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Maintaining research excellence and volume

A report by Evidence Ltd to the Higher Education Funding Councils for England, Scotland and Wales and to Universities UK

Evidence Ltd

Higher Education Funding Council for England

Higher Education Funding Council for Wales

Scottish Higher Education Funding Council

Universities UK

Executive summary

This report describes aspects of the public funding of research within UK universities. It outlines the background and main findings of a study by Evidence Ltd, which may be viewed on their web-site at www.evidenceuk.com/. The context is a desire to ensure that the higher education (HE) sector is able to maintain, or increase, its capacity for carrying out research at the highest levels.

The report concludes that UK research performance is highly competitive and has measurably improved against world baselines over the last 15 years. The UK's peak performance provides tangible value for money in terms of both quality and quantity although, for research of international excellence, the relationship between investment and returns should not be expected to be linear. The UK's gain in performance can be linked to the research assessment process, but this process will need to change if the UK is to continue to build on its achievements. The individual and institutional investment that the Research Assessment Exercise (RAE) has entrained is not sustainable unless quality-related core funding can be maintained at appropriate levels for leading-edge research. Recurrent investment in research excellence has drawn heavily on institutional reserves, and personal staff commitment has led to increased workloads above reasonable long-term levels. Infrastructure investment has helped to support excellence, but has not been sufficiently strategic to sustain the longer-term.

1 Background

Evidence Ltd was commissioned to collect and analyse a diverse range of quantitative and qualitative data on changes in the level of research performance in UK universities. These data have been used in a number of ways:

- The first focus was those research units that improved their RAE grades in 1992 or 1996. An increase in grade will have meant these units received more 'QR' (quality-related research) money from the relevant Funding Council. The study aimed to find out whether units that gained a grade subsequently performed better than those that remained at the lower grade, and how units moving up a grade compared to those already at the higher grade.

- The second focus was an analysis of research strength in 'peak' performers – research units scoring 5 or 5* in the 1996 RAE. The study looked at the comparative international strength of this research, and examined the way research strength, measured in a variety of ways, has changed over time. With the Centre for Economic Performance at the London School of Economics (LSE) the study also looked at value for money.

- The third focus was an investigation of the institutional financial and other costs of maintaining research excellence in the face of increasing international research competitiveness. This was explored through case study visits to, and detailed interviews with, senior staff in universities. One aspect that was studied in detail was the cost of buying and maintaining leading-edge research equipment, and whether UK research groups had sufficient access to facilities of this type.

2 Summary conclusions

Evidence confirms that the international comparative performance of the UK's higher education research base is extremely competitive and that it has measurably and progressively improved over the last 15 years. The cutting-edge of international research moves ahead continuously, however, and this performance may be unsustainable if necessary levels of investment and reinvestment cannot be met.

The data show that high-level performance in the UK is concentrated in the university units graded 5 and 5* in successive Research Assessment Exercises. This is where the majority of research active staff are found, where most research students are trained and where the bulk of other research outputs are generated. The average impact of those publications is significantly higher than the rest of the system.

Economic analyses carried out with the Centre for Economic Performance, LSE, suggest that the UK research peak provides tangible value for money in terms of quantity as well as excellence, although this level of excellence can only be bought at the price of sustained investment. First, there is a measurable improvement in value for money across grades despite the greater funding concentration associated with excellence. Second, the improvement in research performance is progressive as units gain additional QR through the successive steps of grade promotion. Third, universities gear QR against other income streams. An analysis of the strength of association suggests that performance depends not solely on QR but is also correlated with Research Council income. Industrial investment, too, is focused on top graded units. The critical role assigned to QR by all levels of university staff is

that it provides flexibility for restructuring so they can move out of maturing areas and into new research frontiers.

Research assessment has had an effect on research performance. There has been a measurable gain in performance when units moved up a grade at successive RAEs, from 3 to 4 and from 4 to 5. The opportunities provided by stepped resources in the RAE system created a powerful feedback to performance. Newly promoted units perform marginally less well on average than those units with a history at the higher grade, however, so sustained funding builds on the gains that come from short-term improvements.

University staff speak of a change in research culture since 1986 (the first RAE). This change has introduced institutional structures and procedures to guide research, and has led to widespread individual acceptance and ownership of research management. Much of the improvement is attributable to better research management systems at university, departmental and research group levels. The system overall is able to operate more effectively because research is supported more efficiently. It is the individual cultural change, however, rather than management that has had the greatest impact on outcomes.

There is an individual and institutional cost to the effectiveness and achievements of the UK research base. Individual cost comes from a 'squeezing of the assets' that are the academic and research staff. The system depends on their contributions, motivated by research opportunity rather than by personal gain. But the opportunities to pursue research challenges have led to university staff taking on greater workloads and working longer hours than previously. The case studies suggest that sustaining the UK's pattern of improvement in the face of growing international competition is now threatened because these people may become demotivated unless research funds are sufficient to make it worthwhile striving for the highest grades.

The costs to institutions of seeking to do well in the competitive environment induced by the RAE have been high. Some have undoubtedly dug into their capital base and invested more than they can readily afford if future public recurrent financial investment is not as high as they might have expected in the past. Examples of the use of leading-edge research equipment (studied by Policy Research In Engineering, Science & Technology and the Centre for Applied Social Research (PREST/CASR) in a supplementary study) illustrate the extent to which UK research is balanced on a thinly stretched line of resources. UK researchers have access to advanced equipment that should allow them to compete with international peers, but such facilities are often procured later and in smaller numbers than among their rivals. Furthermore, because procurement is not always supported by enough funds to provide support equipment and skilled technical staff, the benefits may not be fully realised. The shortage of support is widely reported in visits to universities. For equipment and more generally, a change in the strategic approach to research infrastructure and investment may be indicated as part of planning for a high-technology, knowledge-based, research economy.

Changing the present levels and balance of funding for grade 4 and 5/5* units (indicated by the funding announcements following the outcome of RAE2001) could be problematic. Although grade 4 research is less excellent than the peak, it has significantly more impact than research at UK and world average level. Grade 4 units are a 'platform' level of quality research that can develop into world class 5 and 5* research. Attrition of this platform through lower core funding and flexibility would have significant medium term effects. The announcement that there will be a review of the research assessment system in 2002 is therefore appropriate and timely, as it is possible that the present structure has essentially fulfilled its purpose. A revision to the assessment process will be required to extend and maintain the present pattern of excellence.

Direct comparisons with the US are difficult. While UK university research is competitive with and overlaps that of leading US institutions, it is also clear that the scale differences between the UK and US systems confer a virtually irreducible advantage on the US. Leading US institutions are unquestionably in a separate league from all except perhaps the top UK universities. The biggest challenge is the scale factor. Even the best UK institutions are smaller than the top in the US: they have smaller research groups, fewer research staff and students and far less disposable income. A like-for-like comparison would be likely to confirm, however, not only that the UK university research system provides excellent returns on investment but also that the UK is as effective for its size as any competitor.

3 Key findings from quantitative analyses

The study used a range of indicators to measure research quality. These included:

- RAE scores in 1989, 1992 and 1996.
- Bibliometric measures, including numbers of papers published in high quality journals, total numbers of citations, average number of citations per paper, numbers of highly cited papers.
- Research training capacity, measured in terms of numbers of post doctoral research associates and postgraduate research students.
- Research income, from public funds, from charitable sources and from industry.

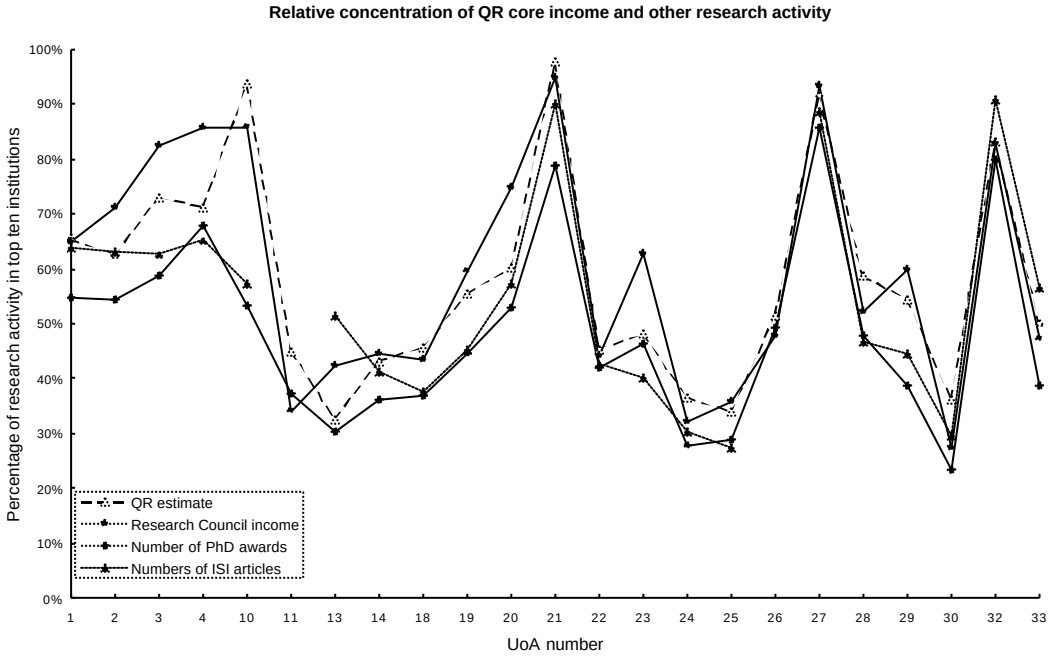
From these data the following conclusions can be drawn:

- The indicators looked at all moved in the same direction and painted the same general picture of change. There is a broad correlation between 'inputs' data on income and expenditure, 'outputs' data on publications and citations, and other indicators of research quality. For example, research units carrying out the highest quality 'blue skies' research are also getting more funding from industry for applied research projects.
- There is a correlation between input funding and the activity and output variables, but funding is more concentrated than staff and output (**Table 1**). The 20% of units submitted to RAE96 that received the highest grades contain about one-third of the research active staff and produce about half of the total research activity at a level about 40% above the rest of the system. After RAE2001 the most highly graded units contained over half of research active staff. The greater concentration of funding is a reflection of the cost of excellence: it becomes progressively more expensive to make successive additional improvements to research quality that already exceeds national and international averages.
- There is now a strong concentration of research activity in most Units of Assessment (UoAs), and this pattern was confirmed by the outcome of RAE2001. The majority of highly qualified research staff are also being trained in an appropriate research environment to enable them to make an effective contribution elsewhere in the economy. Typically, about 50% of research activity is carried out in the ten institutions ranked highest by research impact (**Figure 1**). The units that perform at these international standards of excellence are also those that produce a significant majority of outputs from the HE research base.

Table 1: Summary of the differences between peak and platform

Variable	Percentage (average across units) by which peak exceeds platform	Percentage (average across units) of share of activity in peak	Range of share of total activity in peak
Units submitted to RAE		20%	
Cat A select staff	65%	33.7%	25-50%
Research Council grant income	140%	57.4%	50-70%
Post-Doctoral Research assistants	155%	47.4%	30-60%
Post-Graduate Research students	140%	46%	30-60%
Output in ISI journals	150%	44.2%	
Impact of publications	42%		
Uncited publications	-13.6%		

Figure 1: Relative concentration across Units of Assessment of QR income and other research activity



- The study considered in detail the relative performance of units graded 5 and 5* at RAE96, which it defined as the 'peak' part of the research system. Peak performance is about 1.5 times the world average in many UoAs, as measured by the impact of research publications (average citations per journal paper). In some, it exceeds twice the world average (**Figure 2**).

- Performance shifts between grades are non-linear: that is, there is no simple index that quantifies the amount by which research at a higher grade is 'better' than research at a lower grade. The

study found that bibliometric impact, as a performance measure, is best related to grade-related core income geometrically and not arithmetically (**Table 2**). It is consequently not possible to make a simple calculation of the right ratio of funding between grades that are differentiated in terms of the balance of national and international excellence.

Figure 2: Impact (rebased against world average) of peak and platform in each Unit of Assessment, ranked by order of impact not by conventional UoA sequence

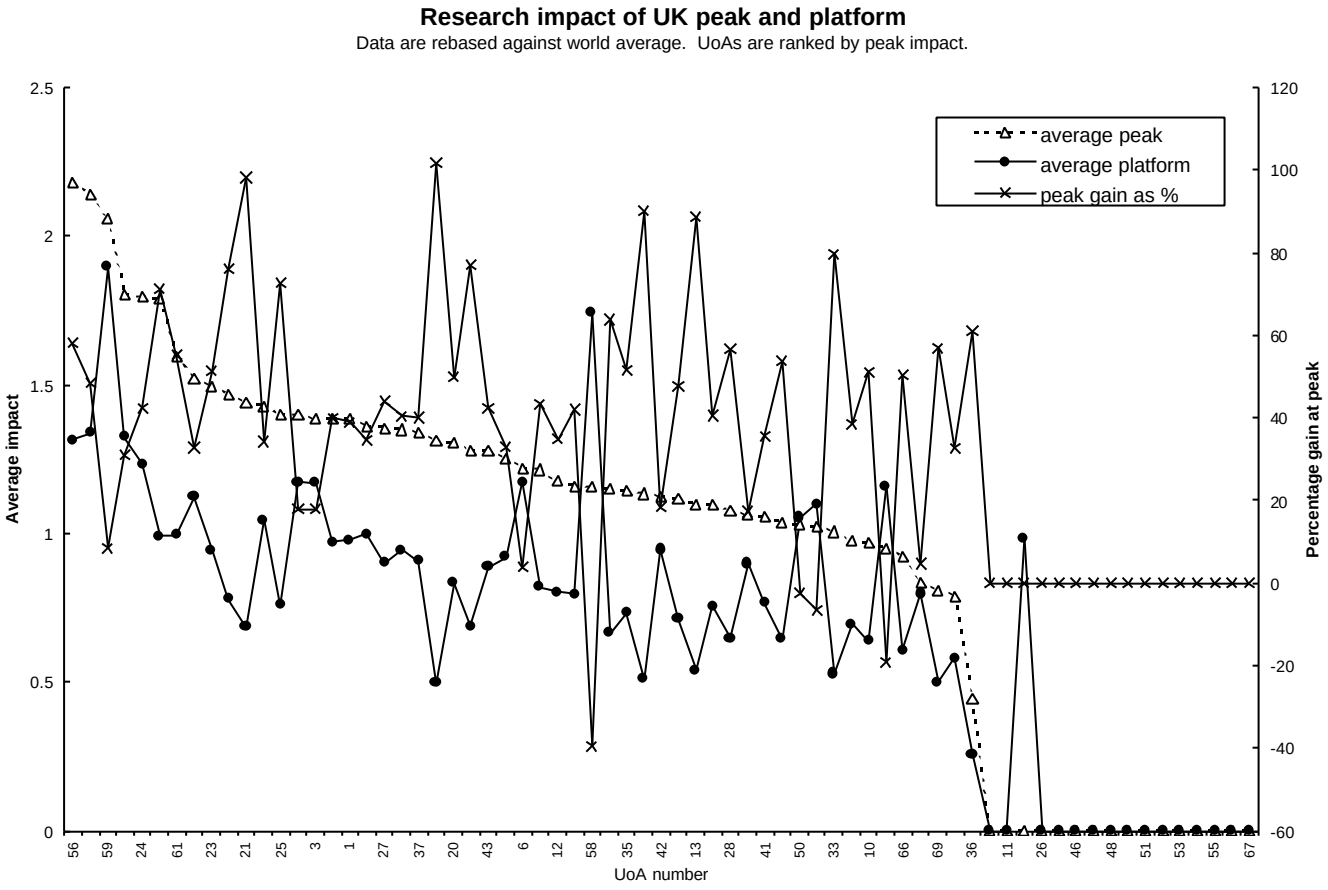


Table 2: Citations per paper in Units of Assessment grouped by broad faculty (Index with world average for each field is set at 1)

RAE grade	3b	3a	4	5	5*
Clinical	0.91	0.93	0.94	1.33	1.41
Pre-clinical		1.14	1.84	1.37	1.38
Biological sciences	0.61	0.90	0.92	1.24	1.44
Environmental sciences	0.71	0.82	1.08	1.14	1.39
Mathematics	1.09	1.04	1.17	1.42	1.95
Physical sciences	0.74	1.03	1.18	1.39	1.35
Engineering	0.60	0.95	0.97	1.16	1.40
Unweighted average	0.78	0.97	1.16	1.29	1.47

- Despite the non-linear relationship between funding input and research quality output, a preliminary 'value for money' analysis carried out collaboratively with the Centre for Economic Performance, LSE, demonstrated that the 5-graded units are providing returns that are arguably better than lower graded units (**Table 3**). There is an apparent improvement in value for money across grades despite the greater funding concentration associated with excellence.

- The study confirmed that when units are promoted between RAE grades there is a clear gain in research performance. They also gain additional QR through grade promotion, so the increase in QR income is measurably supporting an effective research platform, and the recipients of additional QR then gear this against increases in other income streams. To determine the relationship between research performance (measured by citations per paper) and income the study used descriptive statistical models to which data from select UoAs were then fitted. There is closer correlation between performance and – in particular – Research Council income than QR. These are also correlated, but these relativities suggest that performance is not wholly QR dependent (**Table 4**).

- Across a wide range of UoAs, and applying this analysis at different levels of aggregation as the data allowed, a consistent pattern was found for units that gained a grade at RAE96 to be clearly differentiated from those units in the same UoA that did not improve on their performance at RAE92. This conclusion applied to the average results at UoA level and where UoAs were aggregated into cognate super-UoAs (**Table 5**).

- Rising units at RAE96 could also be compared to those already at the higher grade since RAE92. The study found that the newly promoted units tend to acquire marginally less additional research income on average than those units with a history at the higher grade, reflecting the benefits of a longer period of research investment. There are important qualifications to this conclusion, however, and performance as measured by citation impact was actually higher for newcomers – perhaps reflecting the 'currency' of their research performance (**Table 5**).

- The QR gain is seen most clearly in the differential between 3 and 4 rated units, but occurs at all grade boundaries and across most UoAs (some qualifications relate to some social sciences and arts) (**Table 6**). The improvement in those units moving up to grade 4 suggests that the returns on investment at this grade are a significant element in the overall returns from the research base. While not the peak of excellence, as defined here, this grade contains significant volumes of research of international standard.

- Industrial funding of research increases most steeply between 4 and 5 rated units (**Table 6**), and industrial income is greater for those units with an established reputation at any grade than those that had recently risen to that grade (**Table 5**). This may indicate a different cultural approach by industry in its perceptions of excellence, and a complementary approach to making investment decisions.

- International comparative performance was sustained during 1986-2000 despite increasing international research competition from both Europe and South East Asia. Across the HE research base there is a statistically significant improvement in research performance in the 'peak' in most research areas. The UK's comparative international performance across the system provides strong evidence that grade shifts at successive RAEs represent real increases in effectiveness and efficiency, and is not due to grade 'drift' (**Figure 3**).

Table 3: Quality related output per £ of QR investment (indexed with 5* = 100)

RAE grade	3b	3a	4	5	5*
Clinical	23	22	10	60	100
Pre-clinical		8	19	54	100
Biological sciences	38	79	23	65	100
Environmental sciences	19	40	62	50	100
Mathematics	28	41	45	64	100
Physical sciences	60	67	77	72	100
Unweighted average	34	43	39	61	100

Table 4: Summary results of Akaike Information Criteria tests for association between research performance and research grant and contract income

UoA	Subject	Strong associations	Tentative associations
01	Clinical lab sciences	QR & private sector UK & charity & Research Council	
14	Biological sciences	Research Council	
18	Chemistry	Research Council & other public sector	Overseas
19	Physics	Total income (primarily Research Council)	Private UK
29	Electrical eng	Research Council	Overseas & private UK & QR

Table 5: Analysis of average comparative differences in research performance according to type of grade shifts at RAE96

	Grade	Static vs. risers			Newcomers vs. established		
		Non-null cells	Performance drops on grade gain	Performance improves by rising	Non-null cells	Newcomers perform better	Established perform better
Total R income	3 v 4	49	7	42			
	4 v 5	48	16	32	49	24	25
	5 v 5*	46	10	36	46	24	22
Industry income	3 v 4	37	11	26			
	4 v 5	32	10	22	37	15	22
	5 v 5*	35	11	24	32	15	17
Impact	3 v 4	38	11	27			
	4 v 5	37	17	20	37	22	15
	5 v 5*	37	13	24	38	25	13

Comparisons made are between (1) Static vs. risers = units that stayed at their RAE92 grade at RAE96 and those that increased by one grade and (2) Newcomers vs. established = units that gained a grade at RAE96 and those already at the higher grade.

Because not all possible comparisons were valid, some cells in the analysis were blank (null) and a count of non-null cells is therefore provided for each comparison.

Table 6: Grade shift analysis – average percentage gain in performance for select UoAs with a minimum of 3 units static at grade and 3 units gaining grade, for all UoAs and for grouped 'super'-UoAs

Grade shift	Indicator	Average using only selected UoAs	Average using all UoAs	Average across Super UoAs
RA4	Research Income			
3 vs. 4		120.70	121.00	148.32
4 vs. 5		274.51	123.95	12.11
5 vs. 5+		50.91	49.92	32.31
RA4	Research Income – Research Council			
3 vs. 4		181.26	113.93	178.45
4 vs. 5		481.68	205.01	92.98
5 vs. 5+		115.91	97.21	60.88
RA4	Research Income - EU Overseas			
3 vs. 4		152.87	66.73	81.70
4 vs. 5		365.17	62.23	34.35
5 vs. 5+		64.43	25.77	64.37
RA4	Research Income - Industry			
3 vs. 4		55.70	84.70	101.55
4 vs. 5		1039.66	356.48	150.84
5 vs. 5+		63.40	325.21	123.78
RA4	Research Income - JIF			
3 vs. 4		93.18	247.64	70.48
4 vs. 5		63.62	70.11	16.68
5 vs. 5+		69.35	42.37	58.35
RA3	Research Students			
3 vs. 4		82.01	86.40	88.42
4 vs. 5		113.12	22.44	38.02
5 vs. 5+		7.93	47.35	9.04
ISI	Research Output			
3 to 4			20.46	17.18
4 to 5			10.85	14.47
5 to 5+			14.85	23.11
ISI	Research Impact			
3 to 4			16.85	12.20
4 to 5			1.75	3.55
5 to 5+			-1.26	16.12

Figure 3: Comparative international performance of UK research – bibliometric impact

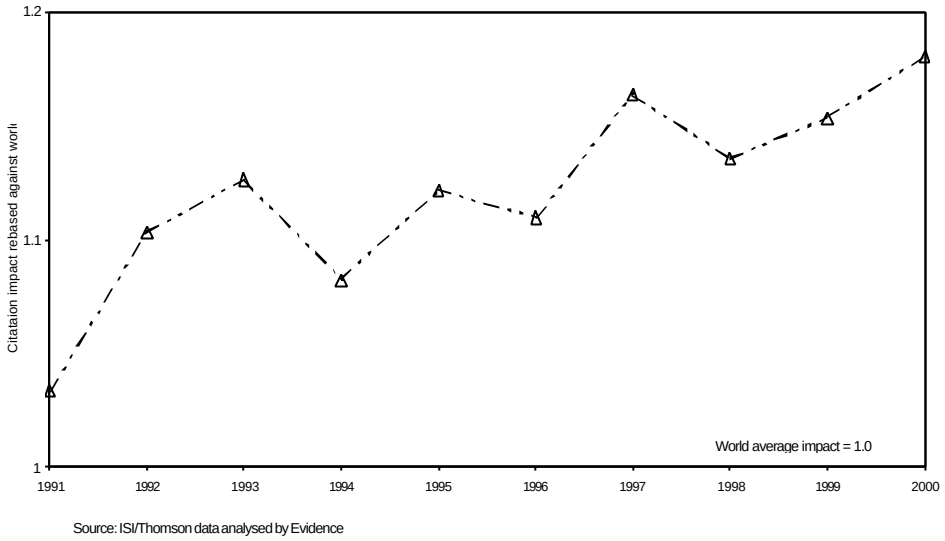
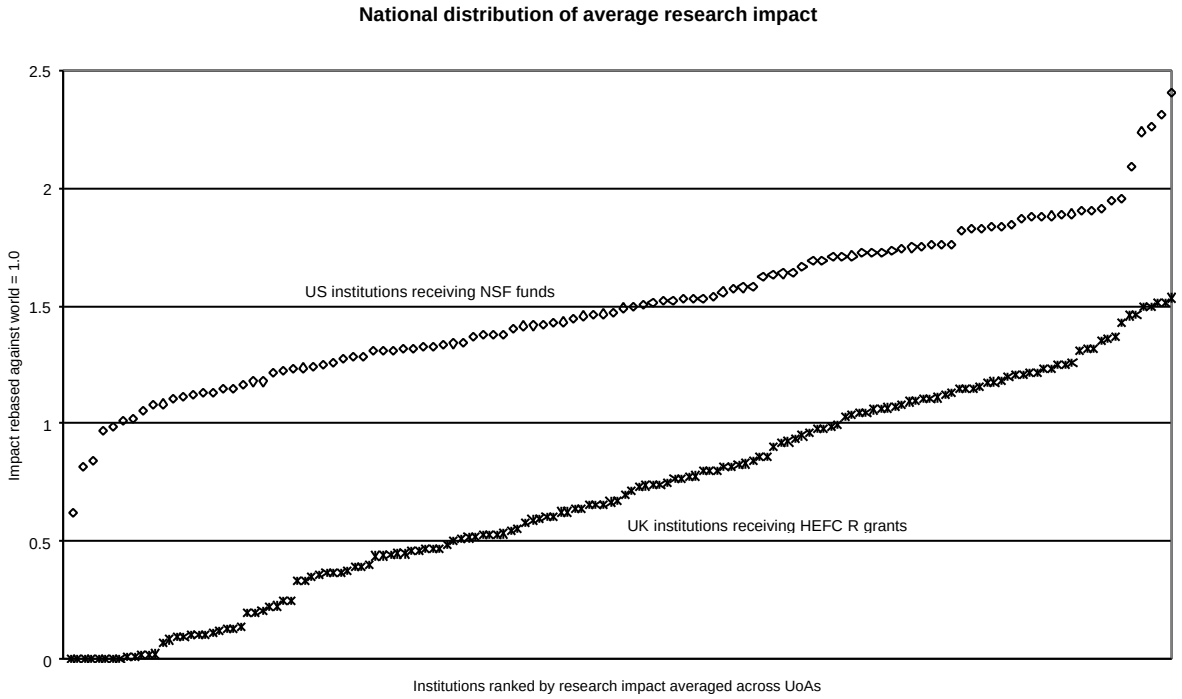


Figure 4: UK and US national distribution of research impact – common axes



- In terms of research impact, the peak of the UK system lags significantly behind that of the US. A well-grounded comparable analysis is difficult to perform, however, because leading institutions in the US are much larger in terms of funding and research staff complement (**Figure 4**). On a size-for-size comparison it is likely that the UK is entirely competitive. At a more detailed level

significant differences were found in relative performance between discipline areas. In environmental and physical sciences, the UK peak gradually forges ahead of the US average and there is significant improvement in the UK environmental science average until this too is ahead of the US. In the clinical and biological sciences the UK peak is well ahead of the US average, and performance tends to improve over the period at both peak and average. In mathematics, UK performance improves early in the period at peak and average but then declines sharply. In engineering, the UK peak is well above world average but consistently below US average.

4 Key findings from case study visits to UK universities

The study drew not only on case study interviews but also on the consultants' experience with earlier site visits to UK universities as part of other studies of research policy. Their conclusions are that the costs to institutions of seeking to achieve and maintain excellence in the competitive environment induced by the RAE have been high. Some have dug into their capital base and invested more than they can afford if future recurrent financial returns are not as high as they might have expected in the past. The extent to which UK research is balanced on a thinly stretched line of resources is illustrated by examples of the use of leading-edge research equipment (studied by PREST/CASR in a supplementary study described in Section 5).

A key trend encountered has been a progressive series of developments in research management in universities through the late 1980s to the present. These shifts appear to have been driven by the RAE cycle and might be summarised as:

- Recognition of a newly established national policy agenda focused on research selectivity and using research assessment.
- Responsive changes in central policy statements.
- Changes to management structures and procedures, including research planning and resource allocation mechanisms at an institutional level.
- Changes in research management at devolved faculty and departmental level.
- Acceptance and ownership of research management by individuals.

The most significant influence on research performance is change in the research culture and the indirect effect this has on every individual. The changing culture has affected research excellence within institutions because of the acceptance of a more focused and strategic approach to research management. Debate and concern about the RAE in the early 1990s has been overtaken by more widespread agreement that the 'RAE is part of the process of a properly managed university'. This may have been qualified by a recognition that the RAE in its present form has largely achieved its objectives and may be ready for review.

Three specific and identifiable mechanisms have operated – at the level of the institution, the department (or resource centre) and the individual.

- Restructuring (in terms of departmental closure or amalgamation, or of faculty re-organisation) has been directed towards a positive reshaping that builds in continuity and flexibility, particularly through interdisciplinarity. Most institutions preferred to subsume areas of research weakness into stronger units rather than use direct closure.

- Resourcing systems have been deployed to encourage appropriate management behaviour. Allied to this are a variety of mechanisms for more targeted or directed strategic funding.

- Change to staff complement and management has been one of the common mechanisms for addressing research performance. Most institutions now operate individual performance and appraisal systems.

The study asked about examples of investment being directed to strengthen top areas or to build up the weakest. The general pattern encountered across institutions was that:

- Top rated departments were seen as sufficiently well resourced and managed to be able to determine their own future, but any slippage in levels of support would threaten this stability.

- The balance of management attention and investment was directed towards the intermediate areas of underperformance that needed to change (e.g. grade 3s with the potential to become 4s).

- The weakest areas tended to be seen as having failed and were therefore restructured into new formations, or absorbed into more effective units, or closed.

The evidence about the assessable internal costs of shifting grade is less clear, but only because most institutions and constituent departments direct essentially all available resources towards achieving the best possible performance. There can be no building of or recycling into reserves, but only a continuing draw-down of available resources in a desire not to slip behind the leading edge. The greatest cost to universities that have worked to improve their research performance has been the squeeze on staff resources in striving to achieve more with the same asset base, but the long term impact on capital is significant and borrowing has markedly increased.

QR is widely considered to be critically important in maintaining research excellence, with a strong emphasis on its role in providing management flexibility and as a key incentive.

- Funds created by top-slicing QR have been used for many different purposes, but the most frequently cited were
  - people
  - flexibility for research management within institutions
  - flexibility for research rewards within departments.

- It allows flexible shifts into new research areas, and university management is now more conscious of the need to be proactive in this.

- QR also supports the growth of interdisciplinary research, which seems likely to be the main vehicle for future research organisation because it is more innately flexible.

- QR enables universities to operate in the long view by supporting diversity in approach. Contention and maverick ideas within a diverse system mean that the national research effort thereby avoids commitment to blind alleys.

There is some evidence in specific disciplines about the challenge of recruitment and retention of academic staff, but the pattern is not uniform. Staff-associated costs generally are important, and salary factors in some disciplines are critical. This is especially true at the top end where recruits are drawn from all over the world, and also in what successful candidates expect in terms of facilities and resources.

5 Leading Edge Equipment

The progress of science in general, and the competitive position of a nation's science base in particular, depend upon access to equipment which is sufficiently technically advanced to enable scientists to carry out experiments at the leading edge of research. Such equipment must be maintained in good working order, and provided in an institutional setting that allows full use. A further question is whether there is sufficient access to those kinds of equipment critical to research innovation to allow the maintenance of UK research excellence.

PREST/CASR took a primarily qualitative (rather than quantitative) approach with the aim of focusing on the most research-intensive areas of science, and on the most research-intensive institutions. The work was based on three types of highly expensive research equipment, and international comparison was restricted to the US.

- High field Nuclear Magnetic Resonance spectrometry (in the chemical and biosciences).
- Electron beam lithography (in physical sciences research).
- High Resolution Electron Microscopy (in physical sciences research).

In each case, several UK groups in research-intensive universities were interviewed in connection with their use of such equipment, and one or two US groups were interviewed to enable comparison with the world's leading research-intensive economy.

PREST concluded that UK researchers have access to *sufficiently advanced*, top-of-the-range equipment in their field to compete with their international peers, but this is often procured at a later date than their rivals. It is less clear that they have access to *sufficient numbers* of top-of-the-range items to be able to compete at a consistent international level. Demand for access to powerful research instruments is always likely to outstrip supply, however, and potential creates its own demand.

The PREST team identified a number of significant issues:

- Major procurements should be associated with sufficient funds to provide a high quality operating environment, including: ancillary and support equipment; highly skilled technical staff; and service contracts.
- At an early planning stage there should be assessment of the capacity to allow, enable and absorb desirable subsequent upgrades to maintain the leading edge.
- Older university buildings rarely provide an ideal environment for modern research facilities.
- Charging regimes are only sometimes conducive to an efficient use of equipment, and may prove a barrier to effective usage. Making high cost facilities available to diverse users to generate income produces unsatisfactory compromises.

The traditional UK pattern of building equipment facilities on the back of successive research grants is not the best way to promote a strong research sector. A better strategy would be to plan for more consistent funding for leading edge research groups so as to nurture quality. This applies as much to the funding of technical staff as to the other resources. A high-technology research environment may require a strategic approach towards funding not just equipment but equipment-intensive research. Encouraging universities similarly to plan strategically could bring many benefits.