be taken as a general truth: there might be differences in distribution of citations between the major female and male dominated areas of science. SCHUBERT & BRAUN [1996] indicate that "characteristic scores and scales" might differ between areas.

Table 1. Descriptives for 151 university researchers

Variable	Observations	Mean	Stddev	Min	Max	Percent	Number
age	151	47.272	8.640	29	68		
male	124			0	1	62.9	78
total_grant	151	3.158	4.063	0.5	26.989		
broadness	151	1.947	0.807	1	4		
sharebas	151			0	1	9.5	14
sharestra	151			0	1	53.1	80
shareuse	151			0	1	35.5	53
no_grants	151	6.179	5.194	1	25		
personnel dept.	151	86.010	46.947	18	189		
ratio_prof/personnel	151	0.124	0.033	0.069	0.176		
no_P	124	14.976	14.997	1	76		
timescit	123	201.098	287.462	1	2022		
CPP	123	11.402	10.504	1	57.75		
CPP/JCSm	123	1.145	0.994	0.1249	10.54		
JCS/FCS	124	1.271	0.403	0.4174	2.582		
CPP/FCSm	123	1.317	0.798	0.1154	4.401		

Results from the regression analyses are shown in Table 2 on the following pages. Results indicate that for quantitative indicators (number of papers P and Times Cited) there are two significant variables: number of grants and total sum of grants.

Table 2. OLS Regression analysis for 151 researchers. Twelve models

	(1)	(2)	(3)	(4)	(5)	(6)
LABELS	m1a	m2a	m3a	m4a	m5a	m6a
	no_p	timescit	cpp	cpp_jcs_m	jcs_fcs	cpp_fcs_m
age	0.0126	–1.906	–0.182	–0.00370	–0.0111*	–0.0194*
	(0.15)	(2.75)	(0.11)	(0.012)	(0.0043)	(0.0097)
male	1.701	38.12	0.360	–0.209	0.00688	–0.0952
	(2.41)	(43.7)	(1.76)	(0.20)	(0.068)	(0.15)
total_grant (million SEK)	0.920**	26.10**	0.342	0.0255	0.00992	0.0473*
	(0.32)	(5.84)	(0.24)	(0.027)	(0.0091)	(0.021)
broadness	3.313	7.974	1.299	0.00676	0.0143	0.0974
	(1.81)	(32.9)	(1.32)	(0.15)	(0.051)	(0.12)
sharebas	–6.512	955.3	51.54	3.438	–0.0626	3.276
	(66.6)	(1208)	(48.7)	(5.49)	(1.87)	(4.26)
sharestra	–4.318	617.0	31.07	3.950	–0.970	2.793
	(66.8)	(1213)	(48.9)	(5.52)	(1.88)	(4.28)
shareuse	–5.592	595.2	29.13	3.707	–0.901	2.852
	(66.8)	(1212)	(48.8)	(5.51)	(1.88)	(4.27)
no_grants	0.831**	11.69*	0.0436	–0.00652	0.00263	–0.0128
	(0.31)	(5.59)	(0.23)	(0.025)	(0.0087)	(0.020)
lpersonnel						
quotaprof_pers						
Constant	3.015	–559.0	–16.90	–2.407	2.549	–0.853
	(67.4)	(1222)	(49.3)	(5.56)	(1.90)	(4.31)
Observations	124	124	124	124	124	124
R–squared	0.38	0.44	0.32	0.04	0.32	0.11

	(7)	(8)	(9)	(10)	(11)	(12)
LABELS	m1b	m2b	m3b	m4b	m5b	m6b
	no_p	timescit	cpp	cpp_jcs_m	jcs_fcs	cpp_fcs_m
age	0.0575	–2.387	–0.200	0.00168	–0.0136**	–0.0192
	(0.15)	(2.82)	(0.11)	(0.013)	(0.0042)	(0.0099)
male	1.044	34.02	0.331	–0.271	0.0244	–0.120
	(2.43)	(44.5)	(1.80)	(0.20)	(0.067)	(0.16)
total_grant (million SEK)	0.867**	25.71**	0.338	0.0206	0.0112	0.0451*
	(0.32)	(5.89)	(0.24)	(0.026)	(0.0089)	(0.021)
broadness	4.080*	11.90	1.310	0.0809	–0.0075	0.125
	(1.86)	(34.0)	(1.37)	(0.15)	(0.051)	(0.12)
sharebas	–9.704	1109	56.01	2.879	0.306	3.492
	(66.6)	(1218)	(49.2)	(5.44)	(1.84)	(4.30)
sharestra	–7.707	767.4	35.46	3.376	–0.600	2.997
	(66.8)	(1223)	(49.4)	(5.46)	(1.84)	(4.32)
shareuse	–8.282	728.2	32.98	3.232	–0.584	3.040
	(66.7)	(1220)	(49.3)	(5.45)	(1.84)	(4.31)
no_grants	0.785*	12.34*	0.0662	–0.0123	0.00538	–0.0128
	(0.31)	(5.64)	(0.23)	(0.025)	(0.0085)	(0.020)
lpersonnel	–0.0505	–0.144	0.00230	–0.00505*	0.00163*	–0.00159
	(0.029)	(0.52)	(0.021)	(0.0023)	(0.00079)	(0.0018)
quotaprof_pers	–59.25	652.5	24.47	–7.128*	3.251**	–0.269
	(42.6)	(780)	(31.5)	(3.48)	(1.18)	(2.75)
Constant	15.14	–755.7	–23.58	–0.855	1.780	–0.921
	(67.8)	(1241)	(50.2)	(5.54)	(1.87)	(4.39)
Observations	124	124	124	124	124	124
R–squared	0.39	0.45	0.33	0.08	0.36	0.12

Standard errors in parentheses
** p<0.01, * p<0.05

Qualitative variables like JCS/FCS and the crown indicator (CPP/FCSm) go well together with other variables. The expected impact factor score (JCS/FCS) seem to be negatively dependent on age and when we introduce personnel and ratio of professors these factors become significant. CPP/JCSm is negatively related to size of department and ratio of professors. This indicates that smaller departments and fewer professors have a positive effect on journal citation scores. The so called Crown Indicator (CPP/FCSm) is also related to age, younger researchers do better quality. When we include personnel and ratio of professors to other personnel this effect disappears (see the full models 7–12). Total sum of grants is the one only factor that is at least weakly related to output. Then again, of course, it is hard to say whether this is an effect of output or is affecting output, or both might be the case. The power of explanation is low for the quality variables which indicate that other factors should be included or that there are no significant patterns involved if we want to explain the quality of research. A surprising result is that the share of basic, strategic or user-need funding does not seem to produce any differences in output variables. Not even broadness (the number of different funding organizations) has any significant effect on research output. A plausible hypothesis could be that higher output will attract more financiers, but that is obviously not the case.

Conclusion

In this small investigation we have tested several variables in relation to a number of quantitative and qualitative variables. The model is interesting and should be used for larger materials. Our contribution indicates that gender of the researcher or project leader is of low importance for quality of research. Female researchers to some extent receive higher field normalized citations, but the variation is too great to draw any further conclusions. The simple input-output model which is behind the implemented research strategy gives some preliminary and interesting results and the model used requires further investigation. Productivity of researchers might be better understood and relations between group sizes and performance might be highlighted by future research. The research potential of the suggested methodology is quite large given that departments from several different universities could be included and compared. Future research should also address the endogeneity of research funding and research output. Causality is likely to go both ways, and collecting data for research groups over a long time span increases the possibilities to disentangle these factors.

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References

BRAUN, T., GLÄNZEL, W., SCHUBERT, A. (1990), Publication productivity: from frequency distributions to scientometric indicators. *Journal of Information Science*, 16 : 37–44.

BRAUN, T., GLÄNZEL, W. (1990), United Germany: The new scientific Superpower? *Scientometrics*, 19 (5–6) : 513–521.

BRAXTON, J., BAYER, A (1986), Assessing faculty scholary performance. In: CRESWELL (Ed.), *Measuring Faculty Research Performance: New directions for institutional research*, 50, Jossey–Bass, San Francisco, 5–14.

DIETZ, J. S., CHOMPALOV, I., BOZEMAN, B., LANE, E. O., PARK, J. (2000), Using the curriculum vita to study the career paths of scientists and engineers: an exploratory assessment. *Scientometrics*, 49 (3) : 419–442.

DIETZ, M., BOZEMAN, B. (2005), Academic careers, patents, and productivity: industry as scientific and technical human capital. *Research Policy*, 34 : 349–367.

DUNDAR, H., LEWIS, D. R. (1995), Departmental productivity in American Universities. *Economics of Education Review*, 14 (2) : 119–144.

FOX, M. F. (1983), Publication productivity among scientists: A critical review. *Social Studies of Science*, 13 : 285–305.

FOX, M. F. (1992), Research, teaching, and publication productivity: mutuality versus competition in academia. *Sociology of Education*, 65 : 293–305.

GLÄNZEL, W. (1996), The need for standards in bibliometric research and technology. *Scientometrics*, 35 : 167–176.

MERTON, R. K. (1961), *Social Theory and Social Structure*. Free Press, Glencoe, IL.

MOED, H. F. (2005), *Citation Analysis in research Evaluation*. Springer Verlag.

NEDERHOF, VISSER (2004), Quantitative deconstruction of citation impact indicators. *Journal of Documentation*, 60 : 658–672.

PORTER, S., UMBACH, P. (2001), Analyzing faculty workload data using multilevel modeling. *Research in Higher Education* 42:171–176.

PRINT, M., HATTIE, J. (1997), Measuring quality in universities: An approach to weighting research productivity. *Higher Education*, 33 : 453–469.

VAN RAAN A. F. J. (2004), Measuring science: Capita selecta of current main issues. In: H. F. MOED, W. GLÄNZEL, U. SCHMOCH (Eds), *Handbook of Quantitative Science and Technology Research*, Dordrecht: Kluwer Academic Publishers, 2004.

VAN RAAN A. F. J. (2006), Statistical properties of bibliometric indicators: Research group indicator distributions and correlations. *Journal of the American Society for Information Science and Technology*, 57 (3) : 408–430.

SANDSTRÖM, U., HÄLLSTEN, M., HEYMAN, U. (2005), Svensk forskningsfinansiering: inriktning och styrning (revised version 2005–12–08), Stockholm: Vetenskapsrådet.

SANDSTRÖM, U., HÄLLSTEN, M. (2008), Persistent nepotism in peer review. *Scientometrics*, 74 (2) 175–189.

SCHUBERT, A., BRAUN, T. (1996), Cross–field normalization of scientometric indicators. *Scientometrics*, 36 : 311–324.

STEPHAN P. E., LEVIN, S. G. (1992), *Striking the Mother Load in Science*. Oxford University Press, New York.

STEPHEN, R., PORTER, UMBACH, PAUL D. (2001), Analyzing faculty workload data using multilevel modeling. *Research in Higher Education*, 42 (2).

TOUTKOUSINAN, R., DUNDAR, H., BECKER, W. (1998), The National Research Council graduate program ratings: What are they measuring? *Review of Higher Education*, 21 : 427–443.

TOUTKOUSINAN, R., PORTER, S. R., DANIELSON, C. HOLLIS, P. R. (2003), Using publications counts to measure an institution's research productivity. *Research in Higher Education*, 44 : 121–48.