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Rankings, Diversity and the Power of Renewal in Science. A Comparison between Germany, the UK and the US

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The Reactivity of Rankings

The systematic entanglement of external performance assessment and the allocation of research funds in science reveal a law that was discovered by the American social psychologist, Donald Campbell (1957, 1976) called Campbell's Law:

> The more any quantitative social indicator is used for social decision making, the more subject it will be to corruption pressures and the more apt it will be to distort and corrupt the social process it was intended to monitor (Campbell, 1976 p. 54).

According to Espeland and Sauder (2007), who carried out a study on the ranking of American law schools by *US News & World Report*, it is the reactivity of rankings that triggers Campbell's Law. This means that the introduction of performance indicators aimed at the performance-dependent allocation of funds makes compliance with the performance indicators an end in itself. All activities — both legitimate and illegitimate — are geared towards the performance indicators. It is of crucial importance to note that these are selective and measure but a small part of the entire scope of achievements (Hornbostel, 1997; Jansen *et al*., 2007). The reactivity of rankings will then result in research being only carried out in such a way as to conform with indicators of relevance to resources. The high diversity of research is reduced to an income-generating level, as Espeland and Sauder (2009) have established in another study. Intrinsic motivation is replaced by extrinsic motivation at the cost of the unlimited unfolding of creativity, and this in a field which builds largely on creativity (Deci *et al*., 1999). The comprehensive use of processes of resource-allocating performance assessment in science would, therefore, have an impact on research that is assumed to destroy diversity. Sauder and Espeland (2009) also showed that comprehensive, resource-allocating external performance controls create a kind of panopticon of science, which Michel Foucault (1977) described as a hallmark of the modern disciplinary society in his study *Discipline and Punish*. Science is increasingly subjected to external controls (Bourdieu, 1975). The typical spreading of ruling by numbers in contemporary society can also be observed in science (Porter, 1995). Therefore, science forms an interesting topic of the so-called governmentality studies that have been developed drawing on Foucault (2008) in the UK, above all (Power, 1997; Dean, 2009; Miller & Rose, 2008). This development is also due to the fact that the UK has subjected the public sector to the new output control in the framework of New

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Public Management in a particularly comprehensive and intensive manner in the wake of its neoliberal reform policy.

In line with this logic, the first *Research Assessment Exercise* (RAE) (RAE, 2008) in science was carried out as early as 1986 to allocate research funds on the basis of a comparative performance assessment of departments. Ever since, research funds have been allocated to university departments every four years in natural, life and engineering sciences and every six in humanities and social sciences on the basis of the sophisticated processes related to the *Research Assessment Exercise*, which was recently re-named *Research Excellence Framework* (REF) (RAE, 2008; REF, 2013; Curran, 2000; Elton, 2000; HEFCE, 2009; Johnes, 1996). As a result, the UK is particularly well suited to analyse the effects of secondary external resource-allocating performance assessment and the resulting rankings.

The comprehensive use of processes of resource-allocating performance assessment and the related rankings involve yet another crucial change in science: the fiercer competition for research funds. One indicator of this is the fact that the share of third-party funds in research funding has grown tremendously over the past 25 years, while the share of basic funds has clearly dropped . Universities with a particularly high level of third-party funding account for almost 50% of third-party funds in their overall budget. This goes hand in hand with a new understanding of the university that is meant to work like a business and aims at investing existing capital in such a way as to produce benefits and achieving an accumulation of capital (Clark, 1998; Slaughter & Leslie, 1997; Slaughter & Rhoades, 2004; Washburn, 2005; Münch, 2011, 2014).

In this context, the circular accumulation of prestige and money is of crucial significance (Münch, 2009). To succeed in this endeavour, universities and their departments must increase their competitiveness by recruiting researchers with a particularly wide record of third-party funds and publications and by admitting the best students of an age cohort. Since these resources are extremely scarce, a struggle for the 'best brains' has flared up, which can only be won by offering top incomes and lavish equipment. In this regard, the richest American universities set the standards — just like American enterprises do with management incomes. Hence, the comprehensive resource-allocating performance assessment generates a kind of academic cannibalism. The richer departments lure the best scientists away from the poorer ones. It is certainly true that an increase in the achievements of all parties is expected as a result of the competition for resource-generating external performance assessment. Nevertheless, this intended effect is opposed by the effect of a growing unequal distribution of human and material resources. In this context, the Matthew effect described by Robert K. Merton (1968, 1995, 1996) for science comes to bear (Bonitz & Scharnhorst, 2001; Bonitz, Bruckner & Scharnhorst, 1997; Bornmann & Daniel, 2006; Cole & Cole, 1973; Goldstone, 1979; McNamee & Willis, 1994; Viner, Powell & Green, 2004).

The comprehensive competition for resources in processes of performance assessment and the resulting rankings bring this more or less hidden mechanism in science to light. The internal performance assessment and recognition of contributions to progress in knowledge entail barriers that do not allow for open capital accumulation. These include, for instance, the principles of good scientific practice that have been identified by Robert K. Merton (1942/1973). Among the four principles of universalism, organised skepticism, intellectual communism and disinterestedness it is, above all, communism and disinterestedness that prevent capitalisation as a result of research achievements. Instead, such achievements are shared with everybody, and resources and knowledge are equally accessible. The new understanding of the competition of entrepreneurial universities for optimum performances in resource-allocating performance assessments and rankings abandons these norms.

Scientific achievement must be translated into competitive advantages. The striking example of this change of scientific resources from a collective to a private good is the growing interest in having knowledge patented. This was triggered by the Bayh-Dole Act in the US, which made it possible for universities to draw benefits from patents acquired by using federal funds (Clark, 1998; Slaughter & Leslie; 1997; Slaughter & Rhoades, 2004; Washburn, 2005; Münch, 2011; Berman; 2012). According to a study on life and material sciences in Japan, the dominance of the entrepreneurial orientation in a research field ensures that scientists no longer share their resources in a generalised exchange with all, but in a targeted manner in a specific exchange with selected partners that promise good profits (Shibayama, Walsh & Baba, 2012).

Paradoxically, the growing inequality in the allocation of human and material resources to departments, which results from the competition for resources in the wake of the Matthew effect, leads to an ever growing restriction of competition. The wide mass of departments is too poorly equipped to challenge the big departments so that the latter merely have to enter into an oligopolistic competition with few rivals. This leads to greater underinvestment among the wide mass and growing overinvestment at the top. This effect should be demonstrated by a curvilinear, reversed u-shaped relationship between the input of third-party funds and the publication output. Many contestants in the wide mass of departments possess too few funds to achieve the optimum productivity level, while few contestants at the top possess far too much to be able to translate all their resources optimally into publication achievements (Jansen *et al.*, 2007; Münch, 2011, 2014). Logically, this should make investors re-distribute their funds to bring higher yields. However, this is not the case. Such a re-distribution of research funds to enhance efficiency is counteracted by the fact that — due to lack of competition — the allocation of resources is not made according to productivity per invested research funds, but to the logic of distinction. Val Burris (2004) has proved this in a study on the connection between the centrality of American sociology departments in the appointments network, their publication performance per staff and their reputation. In line with the logic of distinction, over-equipment is a sign of prestige. In contrast, under-equipment is considered a sign of lacking prestige (Münch, 2007). Nobody will ever criticise Harvard University for the amount of money invested in obtaining a Nobel prize. This phenomenon is similar to the differentiation between a premium segment and a mass segment in the case of consumer goods.

Hypotheses and Methodical Approach

Taking into account this effect of the homogenisation of knowledge and standardisation of methods resulting from the comprehensive use of performance assessment and rankings, we can assume that the growing inequality in the distribution of funds also involves a homogenisation of knowledge and standardisation of methods that make top departments form a centre that serves as an orientation for the departments at the semi-periphery and the periphery. They define ruling knowledge and ruling standards. This hypothesis could be set against the counter-hypothesis which says that diversity does not vanish but migrates to the better equipped centre. The same holds for the question as to the renewal of scientific knowledge. The greater the diversity, the higher the number of sources that may produce something new. This is the essential, widely acknowledged message of Paul K. Feyerabend's (1993) classic *Against Method*. Accordingly, a system of more pronounced differentiation into centre and periphery should offer fewer opportunities for the generation of something new. Much new knowledge cannot be taken into consideration because of its peripheral situation. This has an inhibiting effect on innovation. If the centre is sufficiently diverse, it can also produce something new that has excellent chances of attracting attention. Hence, we find here the counter-hypothesis of maintaining renewability at the centre despite the unequal distribution of resources between centre and periphery.

These ideas should serve as a frame of reference for the following first test of the essential hypotheses. In this context, the British Research Assessment Exercise (RAE) — more recently called Research Excellence Framework (REF) — will be the point of departure. For 25 years, it has allocated research funds *centrally* in a process of performance assessment and resulting rankings. The centralised character of this process is designed to enhance the supposed effects particularly clearly. In contrast, a decentralised allocation of resources in processes of performance assessment will unfold counterforces against the effects of concentration of research funds and staff at the top and the simultaneous impoverishment of the wide mass. Additionally, it works against the curvilinear u-shaped relationship between third-party funds input and publication output; the accompanying decreasing diversity; the standardisation of methods; the homogenisation of knowledge; and the decreasing renewal rate of knowledge. These hypotheses are opposed by the counter-hypothesis that diversity moves to the centre along with research funds so that there is no curvilinear u-shaped relationship between third-party funds input and publication output and no standardisation of methods, no homogenisation of knowledge, and no paralysis of knowledge renewal.

The US, in turn, has boasted an increasing allocation of resources by performance assessment over the past 25 years, but no centralised procedure of resource allocation. Compared to the British RAE/REF, the US shows a ranking by the *National Research Council* (NRC) (*NAS*, *2012*) complemented by a ranking by *US News & World Report* (U.S. News & World Report, 2013). Unlike the British RAE/REF, these do not allocate funds. In the US, the National Science Foundation's (NSF) research funds are allocated on a central basis. The country's federal structure and the diversity of financial resources of both private and state universities generate more decentralisation in the allocation of resources. Hence, the US should be included in our study to form a contrast with the UK. It should also be taken into account that national university systems are placed in an international context by international rankings such as the Shanghai Ranking, the *Times Higher Education* ranking (THE, 2013) or the *CWTS Leiden Ranking* (CWTS, 2013). The indicators used by these rankings affect the national university systems.

A second contrast with the British RAE/REF results from the inclusion of Germany. Like the US, this country also has a federal structure and no centralised procedure of resource allocation by performance assessment as a force working against diversity. In contrast, the German Research Foundation (DFG) assumes a ruling position as supplier of third-party funds and as a power of centralisation, standardisation and homogenisation. This is strengthened by a crucial difference in research funding between the NSF and the DFG. Whilst the NSF allocates only a very small part of its funds to large-scale collaborative projects (NSF, 2012, p. 4), this figure has risen to 58.7% for the DFG in the wake of the *Excellence Initiative for advancing Science and Research at German Universities* (DFG, 2012, p. 37). Added to this is the difference between the departmental structure with many professors and few dependent assistants in the US and the chair structure with few professors and many assistants doing research under their supervision in Germany. This system suggests that there is far less leeway for diversity and renewal in Germany than in the US, a fact that Ben-David (1971) emphasised in his study *The Scientist's Role in Society*. In contrast, the German university system is not very stratified, which counteracts forces of centralisation. The ranking of university departments carried out by the *Centrum für Hochschulentwicklung* (CHE) (Berghoff *et al.*, 2009) of the Bertelsmann Foundation is not firmly anchored, as the recent calls for boycott by a number of disciplinary associations such as the associations in sociology, chemistry, educational science and history have demonstrated. Additionally, compared to the UK, non-university research institutes offer a wider potential for diversity, not least of all due to their large number. In this context, however, we must bear in mind the latters' internal hierarchical organisation with few directors and many assistants, which is a disadvantage for diversity. In any case, the three countries under scrutiny show many institutional differences so that a certain variation in the assumed effects of resource allocating procedures of performance assessment and the resulting rankings can be expected.

Evidence

A look at the Academic Ranking of World Universities published in 2012 by the *Center for World-Class Universities* (CWCU) at Shanghai Jiao Tong University (CWCU, 2012) helps to test the hypotheses elaborated so far in a preliminary way. A comparison between the US, the UK and Germany shows the greatest inequality in achievements according to the criteria of the ranking in the US, closely followed by the UK with only slightly lower inequality, while Germany is well behind these two countries (Table I).

TABLE I. Equality and inequality of universities in the Shanghai Ranking

Years	Alumni	Award	HiCi	N&S	PUB
			Global		
2004	0.2963991	0.3186683	0.3424968	0.3563747	0.1846604
2012	0.3084309	0.3361036	0.3463515	0.347185	0.1803221
			UK		
2004	0.3094711	0.3453381	0.2904721	0.2901751	0.190967
2012	0.3302771	0.3550862	0.2944572	0.3002348	0.1790329
			USA		
2004	0.3330162	0.3243935	0.3401525	0.3602947	0.2141685
2012	0.3542213	0.3552307	0.3451173	0.3779453	0.2029795
			GER		
2004	0.2817274	0.2050711	0.2010524	0.217603	0.1145461
2012	0.2109331	0.1956085	0.2150199	0.2172048	0.1150945

Sources: CWCU 2012; HESA 2012.
Notes: Gini coefficients. Own calculations.

As Halffman and Leydesdorff (2010) have shown for 2003 to 2008, there is no rise in inequality in total publications either for the period from 2004 to 2012. However, this is only half the story. Between 2004 and 2012, inequality grew in the UK and the US for all indicators apart from the total publication score, which shows the lowest level of inequality of all indicators. In Germany, it was only inequality in the distribution of highly cited scientists among universities that rose slightly, while inequality in the distribution of Nobel and Fields alumni decreased considerably and that of Nobel and Fields awards slightly. The publication score remained stable. The increasing inequality in the distribution of alumni, awards, highly cited scientists and publications in *Nature* and *Science* proves the enhanced ability of leading universities to recruit top scientists. This is due to the accumulation of capital in the intensified struggle for resources in an increasingly stratified system consolidated by rankings. Lower and stable inequality in total publications proves that an increasing output of lower-ranked institutions does not help them in their struggle for excellence. They cannot engage in the circular accumulation of money and prestige due to their lack of prestige from previous achievements. The fact that inequality in alumni, awards and highly cited scientists has increased globally, in the US and the UK also in publications in *Nature* and *Science*, though not in total publications, shows a pattern that could be characteristic of the current development. The lower-ranked universities, both within the centre countries and the periphery, and particularly in ASIA, obtain an ever increasing share in total publications, but not in the core criteria of excellence. This also holds true for citations. If we take the example of chemistry and look at the Heeact ranking of 300 universities worldwide, we see that many Asian universities excel in the sheer number of publications, but attain only lower to middle ranks in citations. In contrast, the US-American top universities achieve the highest citation scores, but only a medium number of total publications. The stable or even rising share of the lower and peripheral ranks in total publications is mainly consumptive in nature, i.e. they depend on and cite publications from the centre, but are less productive in themselves (Figures 1 and 2). This pattern has recently been revealed by a network study on the Web of Science (Mazloumian *et al.*, 2013). We must also take into account here that publication growth in the Web of Science occurs largely via the inclusion of previously excluded and new journals, all of which are peripheral. Hence, the catching up of so far middle and lower ranked institutions in total publications remains peripheral, and it takes place mainly in journals with a lesser impact. We could argue that the global system of science is in total imbalance, because one central country is exporting on highest scale and importing on lowest scale, while most other countries are importing on highest scale and exporting on lowest scale. This imbalance keeps diversity within very narrow limits and is a major barrier to the open evolution of scientific knowledge. To change this dangerous state of affairs the quality mark "internationality of scientific research" should be reserved for balanced export/import rates on a high level and not used for the one-sided rule of a hegemonic power and the one-sided subjection of all others to that rule. What international rankings do, however, is to consecrate and consolidate a hegemonic rule which works against diversity and open knowledge evolution.

The lesser inequality in Germany can be explained by the federal structure of higher education with a greater number of relatively equally equipped universities and the only very recently implemented neoliberal agenda of intensified

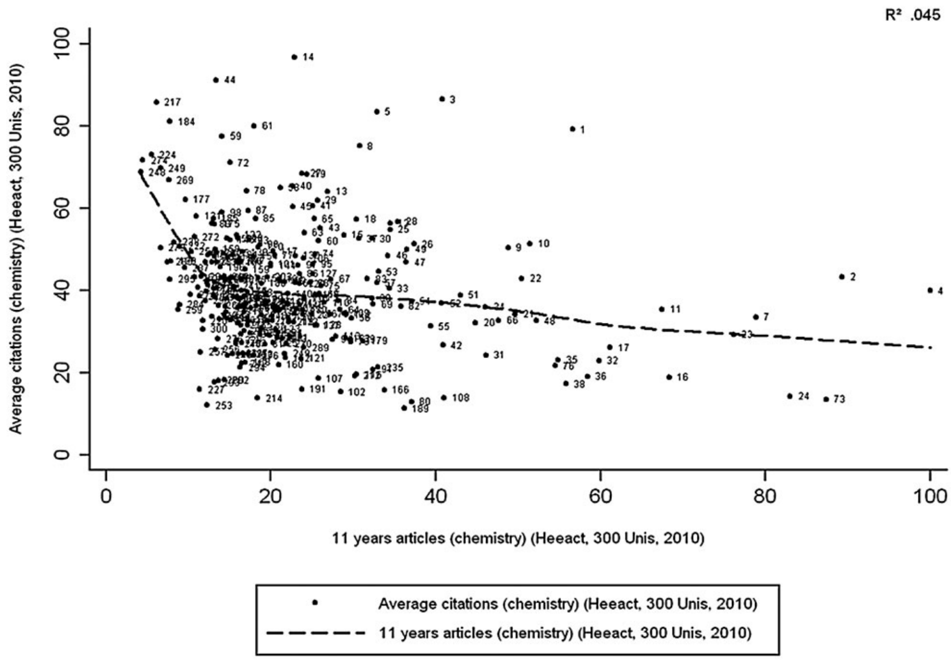

FIGURE 1. Publications and Citations (chemistry) 1
Source: Heeact 2010; Münch 2014.
Note: Own calculations.

competition between universities for money and staff initiated by the *Excellence Initiative for Advancing Science and Research at German Universities*. Both the US and the UK look back on a longer tradition of competing for money, staff and students, which apparently counteracts the equalising efforts of the US's federal structure. As we see, this difference between Germany and the US and the UK is accompanied by a smaller effect of available external funds on the employment of highly cited scientists (and the number of citations). We may explain this difference by a still less powerful link between money and prestige and a weaker circular effect of the accumulation of money and prestige as it is fuelled by rankings in Germany as compared to the UK and the US (Figures 3 to 5).

If we look at multiple OLS regressions highlighting the number of highly cited scientists at an institution as a dependent variable, we see that, in the UK, research income (total research grants & contracts) matters in the ability to attract top scientists, while research income per scientist exerts a positive effect in itself, but is negative when considered in combination with total research income, publications per scientist and publication score. Obviously, the richer institutions employ more highly cited scientists than the poorer ones; yet the staff level is growing to such a degree that research income per staff has shrunk. The explained variance in the models with absolute numbers is high, but not in model 1 with publications per scientist (Table II).

In the US, the score of total publications remains stable throughout models 3 to 7, while research income per scientist once again loses its positive effect in model 7. This shows that size in total publications comes along with the number of highly cited scientists more often than research income as such. Compared to the UK,

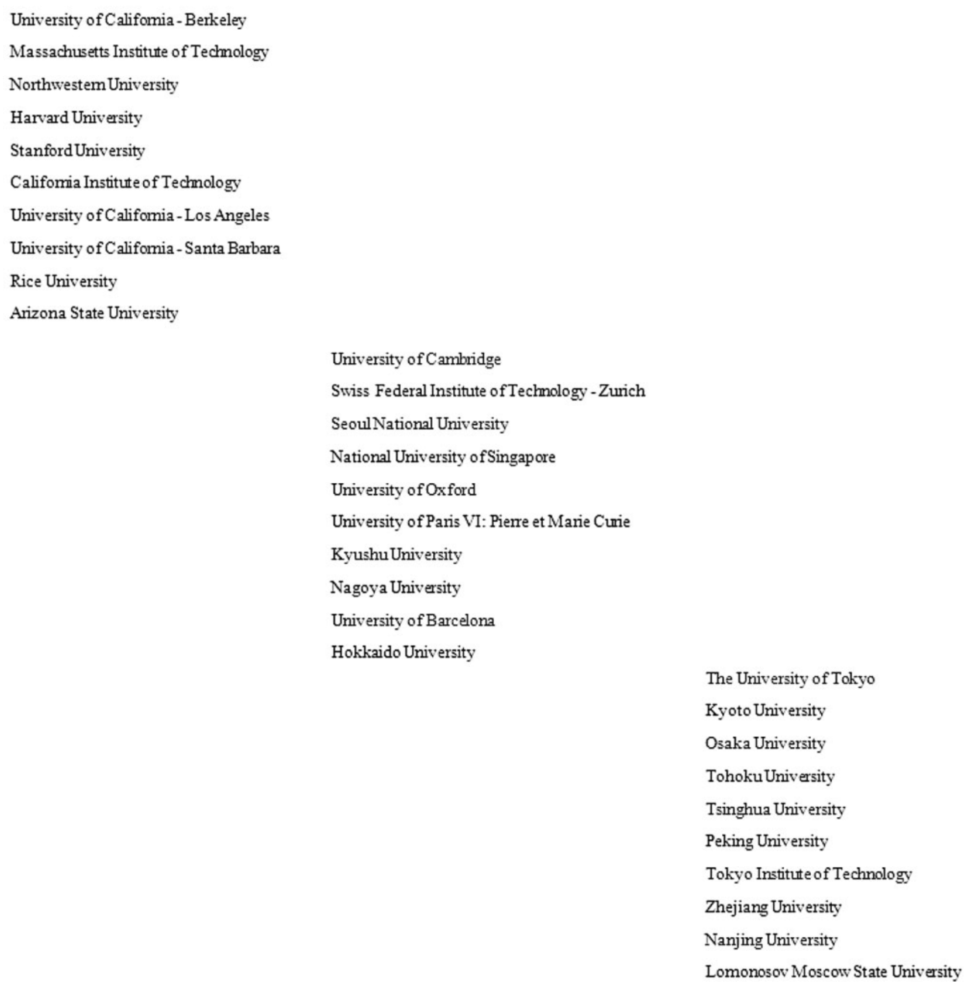

FIGURE 2. Publications and Citations (chemistry) 2

this effect may tell us that the larger number of professors in departments compared to lower ranked staff helps to employ more top scientists as part of the total staff, which is accompanied by higher publication scores. However, like the UK, although not significantly, research income per scientist becomes negative when considered in combination with the other factors. The explained variance in the models with absolute numbers is high, but not in model 1 with publications per scientist (Table III).

Strikingly, we do not establish any really significant effect for Germany. This may be explained by the greater equality in the German system. As the scatter diagram shows, there is a considerably weaker correlation between research income and the number of highly cited scientists in Germany than in the UK and the US. The plots are widely scattered, like in the US, but are very different to the UK. The more broadly scattered plots in Germany and the US indicate greater variety in the system as a source of renewal. This is corroborated by the multiple regression for Germany. Apparently, institutions with higher or lower research income, and higher or lower publication scores — totally and per scientist — are

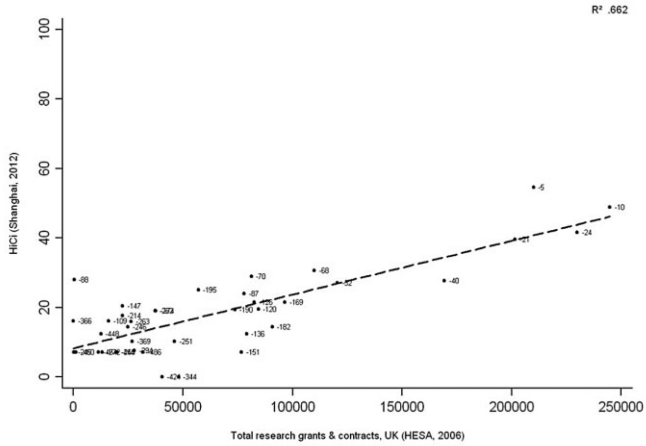

FIGURE 3. External Research Income and Highly-Cited Scientists, UK
Sources: CWCU, 2012; HESA, 2012.
Note: Funds are measured in thousands of British pounds. Own calculations.

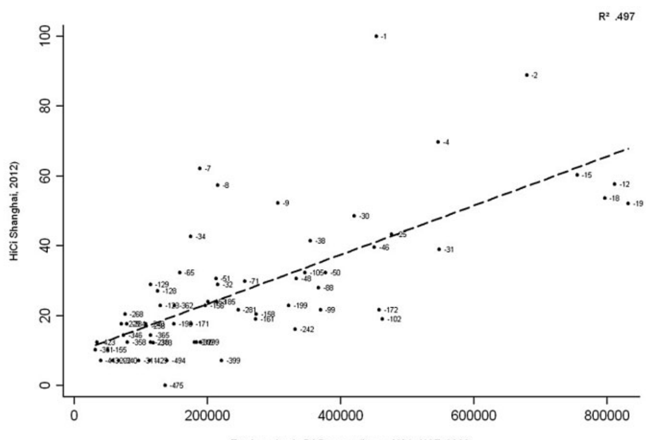

FIGURE 4. External Research Income and Highly-Cited Scientists, US
Sources: CWCU, 2012; NSF, 2011.
Note: Funds are measured in thousands of US dollars. Own calculations.

able to attract top scientists, which is a source of variety and potential of renewal in the system. There is little to no explained variance in all models (Table IV).

What does this mean in terms of scientific achievements? In the wake of the neoliberal agenda, there has been mounting criticism of German universities, because the US-American élite institutions dominate the Shanghai ranking, and Cambridge, Oxford and University College and Imperial College in London are ranked higher than the three 'best' German universities, the LMU Munich, TU Munich and the University of Heidelberg. We must take into account here that public debate defines achievement in terms of the Shanghai ranking. It is not the advancement of science as such which is at stake here, but the competition of universities for positions and their ability to attract star scientists, which are considered crucial for scientific progress in this game. Nevertheless, even in terms

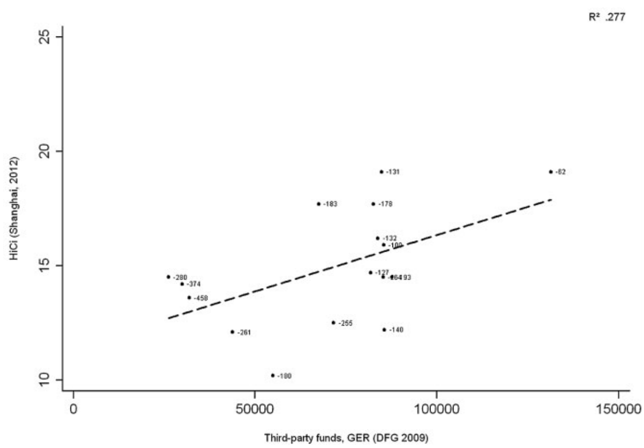

FIGURE 5. External Research Income and Highly-Cited Scientists, Germany
Sources: CWCU, 2012; DFG, 2009, pp. 144–145.
Note: Funds are measured in thousands of euros. Own calculations.

TABLE II. Highly cited scientists, UK

	0	1	2	3	4	5	6	7
Total research grants & contracts, UK (HESA, 2006)	0.00***		0.00***		0.00		0.00	0.00*
	(0.00)		(0.00)		(0.00)		(0.00)	(0.00)
Publications per scientist (Shanghai, 2012)		0.78	−1.15		−0.91		−0.91	0.98
		(1.63)	(0.88)		(0.86)		(0.86)	(1.20)
Publication score (Shanghai, 2012)				0.83***	0.61		0.61	0.46
				(0.09)	(0.36)		(0.36)	(0.35)
Total research grants & contracts per scientist, UK (HESA, 2006)						0.00***		−0.00*
						(0.00)		(0.00)
Constant	6.79***	11.75	17.56*	−13.35***	0.54	2.97	0.54	−5.92
	(1.81)	(16.01)	(8.40)	(3.52)	(12.95)	(2.85)	(12.95)	(12.59)
Observations	34	34	34	34	34	34	34	34
R^2	0.722	0.007	0.737	0.749	0.760	0.579	0.760	0.793
Adjusted R^2	0.713	−0.024	0.720	0.741	0.736	0.566	0.736	0.764

Standard errors in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Sources: CWCU 2012; HESA 2012.
Note: Own calculations.

of this game, the 'performance' of the German universities is remarkable, if we compare it to the British universities. Both countries have 40 universities ranked among the 500 institutions listed in the Shanghai ranking. However, we find 11 British (UK) and only 5 German (D) universities among the first 100, 24 British ones and only 14 German ones among the first 200, 33 British ones and only 24

TABLE III. Highly cited scientists, US

	0	1	2	3	4
Total academic R&D expenditures, US (NSF, 2006)	0.00*** (0.00)		0.00*** (0.00)		0.00 (0.00)
Publications per scientist (Shanghai, 2012)		3.62** (1.21)	2.54** (0.88)		0.13 (0.66)
Publication score (Shanghai, 2012)				1.14*** (0.07)	1.13*** (0.13)
Total academic R&D expenditures per scientist, US (NSF, 2006)					
Constant	9.43** (2.92)	−3.72 (10.76)	−11.64 (7.79)	−17.09*** (3.06)	−17.91** (5.35)
Observations	65	65	65	65	65
R^2	0.497	0.125	0.557	0.798	0.798
Adjusted R^2	0.489	0.111	0.543	0.795	0.788

Standard errors in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Sources: CWCU 2012; NSF 2011.
Note: Own calculations.

TABLE IV. Highly cited scientists, GER

	0	1	2	3	4	5	6	7
Third-party funds, GER (DFG, 2009)	0.02 (0.03)		0.01 (0.04)		−0.05 (0.05)		−0.05 (0.05)	0.60 (0.78)
Publications per scientist (Shanghai, 2012)		0.43 (0.56)	0.30 (0.75)		−1.02 (0.95)		−1.02 (0.95)	4.66 (6.92)
Publication score (Shanghai, 2012)				0.21 (0.13)	0.58+ (0.29)		0.58+ (0.29)	−0.83 (1.72)
Third-party funds per scientist, GER (DFG, 2009)						0.03 (0.14)		−2.61 (3.15)
Constant	13.22*** (2.47)	11.15* (4.90)	11.42* (5.14)	7.45 (4.51)	6.99 (5.20)	14.23*** (2.58)	6.99 (5.20)	6.74 (5.26)
Observations	19	19	19	19	19	19	19	19
R^2	0.028	0.034	0.038	0.140	0.243	0.004	0.243	0.278
Adjusted R^2	−0.029	−0.023	−0.082	0.090	0.091	−0.055	0.091	0.072

Standard errors in parentheses.
+ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
Sources: CWCU 2012; DFG 2009.
Note: Own calculations.

German ones among the first 302, but 36 universities on both sides among the first 402 and 40 among the 501 listed universities. Both countries perform far better than France (F) with a highly centralised system (Table V) (CWCU, 2012; Münch, 2011, p. 56).

We can say that German universities perform as well as British universities in their majority and lag only somewhat behind in the top positions. This can be explained as simply representing the greater inequality in the British system and

TABLE V. Shanghai Ranking 2010

Rank	Country		
	USA	UK	D
1–100	55	11	5
–200	90	23	14
–302	112	33	24
–402	138	36	36
–501	152	40	40

Sources: Münch 2011; CWCU 2012.
Note: Own calculations.

does not mean better performance of the whole university system. German universities would fare even better if we took the heavy bias of the Shanghai ranking in favour of the English language into account. Furthermore, the German universities are handicapped by the much larger amount of research carried out at the non-university institutes of the Max Planck Society, the Leibniz Society, the Helmholtz Society and the Fraunhofer Society, which account for no less than about 40% of Germany's public research budget. Both handicaps compensate for the higher population figure and larger number of scientists in Germany when compared to the UK. If we look at the output of articles published in scientific journals registered in the largely English-biased Web of Science of Thomson Reuters' Institute for Scientific Information in Philadelphia, we see a remarkable stagnation of British output in the years between 1999 and 2009, while Germany raised its output (National Science Board, 2012, table 5–17).

Two rankings, one focusing on the visibility of academic institutions in the Web of Science, and the other on citations measured against the expected average level of citations show Germany and the UK close to each other (Mazloumian *et al.*, 2013).

A look at the awarding of Nobel prizes supplies further information. Without doubt, being in the centre of citation networks is a prerequisite for being a candidate for the Nobel prize. Hence, one must become a well-established, widely acknowledged scientist whose discovery has made it from novelty to established knowledge. And it is, of course, easier to attain this status with early access to the crucial networks. Therefore, there is also a Matthew effect of rewarding established networks of scientists and their home institutions in the allocation of Nobel prizes. Yet one has to have done ground-breaking research to be awarded that prize. We may therefore take the allocation of Nobel prizes as an indicator of a scientific system's ability for diversity and renewal of scientific knowledge, though there are also some conservative effects in the preconditions for being awarded that prize.

If we compare Germany and the UK in this respect, we identify Germany's best performance in the first half of the 20th century, when the country did better than the US and much better than the UK. The turnaround occurred with the emigration of leading German scientists from Nazi Germany and World War II. Between 1949 and 1978, Germany was outranked by the UK and particularly the US. Between 1979 and 2008, Germany regained competitiveness with 15 Nobel prizes as compared to 13 Nobel prizes for the UK. Typically, these prizes are distributed more widely among institutions in Germany than in the UK, namely 42 as against only 25. Also typically, the percentage of non-university institutes having received

Nobel prizes is higher in Germany than in the UK, namely 39% as against 28%. However, both countries were outranked by the US in the most recent period. This also holds true after accounting for the much larger population and number of scientists in the US. If we divide the 170 US-American Nobel prizes of the period between 1979 and 2008 by 4 — due to the country's larger population compared to Germany — and additionally by 2 for English language bias and hegemonic position, i.e. by a total of 6, we arrive at 28 Nobel prizes. This figure is still nearly double that of the 15 German and more than double that of the 13 British Nobel prizes (Nobelprize, 2009; Münch, 2011, p. 58).

What does this mean for our hypotheses? First, we see German universities and the whole system of science in at least the same, to some extent even a better position than the British system, though there is much greater inequality in the British system. The originally more stratified British system was opened in the 1980s with Margaret Thatcher's reforms and allowed a number of new universities to challenge the established élite institutions. However, in the meantime, the allocation of resources in the Research Assessment Exercise (RAE) has led to a new consolidated stratification of the system. In comparison to the less stratified German system, British science has not benefited from having operated competitive resource allocation and a resulting ranking of universities for more than 25 years. Nevertheless, British scientists are remarkably more successful than German scientists in the competition for grants from the European Research Council (ERC). The first tentative explanations could be (i) the better adjustment of British scientists to the standards of successful grant application because of their experience with the RAE; and (ii) their easier access to English and American journals and publishers which have higher impact and international visibility and are regarded as representing excellence in science.

But what about the outstanding performance of the US, even after accounting for population size, language bias and hegemonic position? The country boasts a highly stratified system with globally leading élite universities at the top. Is this not proof of the effectiveness of competitive resource allocation, rankings and the strong consolidated stratification of the system resulting from this strategy? It is not, especially if we take a look at the same strategy in Britain in comparison with the less stratified German system. There must be other factors which explain the better performance of the US-American system, even in terms of capacity for renewal as measured by the number of Nobel prizes awarded.

Looking for explanations, the institutional advantages identified by Ben-David (1971) come to mind: a much less hierarchical system within the university with 85% of staff in the position of professor, only 1% assistants with permanent contracts, and 14% assistants with limited contracts. This must be compared to only 15% professors, 17% assistants with unlimited contracts and 68% assistants with limited contracts in Germany, and 18% professors, 25% senior lecturers and researchers, 22% lecturers, 7% assistants with unlimited contracts and 28% assistants with limited contracts in the UK (Konsortium Bundesbericht wissenschaftlicher Nachwuchs, 2013). Another important feature is the integration of research and teaching in graduate programmes compared to the far-reaching separation of research and teaching in the German system, particularly with the large amount of research carried out at non-university institutes and in large-scale coordinated research in universities, and the less established graduate programmes in Britain. Furthermore, the Shanghai ranking tells us that there are no less than

55 universities competing with each other among the first 100, 90 among the first 200, 112 among the first 302, 138 among the first 402, and 152 among the total 501 in the US. Hence, there is more space for diversity and renewal in the system than in Germany and the UK, despite its stratification and consolidation by rankings. The crucial preconditions for providing more space for diversity and renewal are a faster turnover of generations due to the much greater number of professors in departments, the earlier independence of a much larger number of young scientists after graduation with a PhD, their much greater independence from individual professors even during their PhD studies, the integration of research and teaching in graduate programmes as a crucial site of intellectual curiosity and renewal of scientific knowledge and the much greater number of universities engaged in research and teaching on equal terms. The US represents a case for our counterhypothesis saying that a stratified system with a concentration of resources in the centre may maintain sufficient diversity and power of renewal if it is large enough. However, size must be complemented by the identified renewal-friendly preconditions.

Conclusion

This comparison of Germany, the UK and the US teaches us that more than 25 years of competitive resource allocation and its translation into a clear-cut ranking of universities leading to a highly stratified system did not advance British science compared to Germany with its still much less stratified system, the competitive allocation of resources and rankings still in their infancy. Against this background, there are good reasons for not explaining the outstanding performance of the US by the comprehensive competitive resource allocation, rankings and consolidated stratification but by crucial factors working against the closing effect of these strategies. Germany is representative of the case of a less stratified system's specific potential for renewal; the UK of the case of stratification's hindering effect on renewal; and the US of the specific potential for renewal of a stratified system that is nevertheless large and diverse enough at its centre.

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