The Complex Relationship between Competitive Funding and Performance[1].

Ulf Sandström[*], Ulf Heyman[**] Peter van den Besselaar[***]

[*] *ulfsandstrom@oru.se; ulf.sandstrom@indek.kth.se*
Business Studies, Örebro University, SE-70130 Örebro (SWEDEN)

[**] *ulf.heyman@uuadm.uu.se*
Planning division, Uppsala University, SE-751 05 Uppsala (SWEDEN)

[***] *p.a.a.vanden.besselaar@vu.nl*
Department of organization sciences & Network Institute, VU University Amsterdam (NETHERLANDS)

Abstract

A growing interest for the use of international funding data in relation to scientific output highlights that efficiency at the research system level is a complex research question. As pointed out by many scholars already the OECD expenditure indicators are problematic. Not to mention the problem of how to account for research output. In this paper we suggest a method for treating both of these problems. In the present study we compare the change in scientific output with the change of funding, which to a large extent eliminates the problem of differences between countries but still requires that changes within each country is limited or possible to correct. Based on this contribution we critically discuss a new approach on the role of competitive funding developed by Abramo et al. (2012) in response to a contribution by Auranen & Nieminen (2010). Our results indicate that the level of competitive funding in a research system not at all is correlated to increases in citation performance. Additionally, we find that our data to some extent contradict the systemic relations proposed by Abramo et al.

Introduction of the problem

What is an efficient research system, how to measure efficiency and what characteristics are most important? The debate about efficiency has a long tradition in the political economics of science (for an overview, see Stephan 2012). We would argue that there are actually two problems involved, one conceptual and one empirical.

With respect to the conceptual problem, efficiency of research systems has traditionally been discussed in terms of the level of competitiveness. Competiveness is often defined as the share of basic university funds in total research funding (Abramo et al., 2012): The more institutional funding and the less project funding, the less competition. Also other systems pressures, such as new public management (NPM) and national research assessments, are associated with the level of competition (Auranen and Nieminen (2010). In this work, the authors derive characteristics that would characterize competitive (and therefore better performing) research systems, such as large variety in the quality of higher education institutions (Abramo et al., 2012). Responding to these contributions, we address first the question of the relation between the level of competiveness and performance at the national research systems level: are more competitive systems performing better or not? We then discuss what that would imply for the concept of competition in research systems.

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To answer the question, we are faced with the second issue distinguished above: In order to account for efficiency, one needs reliable input and output data of the science system. This is a longstanding problem. Before addressing our main research question, we will first propose solution to the data problem. After having done so in section 2, we address in section 3 the discussion about competitiveness and performance. This section ends with the specification of the questions to be answered in the paper. In section 4, we discuss in some detail the data used in this study. In section 5, we analyse the relation between funding and output. In the next three sections, we test some presuppositions found in the literature: does the share of direct university funding correlate negative with performance (section 6), do highly competitive countries have a few top universities (section 7), and is performance in Swedish universities uniformly distributed (section 8)? We end with conclusions about the meaning of the concept of competition and concerning the relation between competition and performance.

2. Measuring input s in the research system

Careful accounting for real R&D expenditures is needed when questions of input-output is put into focus. This very problem has followed, we should say haunted, the political economics of research ever since the area started during the 1980s and 1990s (Stephan, 2012; Cole and Phelan, 1999).

Robert May, UK Chief Scientist, disclosed in *Science* (1997) that UK was the most efficient country based on citations per £million government money spent on higher education research (HERD). After a critical debate (Grant & Lewison, 1997), pointing at some data problems, May gave a response based on a new indicator called the “Science Base” Expenditures on R&D (SBRD) which covered expenditures at universities and non-profit making institutions, irrespective of funding sources, and including research establishments (research institutes). UK was still the most efficient country, but Canada, Sweden, the Netherlands and Switzerland had higher ratios between output (papers) and input.

A follow-up study by David King, UK Chief Scientific Advisor, published in *Nature (2004)*, took the discussion to higher levels. King used rebased impact analysis (field normalization) and presented it to a wider audience. King noted that the OECD data for R&D expenditures gave spurious results, but sorted out per cent GDP spent on publicly funded R&D plus per cent GDP spent on higher education R&D (HERD) for his comparison. Again, UK was low on input indicators but first in all “normalized” output indicators (publications/researcher, citation/researcher, citations/unit HERD).

Two British high profile scientists gave their view but, still, it was very unclear what type of research money that should be counted. Return on investment is a serious problem and measurement issues that arise have to be discussed. The thread was taken up by Swedish researchers Jacobsson and Rickne (2004), who questioned the idea that the Swedish academic sector was bigger than in other countries. Conventional measures were considered inappropriate and the results were skewed to such an extent that figures probably had to be interpreted with care as organizational boundaries were drawn differently in different countries. Basically, they argued that the actual distribution over financial categories were the result of “different organizational choices”.

In a subsequent article Granberg and Jacobsson (2006) gave more details attacking the myth of Sweden as a well-funded research system. Monetary values were affected by structural differences, e.g. how PhD-student salaries were accounted, how their PhD-education was financed, and how buildings and office space was taken into account. They found that the HERD indicator was seriously flawed.

The discussion on these issues have continued, e.g. by Leydesdorff and Wagner (2009). They presented another analysis using macro-level indicators for funding and output. Without addressing the problematic nature of these data discussed above, they used both HERD and GOVERD (Government Expenditure on R&D) to account for differences between countries. These figures indicated that most of the countries in the northwest of Europe had about the same costs (<200,000 $PPP/publication), but there were outliers and strange results which made the analysis hard to interpret. Considerable ranges in terms of cost per publication were found also for countries that in the authors view were very much the same system.

How to solve this problem? So far, we note that on both sides of the input-output relation there are a lot of difficulties. Is it possible to measure countries research efficiency if the problem on how to proceed with databases and measurements is still unsolved? The imperative for use of statistical data is often hard to avoid (c.f. Allik, 2013).

3. Competitiveness in the research system

In this context we point at an interesting and constructive attempt to build an interesting data set for seven European countries plus Australia (selection of countries were not justified) by Auranen and Nieminen (2010). Also this time UK come out on top, and consequently, Sweden and the Netherlands were considered as poor performers with low efficiency, i.e. high cost per paper. Finland, Australia and Denmark were a group in between. Germany and Norway were close to Sweden and Netherlands.

The methodological innovation consisted in setting the issue of efficiency in relation to the ongoing changes in the research system due to pressures for better performance under the new regime defined by excellence initiatives, research assessments, and New Public Management. In their analysis Auranen and Nieminen proposed a typology of input- and output oriented core funding on one axis and share of external funding on the other axis.

Obviously, UK had been involved in RAE since many years so their system would be described as an output oriented core funding system, and, paradoxically, on top of that relatively more research money was distributed over the research funding agencies in the UK. High levels of external funding were combined with output oriented core funding. On the other hand countries like Sweden were considered as “a quite non-competitive environment” based on the fact that core funding was input oriented (student numbers, history and politics).

There are two opposed positions in a quadrant: one the one hand the diagonal positions output oriented-small share external *versus* input oriented large share external. Country-wise that would be Australia versus Finland and Sweden. The other opposed diagonal were on the one hand UK (output – large external) *versus* Norway, Netherlands, Germany and Denmark (input – small external).

However, although the analytical scheme seems interesting it does not produce interpretable results. Anomalies are commonplace; Denmark and Australia are in the wrong quadrant, Finland as well. When the authors discuss their results they ignore these anomalies and at the end they consider Sweden to be a (typical) example of a non-competitive research system, a statement we find highly improbable. Therefore, our paper aims to test some of the propositions that follow from the work of Auranen and Nieminen (2010) and especially how these have been developed by Abramo et al., (2012).

Abramo et al. (2012) formulated theoretical propositions, intrigued by the results in Auranen et al (2010), concerning the expected effects of a ‘really’ competitive academic system. They argued that over time competitive arrangements should lead to the concentration of high performing scholars between universities, i.e. the competitive process should lead to a selection of competencies and concentration in a few top universities. This, in their view, leads to a higher performance variety between universities and at the same time to a lower performance variety within each university. Low competition would lead to the opposite pattern: performance differences between universities will be small (as there is a lack of concentration of top talent) but the performance differences within universities will be large. With an empirical test they showed that Italian data confirmed the hypothesis that Italy was a non-competitive system, and they challenged other researchers to do follow-up on other countries. They saw a new competition indicator at the front line.

In the following we will test the hypothesized relation between performance and level of competition within research systems in three different ways – as presented above:

- Firstly, does the level of indirect (project) funding correlate with performance? The assumption is that systems with large General University Funds are less competitive. To test this, we will compare changes in output with changes in funding.
- Secondly, test the Abramo et al. hypothesis that highly competitive systems have a high concentration of performance in a few universities. We will use the Leiden ranking for this.
- Thirdly, we will tentatively test the Abramo et al. hypothesis that highly competitive systems may show larger performance differences between HE institutions, but low performance differences within each university. We will use Swedish university data to do this.

4 Data

Publication and citation data was collected from Web of Science and basic calculations kindly performed by the library at KTH and/or the authors. Basically, we have used the field normalized citation score (MNCS) multiplied by the fractionalized number of papers (Frac P) as a measure of scientific output.

Total funding for R&D in the higher education sector (HERD) in local currency and constant prices was chosen as measure of resource input. In most countries the vast majority of scientific articles originate from the HE-sector, the exception being countries with a large institutional sector that is not included in HERD in the OECD statistics (e.g. Italy). HERD is however by far the best measure since it includes all funding and excludes most of the R&D that results in very few papers.

Since the study concerns the rate of change in input and output it has been important to use a fairly long time period. Older data is however often of lesser quality and also longer series increases the probability of structural changes that may affect the results. The final dataset spans the period 1997-2011 and consist of 32 countries, for which economic data where present and publication data of reasonable magnitude.

There are several reasons for not using the direct indicators of bibliometric index divided by funding in PPPs. The cost of graduate students vary depending on if they receive a salary or not, renting or owning the premises results in large differences in cost, funds are to different extent recycled back to the government etc. This results in a lack of coherence between the economic data and the personnel data (which suffers from other comparability problems) in the OECD statistics. A correlation between indices of bibliometric index divided by HERD in PPP respectively full time equivalents of R&D personnel yields an R-square of 0.06 for the whole dataset, which hardly is good enough for an analysis.

If the rate of change of the variables is used instead of the direct quotients, much of the effects of structural differences between countries will be eliminated, and only changes within each country during the time period studied will affect the comparison. Indeed the R-square between change of scientific output divided by change of respectively personnel and funding rises to 0.48, which seems more reasonable in view of methodological difficulties.[2]

For analysing the performance differences between universities, we use the CWTS ranking data. For a set of countries we calculated the Coefficient of Variance (Cv) of the PP(10%) scores and the (Cv) of the MNCS scores. Consequently, the higher the differences between the universities (independent of the average level[3]), the higher the two measures for Cv will be. For the analysis at university level analysing the variety in performance levels within universities, we use disambiguated Swedish data for individual researchers at universities.

5. How research funding is related to scientific output

The relation between change of funding and change of citations for the total dataset gives an R-square of 0.42, which must be considered fairly strong in view of the large differences between countries. From their economic state and history three quite distinct groups of countries can be discerned: The fast growing emerging countries, the old OECD-countries and the countries from former Eastern Europe.

The former Eastern European countries show a lot of variation both in funding and resources and this should come as no surprise in view of the great political changes in especially the nineties. The large variability and possibly lower quality statistics explains why there is no relationship between output and input for these countries (Fig 1) and they are excluded from further analysis.

In the emerging countries it seems as if a monetary input is much more effective than in the rest of the countries and the relation between funding and citations is fairly strong (Fig 1). The fast development and high efficiency does however seem to be more of a transition state than a structural difference, since regressions made for the period 2004-2011 show much less difference between this group and the established countries.

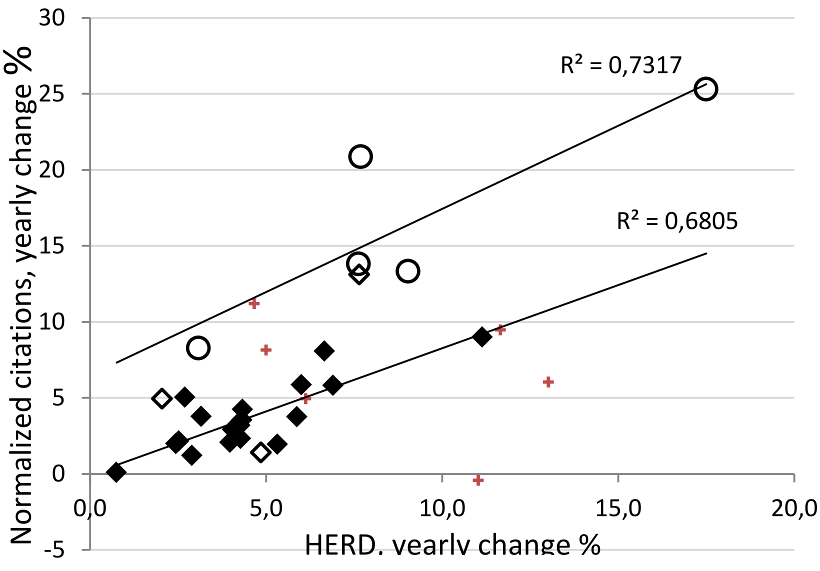

Figure 1. Relation between change in funding and change in citations.

Note: Open circles denote emerging countries; small crosses former Eastern European and diamonds other OECD-countries. The open diamonds denotes countries that are excluded from the regression.

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[2] Coherence of OECD data and how to treat breaks in the time series and other methodological issues will be considered in the full paper, c.f. Maass (2003).

[3] (Cv) = standard deviation divided by the mean.

On the basis of known database problem we suggest the exclusion of some countries, US, Italy, Portugal. It is reasonable to exclude these countries when calculating a regression line, which gives a strong correlation between input and output (R-square 0.68).
Using the rate of change as measures of funding and citations thus gives the quite unsurprising result that increased funding is the main factor for increasing research output (confirming results presented by Bornmann et al., 2014). It also shows that the fast growing, especially Asian, countries tends to blend with the more established countries so that change of funding between 2004 and 2011 results in almost the same change of citations for the two groups. For the established countries the slope of the regression line increases with the shorter time span and the fit is very good (r^2=0.74) for the last available eight-year period (2002-2009) for funding data.

6 The effect of direct funding

The level of funding is a dominant factor for the development of a country's publication record. To evaluate the influence of other factors, we must eliminate the effect of funding. This can be done by comparing the rate of change in funding with the rate of change in productivity. Countries below the regression line can be deemed less efficient than countries above (Figure 1). The deviations from the estimated value (the residual) lead to an efficiency ranking of the various countries' research systems (Figure 2).

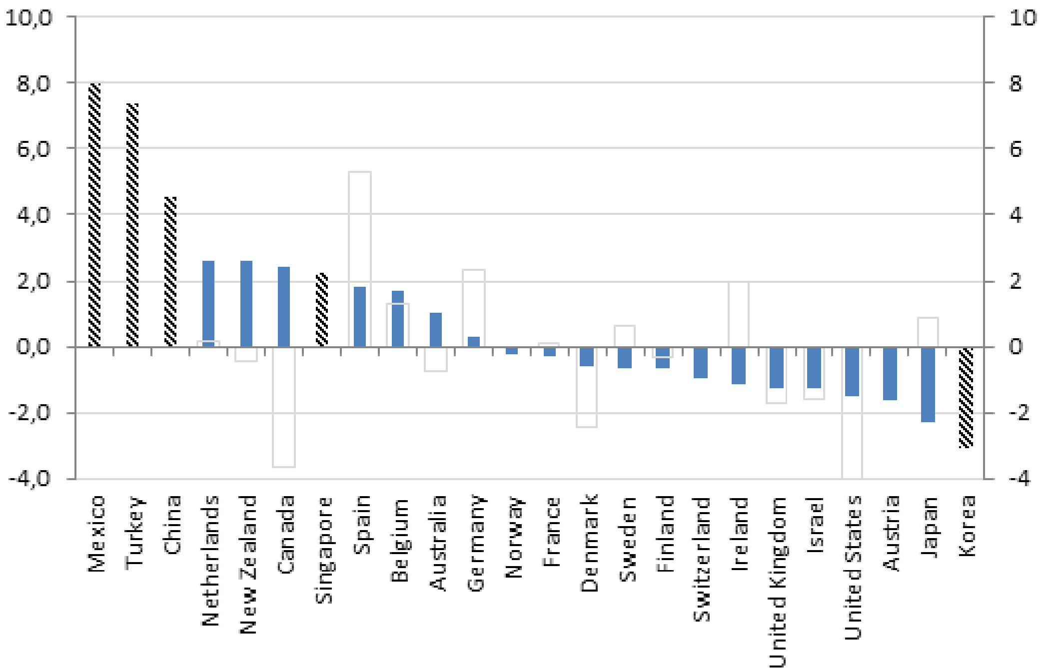


Figure 2. Efficiency of research systems, period 2002-2009

Note: Based on the residuals. Open bars represent residuals for the period 1991-1998.

The OECD data includes general university funds (GUF) which is the sum of direct government funding and the universities own funds. Here we have calculated university GUF using the figure for Civil GBAORD for General University Funds divided with the figure for HERD. The statistics is a contested area and there are probably differences in how concepts behind the statistics are interpreted in each country. Therefore, we include in Table 1 figures from a recent OECD-project (van Steen, 2012) showing the institutional funding (and level of project funding) to the HE sector. Project funding is to a large extent competitive, but since also the direct funding may have competitive components (due to PBRF) it is not a measure of competitiveness but may be used as an indicator.

Table 1. Parameters and Coefficients of variation per country

COUNTRY	INST%*	GUF%**	Residual	PBRF	Cv_MNCS	Cv_top10%
New Zealand	90	22	2,6	2001	0.457	0.501
Netherlands	80	**66**	2,6	1983	0.072	0.077
Canada	55	25,4	2,5		0.133	0.185
Spain		48,8	1,8	1989	0.097	0.172
Belgium	35	26,1	1,7	1991	0.073	0.112
Australia	47	56,8	1	1993	0.109	0.161
Germany	90	60,8	0,3		0.089	0.128
Norway	60	64,4	-0,2		0.020	0.030
France		52	-0,3		0.126	0.166
Denmark	95	59,7	-0,6		0.107	0.119
Sweden	**45**	45,9	-0,6		0.085	0.119
Finland	**45**	44,4	-0,7		0.083	0.099
Switzerland	80	65,7	-1		0.107	0.129
Ireland	50	35	-1,2		0.091	0.136
Israel	95	47,2	-1,3		0.260	0.420
United Kingdom	**35**	34,3	-1,3	1986	0.140	0.196
United States		66,4	-1,5		0.239	0.322
Austria	90	67,5	-1,6		0.079	0.120
Japan		39	-2,3		0.163	0.298

Notes:* based on van Steen (2012), p 19, **based on MSTI (2014) period 2008-2010, PBRF=year of intro. Figures in bold are added by the authors as approximations. Cv columns are based on own calculations.

There's no need for a multiple regression in order to establish that the group of "old" countries (the emerging group is too small and lacks to some extent information on GUF), when they are ordered according residuals, there's no correlation to neither GUF nor institutional funding. In the first group of countries with a positive residual there are both countries with a high GUF or a high level of institutional funding in the HE sector (based on figures presented in van Steen, 2012) and countries with low figures on these parameters.

Obviously, there seems to be more of an explanation if we look at the column for introduction of PBRF (Performance Based Research Funding), all countries, with the exception for Canada, have introduced or started to discuss PBRF during the 1990s. One interpretation would be that this has changed the publication culture in the system towards more WoS-publications and in turn this has geared the system towards higher impact (citations). There is one exception to the rule, the UK variant of RAE does not seem to imply higher efficiency, which might be due to 1) the construction based on peer review (only) and 2) the relative unimportance of direct funding in a system based in project funding.

7. Does highly competitive countries have a few top universities?

We calculated the coefficient of variation, $Cv_,$ for several countries, in order to test whether larger performance differences between national universities correlates to higher (positive) residuals. If higher efficiency in the research system is related to the level of competition as predicted by Abramo et al. (2012) there would be a strong correlation. Top here is actually measured in terms of relative top. In the full version we will include 'absolute' (international) top too.

Using the CWTS ranking, we have information per country about the share in the top 10% most cited papers (PP10%) and about the mean normalized citation score (MNCS) of each individual university. We calculate per country the Cv for PP(10%) and for MNCS – which correlate high (r=.96). Columns to the right in Table 1 shows the results, and data for Cv_MNCS in relation to institutional funding is plotted in Figure 3.

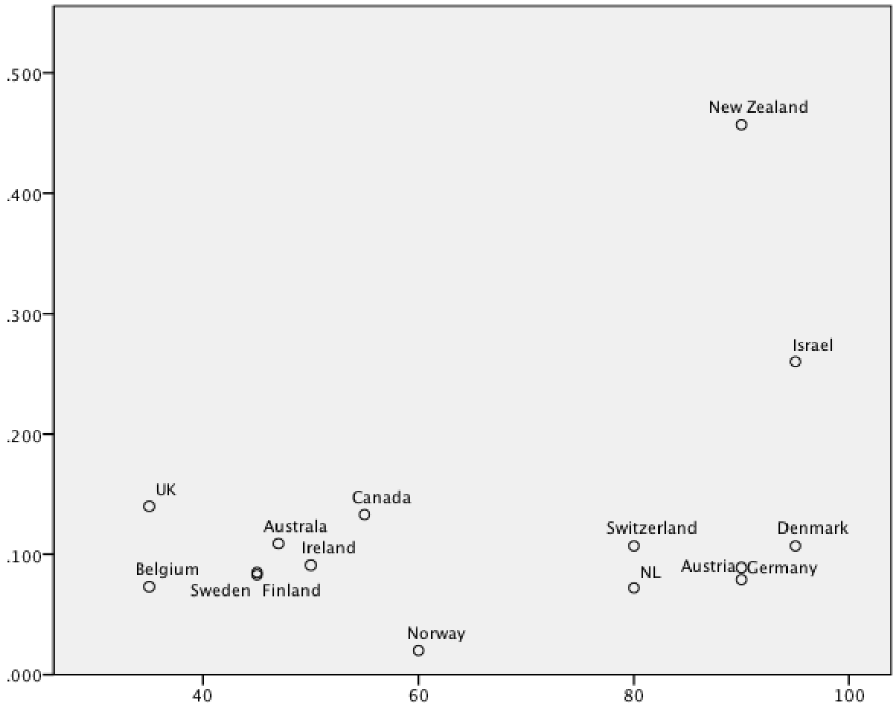


Figure 3. Performance differences (Cv MNCS) by % institutional funding

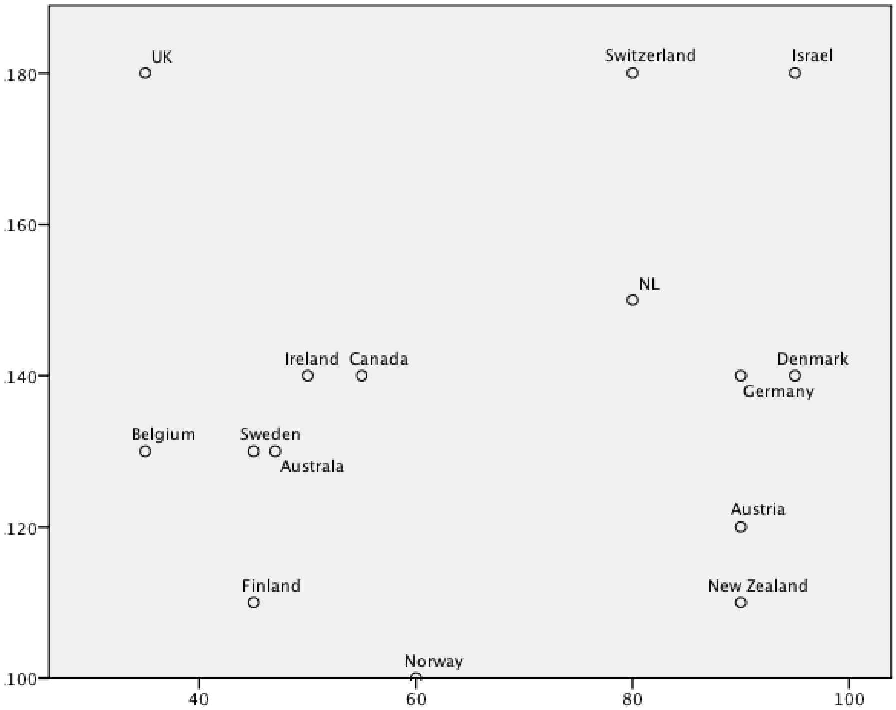


Figure 4. Performance, country's best university (share in top 10% cited papers), by % institutional funding

As Figure 3 shows, there is no indication that the share of institutional funding correlates with differences between universities at the country level. That could either mean that competitiveness plays no role, or that competitiveness is not adequately measured by the share of project/institutional funding. The same holds for the relation between the residual and the level of the top university (measured as its share in the top 10% cited articles) as becomes clear in figure 4.

8. Are performances at Swedish universities equally distributed?[4]

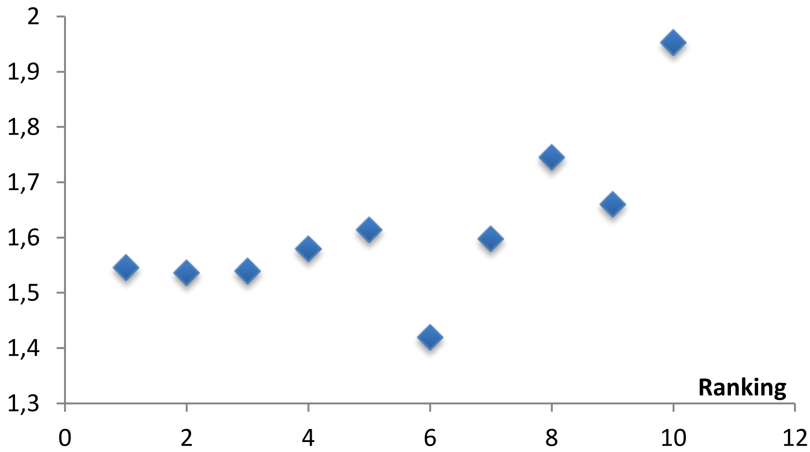
We use data per university per individual researcher's performance for of the eleven main Swedish universities (same type of data was used by the Italian team). For each of the universities the Coefficient of Variance (Cv$_)$ of the (field normalized) top 10% cited papers and the MNCS (so two indicators for the differences in performance levels) were calculated for all researchers per university. We then took the weighted average of the two measures to have one measure for the level of homogeneity in performance levels for each university. We also took the average of the ranking based on the top 10% cited papers, and based on the MNCS. Table 3 show the findings.

Table 3. Indicator variety within universities

Coefficient of Variation	MNCS	Top10%	Weighted average	Ranking
Swedish Univ Agr Sci	0.98	2.30	1.42	6
Karolinska Inst	1.10	2.41	1.54	2
Univ Gothenburg	1.09	2.43	1.54	3
Stockholm Univ	1.21	2.22	1.55	1
Chalmers Univ Technol	1.14	2.46	1.58	4
Lund Univ	1.13	2.54	1.60	7
Uppsala Univ	1.21	2.43	1.61	5
Linköping Univ	1.15	2.69	1.66	9
KTH	1.35	2.54	1.75	8
Umeå Univ	1.64	2.58	1.95	10

There seem to be a relation between the ranking and the level of homogeneity of performance: the lower the Cv, the higher the position on the ranking. This may also be an effect of the skewed distribution of the parameters. Figure 5 shows the association between the Cv and the ranking.

Figure 5. Performance homogeneity* by ranking



* Concentration is the 'weighted average' in table 3. The higher the score, the more the variation in performance. The lower the ranking#, the better the university

[4] The CWTS ranking can be used for this too: performance indicators per discipline can be used to derive a proxy for performance variety within universities.

9. Conclusion

Although previous contributions have formulated ideas about the level of competitiveness and the performance of research systems, our analysis indicates that the relation between these two variables is less obvious than suggested. First of all, the share of institutional funding does not correlate with competitiveness, overall performance, and top performance. And, more competitive systems do not result in larger differences between performances of universities. Finally, better performing universities seem to have a somewhat more homogeneous performance at the individual level than lower performing universities, but this is also not in line with the hypothesis that the within university variety of performance is related to the competitiveness of the research system.

Obviously, there is a lack of understanding concerning the nature of competition, and how competitive mechanisms manifests themselves at the level of university, in order to establish a relationship between national systems' performance, and national systems' competitiveness.

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