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Funding a healthy research and innovation ecosystem

UNIVERSITY ALLIANCE

About University Alliance

University Alliance brings together the UK's leading innovative and entrepreneurial universities known for securing UK-wide competitiveness through our focus on industry and the professions, practice-based teaching and learning and real world research. Together we educate 25% of all STEM undergraduates in the UK, have a quarter of all research units with world-leading and internationally excellent (4* and 3*) research in engineering, health and art & design, and lead the entrepreneurship agenda with our graduates producing 44% of turnover from graduate start-ups.

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Report by Faye Taylor

About this report

Along with our Vice-Chancellors and colleagues at Alliance universities, this report was informed by a series of consultations with a range of experts. Whilst the views (and any errors) contained herein are those of University Alliance, we would like to thank those who contributed comments and suggestions throughout the consultation, in particular:

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Preface

A world-class research and innovation ecosystem is critical to our future competitiveness and the wellbeing of our society.

We must ensure this ecosystem can remain excellent – through responding and adapting to fast-paced change and increased competition from traditional and emerging powers. This will require not only continued investment in universities but also efficient and effective use of the existing excellence and capability in the system.

We consulted widely about what characteristics a successful British research and innovation ecosystem should have. We got four strong messages in response. Research funding must be **selective**, so we continue to develop world-leading expertise. It must encourage **collaboration** to maximise complementary strength. It must incentivise research that is **responsive** and relevant to society and industry. Finally, it must **nurture** the researchers of the future.

Alliance universities are essential to the research and innovation ecosystem. We have particular strengths that enable us to meet today's challenges. The recent Research Excellence Framework (REF) saw our research power grow by 27 per cent since 2008, far outstripping the national average in quality improvement. Over the same period, we also increased our share of research postgraduates. We are globally connected and locally rooted. This enables us to bring the benefits of our global partnerships to our home cities and regions and thus to act as powerful forces for social improvement and economic growth.

We recognise that the future success of the ecosystem relies on balancing stability and dynamism. We believe a long-term commitment to investment, distributed through our successful dual support system is the right way to maintain this balance.

Within this, open competition must underpin every investment. The best research must be funded wherever it is found. In judging what is best, we must value connectivity within the research community and with the rest of society.

This report sets out how universities and funders can help secure a research ecosystem that will support the excellent research and innovation that the UK needs to succeed.

Contents

Executive summary and recommendations

The science and innovation ecosystem is essential to future UK competitiveness

The UK's research and innovation ecosystem is at the heart of the UK's global success. The complex interactions that make this ecosystem thrive can be understood through the analogy of the natural environment: where the success of the whole requires diverse agents both to excel through competition, and co-evolve through interdependency.

In the UK, universities are at the heart of our science and innovation ecosystem. Through their world-leading research, universities advance knowledge and understanding of the big issues faced by society, and solve many of its problems. Businesses of all sizes, charities and governments also have their own sets of challenges. Universities, with their networks which span from local communities to global research partners, provide an enviable connectivity that is at the core of the UK's research and innovation capacity and knowledge economy.

This connectivity is essential for the creation of world-leading science in the twenty-first century. The role of universities, funders and government is to ensure that the science and innovation ecosystem is operating efficiently and harmoniously, to maximise capacity, drive productivity and enable evolution.

This report explores four essential characteristics of the research and innovation ecosystem, the role of universities within this, and the funding implications that will ensure these characteristics are optimised. Central to the success of the whole ecosystem is the need for continued and sustained investment.

Recommendation

Investment in research is an investment in the future. Public funding must support real terms increases and sustained commitment to the science budget to ensure future UK competitiveness

Selectivity drives excellence

The strength and quality of the UK research ecosystem rests on important characteristics of selectivity which encourage the evolution and development of specialised peaks of expertise. This selectivity is enhanced by open, competitive, and peer-reviewed funding allocations, a dual support system that balances funding for projects with that of strategic investment, and a consensus that universities are the best place to deliver research of all kinds.

The key to maximising this selectivity is to fund excellence wherever it is found. Although funding concentration is not an explicit policy, in many cases it is a reality – partly due to the use of unselective or closed competition allocation methods. Mechanisms which allocate funding on the basis of either scale or historic funding volume will not drive the overall performance of the research base, but rather are proven to deliver diminishing returns. Instead, quality is a driver of scale: smaller units that perform good research acquire resources to grow, but larger units do not continue to improve with concentrated funds. Therefore funding allocated according to quality, drives quality, but concentration would eliminate some of the best units.

Uncompetitive funding systems are also shutting down opportunities to leverage private investment. Restricted eligibility funding mechanisms which prevent some universities from applying for funding means that matched investments that would be offered by these universities' strategic and long-standing businesses partners are not realised.

Recommendations

Government and funders should continue their commitment to funding excellence wherever it is found, determined through a competitive process

The dual support funding system is essential to the health of the research and innovation ecosystem and must be retained

Open innovation means open competition – funders should ensure that the leverage of private investment is not curtailed by closed funding schemes

Nurturing new talent future-proofs the system

Postgraduate researchers are essential to the future capability of the UK's research and innovation ecosystem, and must be nurtured across the full range of disciplines. But we are seeing a worrying trend towards the concentration of funding within postgraduate training support. This risks excluding many excellent experienced researchers and research units from nurturing future talent, with serious consequences for access, diversity and social mobility. Cross-subsidy for PGR, from their own resources, by universities excluded from public funding to maintain this future capacity is unsustainable.

New models of PhD training through cohorts are creating dynamic, rich training environments. These are often delivered by multiple partners, which enable students and researchers to forge new connections, and create an environment conducive to innovation. Funding should encourage these multi-institutional and collaborative doctoral training schemes, to allow the best of the future to work with the best in the system: providing students with access to a diversity of supervisors with a range of skills and expertise.

Recommendations

Funders should recognise and support the training of future researchers and innovators within peaks of research excellence

Research councils should support consortia of universities to deliver doctoral training to ensure excellence is funded wherever it is found

Collaboration optimises the system

Selectivity developed by universities' strategic research investments and competition results in plurality. A healthy ecosystem thrives off the interdependency of these specialisms, whilst operating in silos can hold back progress. Specialisation underpins strong, effective collaborations between complementary partners, allowing existing capacity to be realised and exploited in innovative ways. Collaboration also works against duplication and inefficiency. More could be made of latent capacity in the system by recognising the contributions of all partners, and by smoothing the transition from competitive to collaborative mode.

Recommendations

Funders should encourage more collaborative and interdisciplinary research pursuits through open competition, including doctoral training schemes

Funders should recognise the contributions of collaborating institutions through tracking 'pass through' funds and recognising Co-Investigators

Universities should continue to work proactively to share research assets with each other and industry

National bodies should work with universities towards an open, accessible and inclusive national asset sharing system, to make best use of the national innovation capability

National and international-level research facilities should be open to all researchers

Responsiveness delivers the greatest benefit from research

The future health of the ecosystem relies on its ability to adapt and respond to a fast-changing environment. Responsiveness can be built into the system by ensuring that different agents are engaging across the system, and that new connections are constantly being formed, leading to smarter exploitation of new knowledge.

Research excellence can therefore no longer be narrowly defined solely in terms of its reach within the academic community, but must articulate its value through the wider benefits of research for society. The impact agenda is helping to incentivise this. The multiplicity of other knowledge exchange activities undertaken by universities are also essential to build links between academia and the rest of the world.

Recommendations

Funding councils should continue to recognise and reward impact in indicators of research quality, using a case study approach

Funders must continue to prioritise funding streams like QR and HEIF, which build in agility and responsiveness to research and knowledge exchange activities

Government should invest more in a dedicated funding stream for higher education innovation activities

1 | Introduction - the Research Ecosystem

Research and innovation are crucial to the success of the UK. Just as in the natural environment, the research and innovation ecosystem flourishes through a complex interplay of competition and collaboration. In ecological models, individual agents develop unique strengths and niches, creating a healthy biodiversity which is optimised by a dynamic interdependency with other agents in the community.

Universities play a pivotal role within the science and innovation ecosystem. Universities advance knowledge and find solutions for the big issues faced by society, industry of all sizes and government through world-leading research. Substantial value is placed on the knowledge and expertise generated by the UK's publicly-funded university research and researchers – total knowledge exchange investment rose by 5 per cent in the last year, from £3.4 billion in 2011-12 to £3.6 billion in 2012-13.[1] Universities carry out 74.3 per cent of publicly-funded Gross Expenditure on Research and Development (GERD) and 26.5 per cent of total GERD – significantly above the OECD average.[2]

But more than this, universities are highly connected facilitators. They have the networks and resources to make connections between agents across the ecosystem, bringing the world's knowledge to the UK, and the UK's expertise to the world. Input from outside academia is vital throughout the spectrum of research activities, if university research is to be relevant and accountable to the society that funds its endeavours.

The government and funders have a critical role to play in optimising the research and innovation ecosystem, facilitating its strongest characteristics and removing barriers to allow the whole system to thrive. First and foremost, continued investment at globally competitive levels is essential. It is an investment in the future: in a high-skill, high-growth knowledge economy and in our ability to meet great societal challenges.

But the ecosystem also needs to operate efficiently and cost-effectively, especially in times of fiscal pressure, to raise productivity through optimising existing expertise and capacity. This report is framed around the four essential characteristics of the twenty-first century research and innovation ecosystem:

Selective. An element of competition ensures excellence-seeking is embedded within the ecosystem, and allows new areas of expertise and specialisation to develop.

Nurturing. The researchers and innovators of the future must be supported across the range of expertise that the UK ecosystem boasts so that the science base remains dynamic.

Collaborative. Selectivity and specialisation results in complementary expertise across the ecosystem, working against unnecessary duplication and resulting in healthy interdependency. These collaborations make the ecosystem stronger, more innovative and more resilient as a whole.

Responsive. The ecosystem must remain responsive if it is to adapt with flexibility to the fast-paced changing landscape. To be responsive, the ecosystem must engage in a highly networked manner with the users of research and to accelerate knowledge exploitation.

Each of these essential characteristics, are examined in turn through this report, with resulting funding implications.

Recommendation

Investment in research is an investment in the future. Public funding must support real terms increases and sustained commitment to the science budget to ensure future UK competitiveness

1 HE-BCI data, 2011-13

2 Universities UK (2014) Higher Education in Focus 2014: Research and postgraduate research training. London: UUK, pp. 6-7

2 | Selectivity drives excellence

The UK has one of the most highly selective research funding methods in the world. The policy of selective funding, based on quality established by peer review and a robust dual support system, has driven up the quality of UK research, with a notable increase in the UK's share of world citations since the introduction of the first Research Assessment Exercise (RAE) in 1986.[3]

The dual support of research and funding excellence through open competition is the best way to ensure quality, responsiveness and resilience in the research ecosystem

A system that supports selectivity has driven the overall global competitiveness of UK research. Central to this is the dual support mechanism and institutional autonomy, which has been shown to correlate directly with the quality of a system and to increase the competitive success of institutions.[4] The UK system is recognised as being distinct both in its level of autonomy and its quality.[5] Providing the flexibility to invest strategically remains critical to the dynamism and responsiveness of UK research, allowing universities to develop their areas of strength including in new and high-risk areas, across the spectrum of research activities.[6]

National and international policies have recognised that specialisation and complementarity at the unit level is important for success at system level. This is seen, for example, in the European Commission's Smart Specialisation agenda.[7] This initiative recognises that enabling units – in this case regions – to focus on their strengths, can boost innovation and increase the impact of research investment, preventing unnecessary duplication across the system as a whole.

The same principle applies to university research, as is shown by peaks of research excellence: specialised and exceptional units of research activity. REF 2014 results show that these peaks are widely distributed, with world class activity in research units of various sizes and across the UK higher education sector. This clearly demonstrates how this selective and strategic investment has paid off. An overall increase in the proportion of world-leading and internationally excellent (4* and 3* rated) research found by REF 2014 was consistent with independent and international evidence of the enhanced quality of UK research.[8]

Peaks of excellence are important and are found across the sector

A major part of this picture is institutional diversity which has strengthened the UK's research portfolio.

Alliance universities outstripped national improvement between RAE 2008 and REF 2014, doubling their proportion of world-leading research and increasing internationally excellent research by 50 per cent (compared to sector averages of 74 per cent and 24 per cent respectively). With less public funding for research, these universities are committed to identifying their competitive advantage, to making strategic and focused decisions about research investments. Differentiation through investment in areas of strength at institutional level supports a rich ecosystem in the UK within which there is often complementarity rather than duplication.

'Research excellence is a critical asset for the UK, providing a competitive advantage in the global race for prosperity. The UK's strong research base is vital in pushing back the frontiers of human knowledge, supporting the wealth and welfare of the nation, tackling current and future challenges and contributing to the cultural richness of the UK. World class research plays a key role in economic growth through creating new businesses, improving the performance of existing businesses, delivering highly skilled people to the labour market, and attracting investment from global businesses. It is also vital to the implementation of the Government's Industrial Strategy.'

BIS, The Allocation of Science and Research Funding 2015/16. Investing in World-Class Science and Research, 2014.

3 J. Adams and D. Smith (2006) Evaluation of the British Research Assessment Exercise. In: L. Bakker, J. Boston, L. Campbell and R. Smyth (eds.) Evaluation of the Performance- Based Research Fund, pp. 109-17; Wellington: Institute of Policy Studies, Victoria, cited in Libby Aston and Liz Shutt, Concentration and Diversity: Understanding the Relationship between Excellence, Concentration and Critical Mass in UK Research, 2009

4 Laura De Dominicis, Susana Elena Pérez and Ana Fernández-Zubieta, European University Funding and Financial Autonomy (2011) A Study on the Degree of Diversification of University Budget and the Share of Competitive Funding, http://dx.doi.org/10.2791/55199

5 Philippe Aghion and others (2008) Higher Aspirations: An Agenda for Reforming European Universities, Bruegel Blueprint Series, V

6 PACEC and Centre for Business Research (2014) A Review of QR Funding in English HEIs: Process and Impact. Report to the Higher Education Funding Council for England (HEFCE)

7 http://ec.europa.eu/research/regions/index_en.cfm?pg=smart_specialisation

8 http://www.ref.ac.uk/results/analysis/comparisonwith2008raeresults/

2.1 Funding excellence wherever it is found supports selectivity

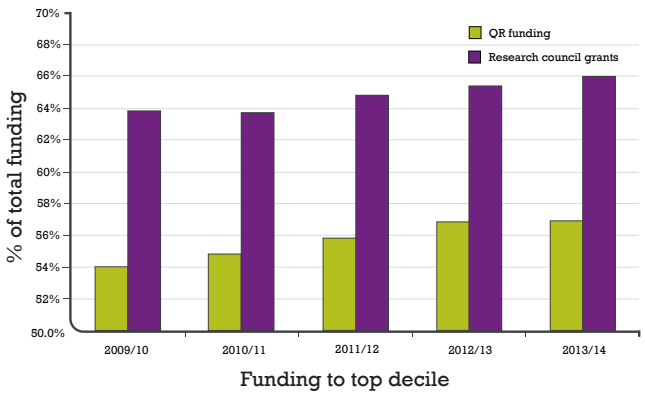
Funding excellence wherever it is found underpins this process of selectivity, and is a guiding principle of UK research funding. The recent 2015/16 grant letter to HEFCE underlined this principle,[9] as did a commitment in the Science and Innovation Strategy.[10]

2.1.1 Funding has become more concentrated in recent years

The reconfirmation of the principle of funding excellence wherever it is found may help reverse the recent trends towards increasing concentration. At the hard edge of some funding decisions this guiding principle can be threatened by the use of closed or uncompetitive allocation mechanisms (section 2.2), so that public funding distribution does not necessarily reflect the distribution of excellence. Whilst selectivity will lead to some focusing of funding where quality exists, it should not be an overriding policy driver.

The Higher Education Commission's report *Too Good to Fail* highlighted the threat that concentration of funding makes to the dynamism of the research ecosystem.[11] Yet recent reports for HEFCE and by Universities UK into the funding environment have noted a trend of increasing concentration of research funding across institutions which is not in line with quality distribution. For the top decile, increases in QR and research council funding have risen by 3 per cent and 2 per cent respectively over the last five years (Figure 1). 11 universities received 50 per cent of the funding for which the top 3 account for over 20 per cent and over 90 per cent of research council funding goes to the fifth quintile.[12] Quality-related (QR) funding allocation based on REF 2014 results is yet to be announced.

Figure 1 Concentration of funding towards the top decile has increased in recent years
Source: HESA Finance Returns

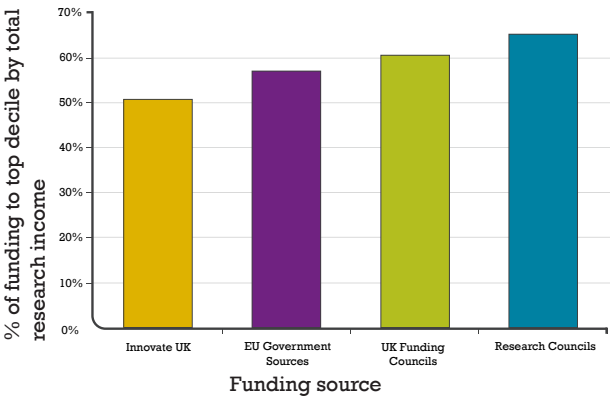


'Whilst concentrating research funding may be more efficient in terms of economies of scale, and enhancing the reputation of a subset of English universities, spreading research funding to wherever excellence is found allows for an element of dynamism in the system and more opportunities for early career researchers to prove themselves. The Commission would recommend that good research, wherever it exists in the sector, continues to be funded.'

Higher Education Commission, Too Good to Fail. 2014.

Different levels of concentration to some extent reflect nuances including subject costs, and scale. But high levels of concentration are more common in the UK's public funding for research. EU funding has lower levels of concentration within the UK's top decile receiving 57 per cent compared to 65 per cent for RCUK funding (Figure 2). Alliance universities draw over 70 per cent more proportionately from EU public funding sources compared to equivalent UK sources. Innovation funding from Innovate UK which includes research and knowledge exchange is also markedly less concentrated at 51 per cent.

Figure 2 Innovate UK and EU funding is less concentrated than other public funding, particularly from RCUK
Source: HESA Finance Returns and Innovate UK funding for projects from 2013



Before analysing some of the mechanisms for allocation which exacerbate the problem, certain myths around the benefits of concentration must be dispelled. First, that policies of funding concentration improve the quality of the whole system; second, that bigger research units perform better and thus research funding should be allocated on the basis of the size; and third, that allocating funding based on previous funding levels is the most efficient use of public money.

9 Department for Business Innovation & Skills (2015) Grant Letter to HEFCE, 2015-16
10 HM Treasury and Department for Business Innovation & Skills (2014) Our Plan for Growth: Science and Innovation
11 Higher Education Commission (2014) Too Good to Fail - The Financial Sustainability of Higher Education in England
12 Tomas Coates Ulrichsen (2014) Knowledge Exchange Performance and the Impact of HEIF in the English Higher Education Sector; Universities UK (2014) The Funding Environment for Universities 2014. Research and Postgraduate Research Training. Previous reports commissioned by Universities UK into this subject are Evidence Ltd (2003) Funding Research Diversity: The Impact of Further Concentration on University Research Performance and Regional Research Capacity. A Report for Universities UK; Evidence Ltd (2007) Monitoring Research Diversity, Changes between 2000 and 2005. A Report for Universities UK; Evidence Ltd (2009) Monitoring Research Diversity and Concentration, Changes between 1994 and 2007. A Report for Universities UK

Alliance universities have 13.8 per cent of units with research rated 4* or 3* in the REF but receive 3 per cent of UK public funding for research

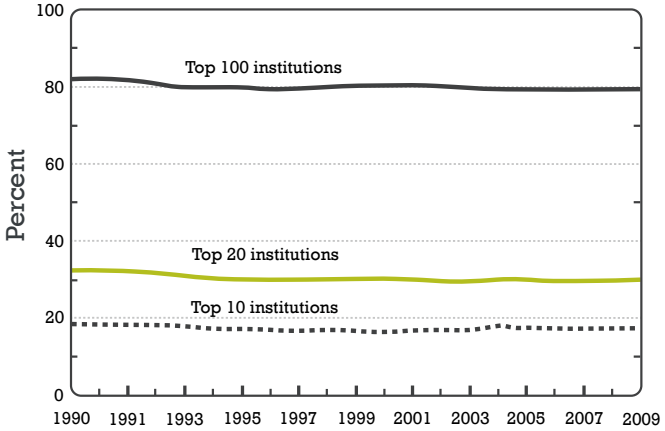
2.1.2 Concentration does not improve whole system performance

International comparisons show that there is no necessary correlation between concentration and research performance

The US system is by most measures the world leader in research and development but has a lower concentration of funding than the UK. As Figure 3 shows, the concentration of academic R&D funds for science and engineering among the top US 100 institutions, and the shares held by both the top 10 and the top 20 institutions, have remained largely constant over the last two decades (although the make-up of the 'top 10/20' has changed). Similar concentration levels are found among universities that perform non-science and engineering R&D, where the top 20 performers accounted for 36 per cent of the total non-science and engineering R&D expenditures in 2009.[13] This compares to the much higher level of concentration in the UK noted above. On the other hand, Germany has an explicit policy of concentrating research in a small number of research institutes, but research quality is not as high as in the UK.[14]

Figure 3 Concentration levels in the US have remained largely constant over recent years

Share of US academic R&D by institution rank in R&D expenditures: Financial year 1988-2009, Source: National Science Foundation (2012), Science and Engineering Indicators, fig. 5-9



2.1.3 The 'critical mass' myth: bigger does not mean better, instead quality is a driver of scale

Arguments that large academic research groups perform better than small ones are not new, and underpin suggestions that funding should be concentrated in fewer institutions.[15] They claim that departments above a certain size achieve a 'critical mass' that is able to make more effective use of research funding.

The assumption that volume may lead to improved performance is not without some basis; in fact it is observed to be true for some of the physical and clinical sciences in academia, and in research and development productivity within the pharmaceutical industry.[16] The idea of the 'well-found lab', a research community which benefits from sharing expensive and rare (often unique) capital and technological resources, is widely accepted. The idea of critical mass might also be usefully applied to other elements of the research environment, for example in the creation of a cohort of peer support in doctoral training (section 3.3). Yet the assumption that this type of critical mass must exist within one institution is misguided. Indeed, often collaborations between experts in different departments or institutions is the most efficient and effective means of creating this mass and further innovation (section 4.1).

Funding based on the size of a research unit does not and will not improve the quality of the research base

The evidence does not support a broad-brush presumption that 'bigger means better' for research units; in fact, beyond the very smallest groups, quite the contrary. The relationship between volume and excellence varies by discipline although the vast majority do not correlate: Evidence Ltd found no correlation in 69 out of 72 Units of Assessment (UoAs) in RAE 2008 results – the three exceptions all being physical sciences.[17] Even in the small number of disciplines where volume correlates to quality throughout, there is no identifiable standard lower threshold or 'critical mass', and there is a point above which performance stops increasing as rapidly or, in some cases, starts to decrease.[18] Figure 4 maps REF 2014 results against the size of research units in four UoAs. It shows that among smaller

13 National Science Foundation (2012) Science and Engineering Indicators

14 Overall country quality comparisons evidenced for example by article share and field-weighted citation impact, see: Elsevier and BIS (2013) International Comparative Performance of the UK Research Base 2013

15 Russell Group, Jewels in the Crown (2012) The Importance and Characteristics of the UK's World-Class Universities

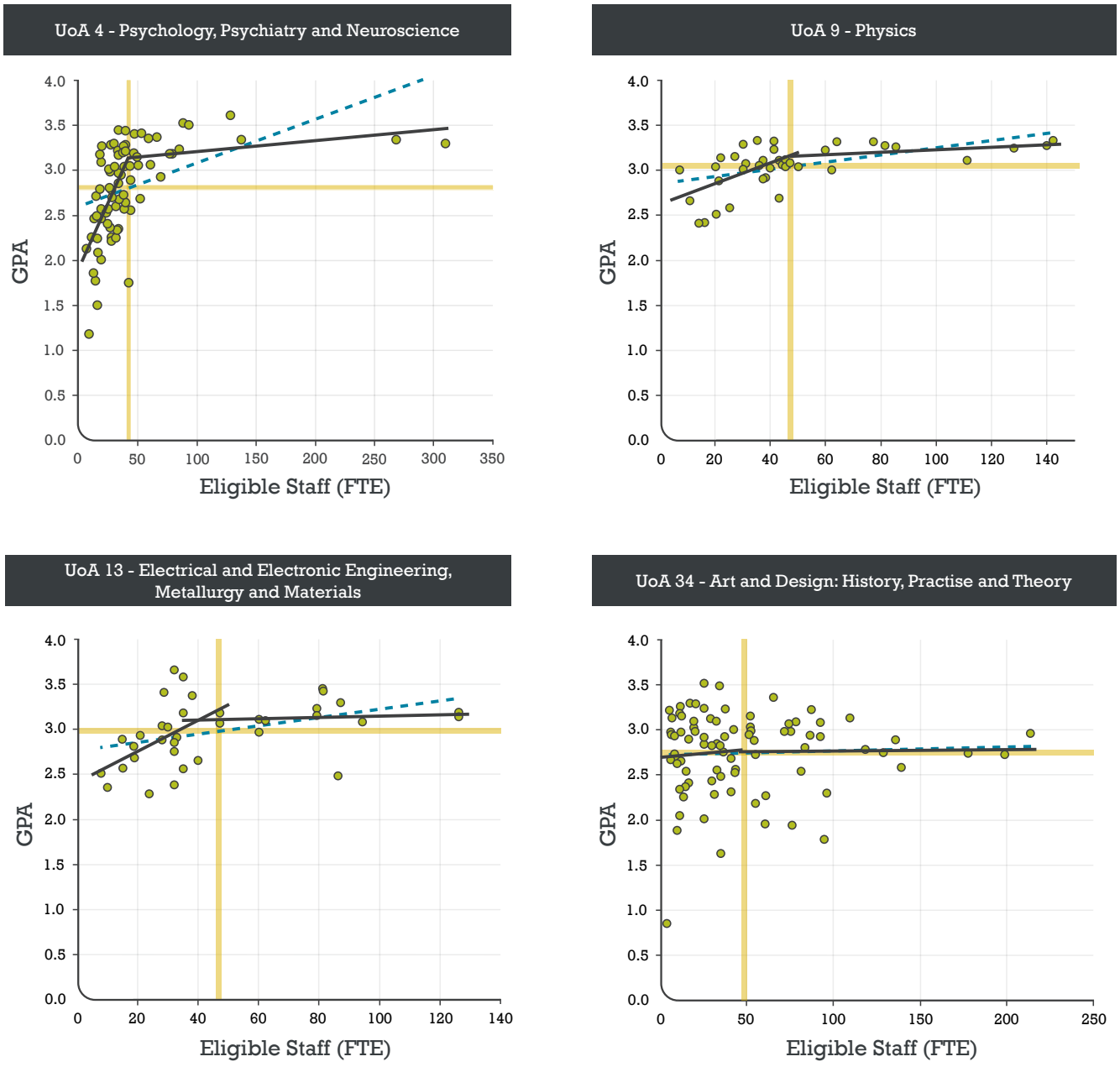
16 R Henderson and I Cockburn (1996) 'Scale, Scope, and Spillovers: The Determinants of Research Productivity in Drug Discovery,' The RAND Journal of Economics, http://www.jstor.org/stable/2555791

17 The granular-level analysis provided by the more detailed RAE 2008 results Evidence Ltd (2011) Funding Research Excellence: Research Group Size, Critical Mass & Performance

18 Higher Education Policy Unit at the University of Leeds (2000) HEFCE Fundamental Review of Research Policy and Funding. The Role of Selectivity and the Characteristics of Excellence. Final Report to HEFCE; see the many sources cited in Evidence Ltd (2011) Funding Research Excellence, p. 5

research units there may be a significant positive correlation between size and performance but above a certain threshold no further improvement is evident. Correlation between size and quality in the smallest research groups can be attributed to the added value of new connections that an individual brings to a group, although this effect quickly levels out at an 'upper critical mass' when the connections are 'maxed out': a type of Dunbar's number, a limit above which meaningful communication drops off.[19]

Figure 4 Beyond the very smallest research units there is no correlation in size and performance
Source: REF 2014



Analysis of the REF 2014 results shows that there are small and medium-sized groups of researchers that perform as well as, and often better than, the largest in most UoAs.[20] Analysis of relationships of size (measured by the number of full-time equivalent Category A Staff) to performance (measured by the GPA outcomes of REF 2014) show that there is no continuous relationship between research unit size and performance in most UoAs. It is also apparent that there are small and medium sized groups which perform as well as, and in some cases better than, the largest units, as Figure 5 shows for all submissions to REF 2014. This pattern holds for most disciplines, as shown by the indicative charts at Figure 6, mapping Alliance universities' performance against the rest of the sector.

19 R. Kenna and B. Berche (2010) The Extensive Nature of Group Quality, EPL (Europhysics Letters), 90, 58002, http://dx.doi.org/10.1209/0295-5075/90/58002
20 http://www.ref.ac.uk/panels/unitsofassessment/

Figure 5 Small and medium size research units perform as well if not better than the largest

Data: HEFCE, REF 2014 results, all UoAs

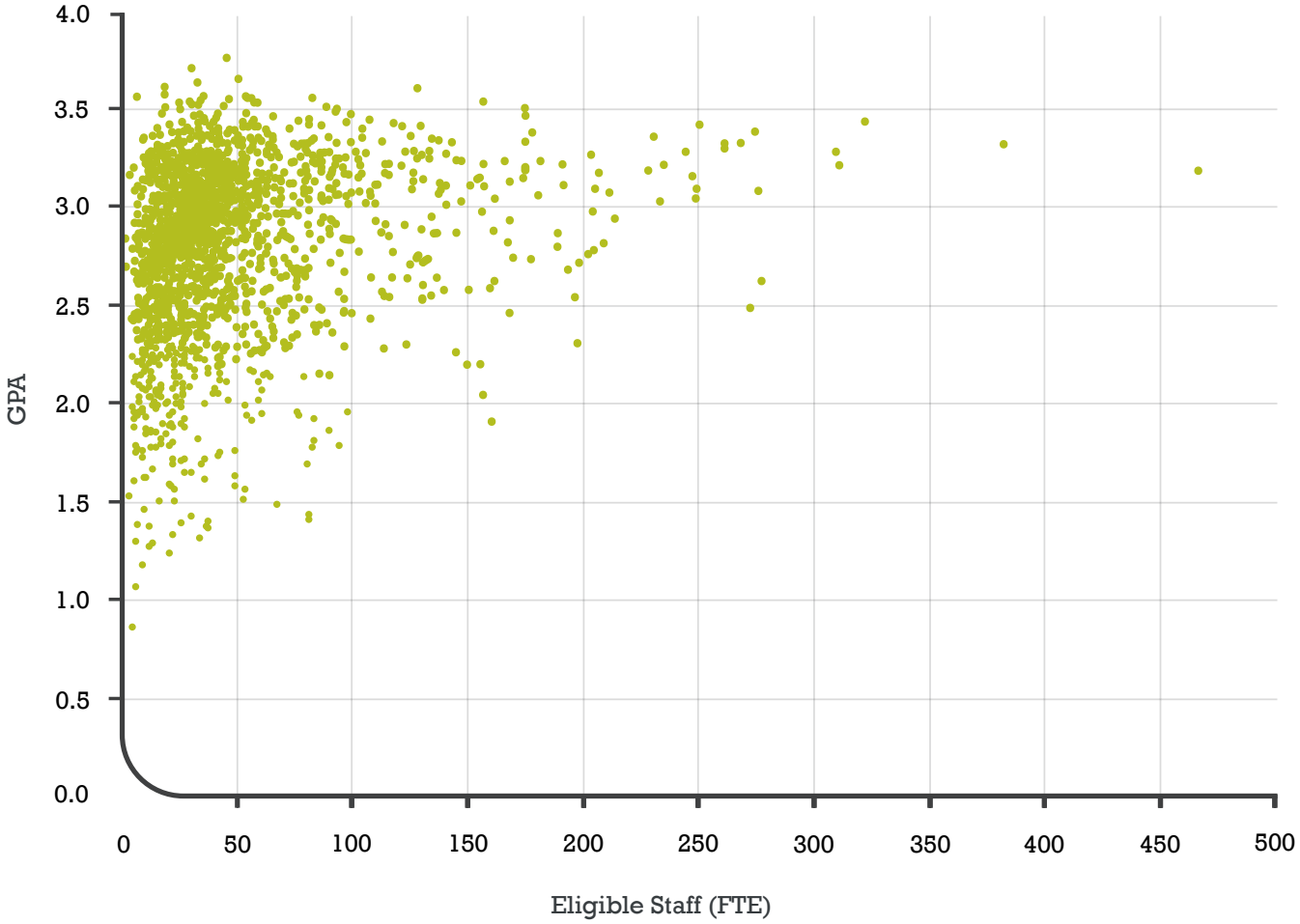
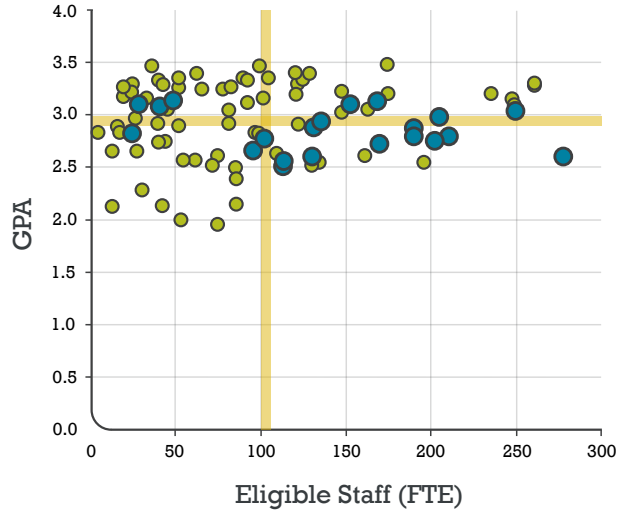


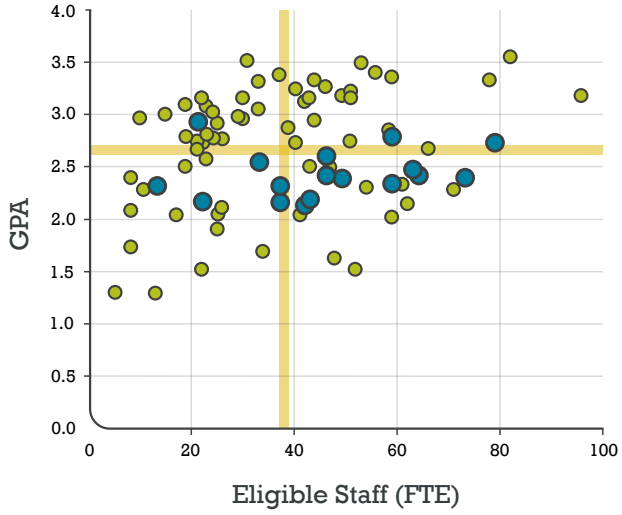
Figure 6 In many UoAs, small and medium size research units perform as well if not better than the largest

Source. HEFCE, REF 2014 Results. University Alliance institutions plotted in blue

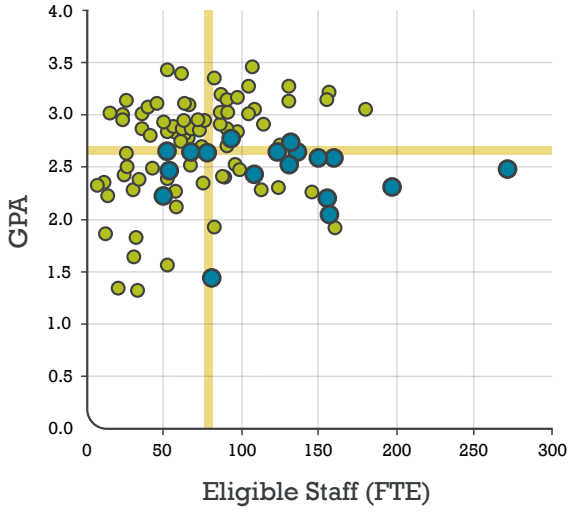
UoA 3 - Allied Health Proffesions, Denistry, Nursing and Pharmacy



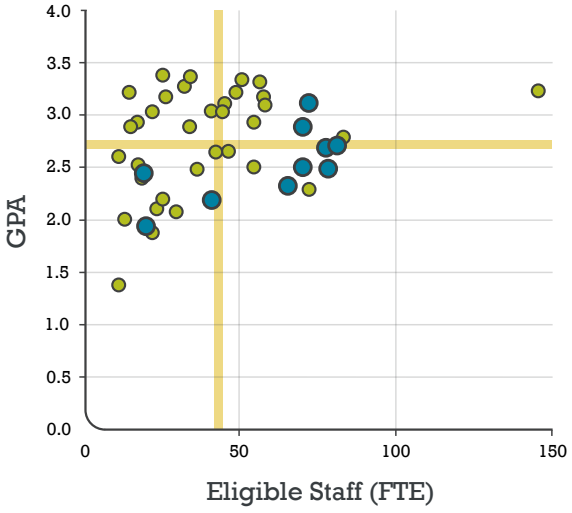
UoA 11 - Computer Science and Informatics



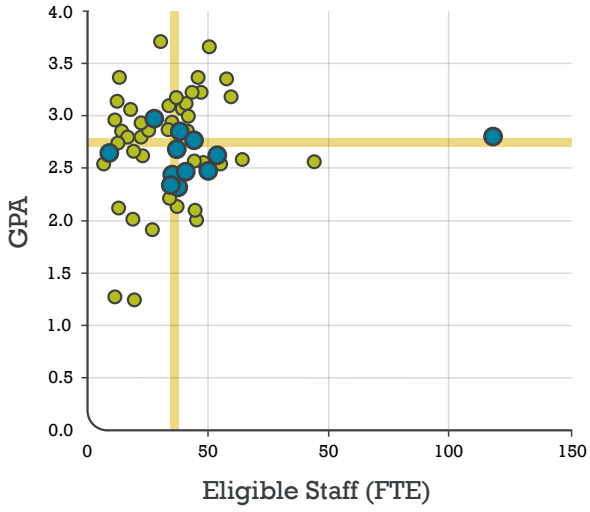
UoA 19 - Business and Management Studies



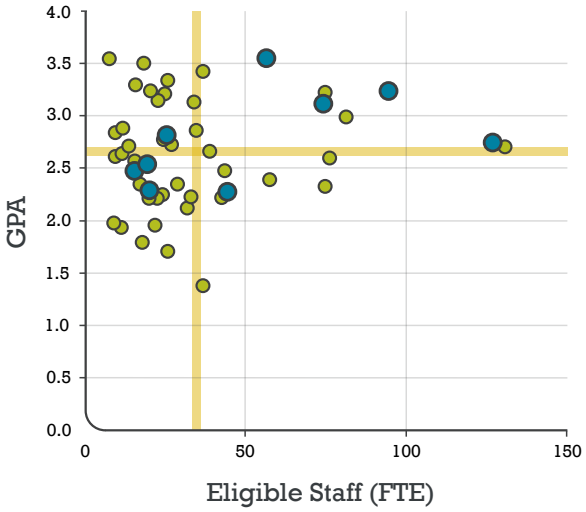
UoA 16 - Architecture, Built Environment and Planning



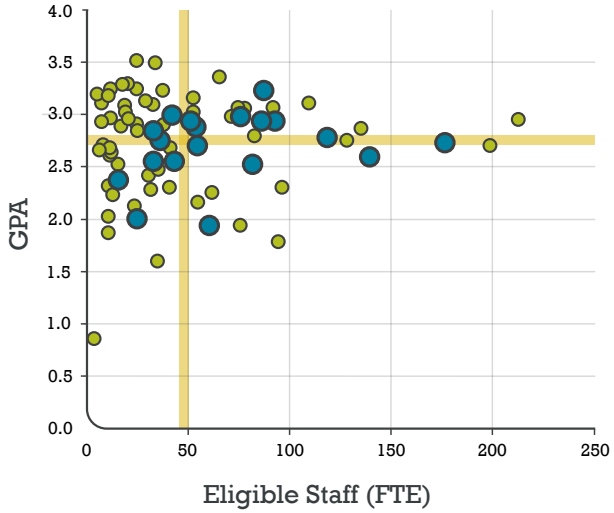
UoA 22 - Social Work and Social Policy



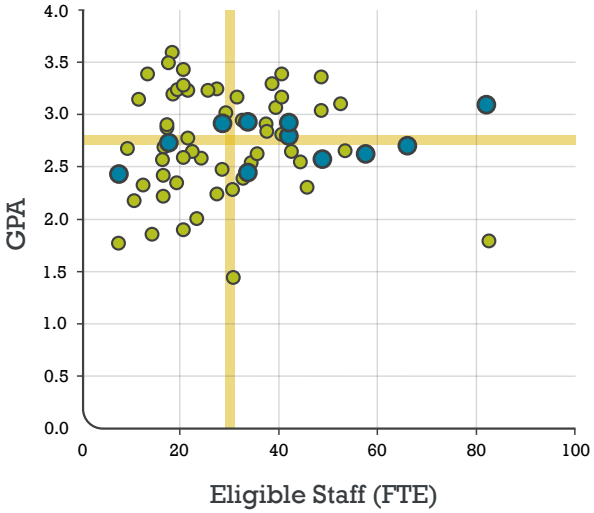
UoA 26 - Sport and Exercise Sciences, Leisure and Tourism



UoA 34 - Art and Design: History, Practise and Theory



UoA 36 - Communications, Cultural and Media Studies, Library and Information Management



Small and medium sized research units also tend to be at least as productive as large units, and peak productivity is not generally associated with the largest units, but is often found around the median. For example, peak productivity in biological sciences has been suggested to be 10-15 people according to a recent study, consistent with a study concluding that 'middle sized labs do best'.[21]

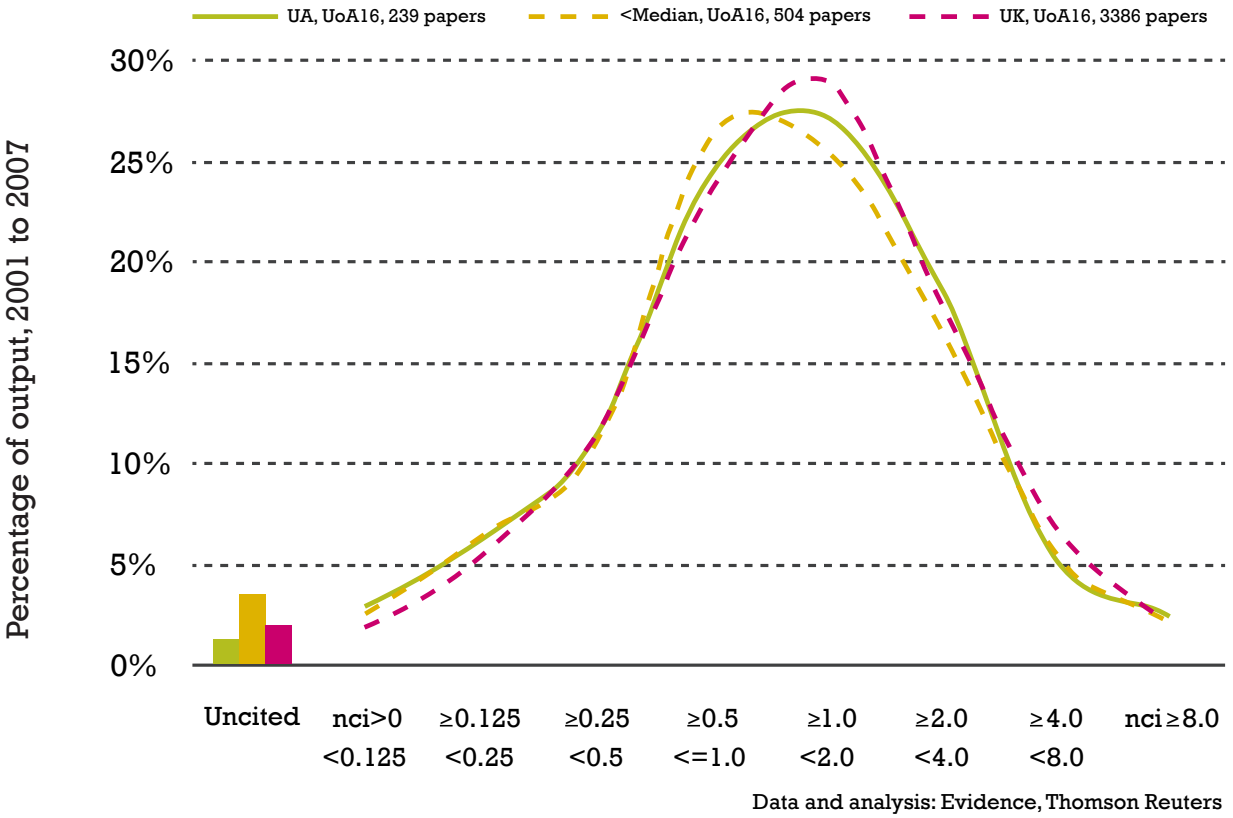
Similarly, analyses of citation distribution patterns have found no significant correlation between normalised citation impact and research unit size. Again, small and medium sized units can perform as well as the largest units, and the best performing units are often not the largest.

Citation data are highly skewed with many papers receiving no citations and few receiving many citations. Impact Profiles™ allow such distributions of citations to a body of papers to be visualised, as Evidence Ltd analysis shows in Figure 7 for RAE 2008 UoA16 (Agriculture, Veterinary and Food Science). This pattern held true for most of the UoAs analysed. There is little difference in the profiles of Alliance universities when compared with the UK as a whole and the group of institutions with fewer than the median number of Category A Staff. A similar percentage of the research papers published by each of these groups receive equivalent numbers of citations.

Conclusions. There is no evidence that funding on the basis of scale would improve overall performance or productivity, but it might eliminate some of the best units. Instead, quality is a driver of scale. That is to say, smaller units that perform good research acquire resources to grow, whilst large units that perform poorly lose resources and decline, leading to a natural regeneration of the ecosystem.[22]

Therefore concentrating resources on the basis of existing scale would eliminate many areas of excellence. Small or medium sized excellent and growing units could be lost and the development of future niche and specialist areas would be stifled, with dangerous consequences for the dynamism and future health of the UK research and innovation ecosystem.[23]

Figure 7 Larger institutions do not outperform smaller ones in citation impact (RAE 2008 UoA16)
Source. Evidence Ltd, Funding Research Excellence



21 Chris Woolston (2015) Bigger Is Not Better When It Comes to Lab Size, Nature, 518, 141–141 http://dx.doi.org/10.1038/518141f citing; Isabelle Cook, Sam Grange and Adam Eyre-Walker (2015) Research Groups: How Big Should They Be? http://dx.doi.org/10.7287/peerj.preprints.812v1. Meredith Wadman (2010) Study Says Middle Sized Labs Do Best, Nature, 468, 356–57 http://dx.doi.org/10.1038/468356a; Kenna and Berche (2010)
22 Evidence Ltd (2003)
23 Mark Harrison, 'Does High-Quality Research Require 'Critical Mass'?,' in The question of R&D specialisation: perspectives and policy implications. JRC Scientific and Technical Reports (EUR collection): perspectives and policy implications. JRC Scientific and Technical Reports (EUR collection), ed. by Dimitrios Pontikakis, Dimitrios Kyriakou, and Rene van Bavel (Office for Official Publications of the European Communities, 2009), pp. 53–55; Evidence Ltd (2003)

2.2 Uncompetitive funding allocation restricts capacity and performance

The principle of funding excellence wherever it is found relies on competitive processes for establishing excellence. The UK is unique in building the funding of excellence into core funding through QR, based on the results of the REF – the most extensive and comprehensive peer-review system of quality in the world. Many research councils also ensure that a significant amount of research funds are allocated according to quality through established peer review colleges.

Public funding for science and research was ring fenced until 2014-15 as part of the 2010 Comprehensive Spending Review; welcome protection in an era of fiscal pressure. Real term declines however, combined with a decrease in research capital spending (which lies outside the ring fence), produced a drop of the overall value of grants for research of £248 million in real terms over the last four years.

Funding councils have received significant reductions to their budgets in recent years which have necessarily driven back-office efficiencies. One consequence of this has been that some efficiency measures at some research councils have led to uncompetitive responsive-mode funding allocations in certain cases. These have restricted funding opportunities to priority lists of institutions and the use of algorithm-based determinants of 'excellence' based on historical award income. The result is that some parts of the ecosystem, which might offer greater excellence, are excluded from applying.

To give two examples, historic funding volume algorithms were used to distribute funding for the ESRC, STFC and EPSRC's Impact Acceleration Accounts (IAAs). Similar algorithms have also closed off competitive applications for doctoral training including EPSRC Doctoral Training Partnerships (DTPs) and Industrial CASE (iCASE) awards, and STFC DTPs.[24]

Although these allocation methods can lead to cost savings related to the processes of assessing applications, they could be a false economy if the research outcomes do not deliver value for money and do not achieve the maximum societal return. They also close down opportunities to leverage investment from other sources.

By using rear-view algorithms, 'excellence' is determined on the basis of previous success in funding awards. Yet allocation mechanisms that determine funding based upon previous funding do not improve productivity and performance, just as allocating research funds according to unit size does not. Data from the US National Institutes of Health (NIH) showed that at higher funding levels publication levels, and average 'impact factor' declined discernibly.[25] Likewise, a Canadian study of researchers in the three disciplines funded by the Natural Sciences and Engineering Research Council of Canada (NSERC) noted that citation impact was generally a decelerating function of funding, that impact per dollar was lower for larger grant-holders, and that the citation impact of researchers who received increases in funding did not predictably increase.[26]

Over-concentration of funding on the basis of previous funding therefore delivers diminishing returns. The rear-view allocation model also works against innovation in practice, and stifles competition. The presumption is that historic funding distribution has recognised all forms of excellence across the whole system, and that all universities' research units are equally well equipped to deliver a full spectrum of research activities. In reality, different strengths exist in different places. The rear-view approach can fail to divert funds to the existing excellence best suited to deliver the objectives of the latest funding round: those in receipt of funding previous research priority streams from research councils may not be best-placed to deliver the impact objectives of the IAAs, for example. This is problematic for the UK's research capability as it both fails to recognise and drive development in a full range and scale of research activities, and does not incentivise innovation or new areas of excellence.

24 www.esrc.ac.uk/collaboration/knowledge-exchange/opportunities/ImpactAccelerationAccounts.aspx; http://www.stfc.ac.uk/2880.aspx; www.epsrc.ac.uk/skills/students/dta/; www.stfc.ac.uk/1834.aspx [Accessed September 2014] We note and welcome the recommendation in the recent review of ESRC doctoral training provision that the call for the next round of DTCs be fully transparent and open to all institutions 'for reasons of fairness and to ensure continuing high quality': Richard Bartholomew and others (2015) Review of the ESRC Doctoral Training Centres Network, p. 6

25 Wadman

26 Jean-Michel Fortin and David J Currie (2013) Big Science vs. Little Science: How Scientific Impact Scales with Funding, PloS one, 8 http://dx.doi.org/10.1371/journal.pone.0065263

2.2.1 Uncompetitive public funding works against the leverage of private investment: open innovation needs open competition

A broader principle is at stake. Non-competitive public funding streams are at odds with the market forces that are in play in the wider research and innovation ecosystem, and at odds with policies that encourage the leverage of private investment. Public funds can be (and increasingly are) used to leverage significant contributions from the private sector, but this private investment cannot be maximised if there are restrictions on where and with which partners the public funds can be spent. In other words, open innovation needs open competition.

Industry partners choose to work with a variety of universities that suit their needs. Restricting the public funding which can support these partnerships to only part of the university sector not only fails to make use of existing university-business relationships, but asks companies to act in a non-competitive funding environment counter to market forces.

One example is a new allocation method of public funding for iCASE awards by the EPSRC. Only the 44 HE institutions in receipt of a Doctoral Training Grant (DTG) are eligible for this, an eligibility list based on previous funding awards. These awards are described as 'funding for PhD studentships where businesses take the lead in arranging projects with an academic partner of their choice'. They provide PhD students with a challenging research training experience, including a mandatory industrial placement, within the context of a mutually beneficial research collaboration between academic and non-academic partner organisations.[27]

The result of uncompetitive funding allocation in this case means that private funds for investment in PhD training have been left unleveraged, symptomatic of a misalignment of the objectives in research funding. Due to the limitations on the eligibility of academic institutions, businesses do not have a full choice of partners. Those who are prepared to invest in an iCASE studentship may not, if they cannot work with their partner of choice. Alliance universities have reported multiple instances of significant industrial partners including EDF Energy, BAE Systems, Hydro International and Green Frog Group, plus numerous SMEs, who were willing but unable to invest in an iCASE with their preferred partner.

Collaborative partnerships are based on trust, and often take many years to establish successfully. Institutions with excellent track records in iCASE studentships and business relationships who are now disbarred from this part of the public funding system are prevented from delivering the benefits of their strong industry relationships and collaborative research training offering to students and other business partners. There are also knock-on effects, including for other packages for business collaboration including KTPs. These schemes work best when synergised and can be used flexibly and responsively to business need.

2.3 Funding implications for ensuring an ecosystem that thrives on selectivity

Determining and developing unique strengths is an essential element of the selectivity which characterises a healthy research and innovation ecosystem. An element of competition ensures excellence-seeking is embedded within the ecosystem. Our robust dual support system in the UK is a strength which allows universities to invest in and develop their unique strengths, strengthening the ecosystem as a whole.

The evidence presented demonstrates that the contrived concentration of funding either for reasons of size or on the basis of historical institutional funding would not improve the performance or productivity of the research base. Funding uncompetitively runs the risk of eliminating pockets of excellence, works against innovation and alienates private investment for research.

The policy implication is that the best way to improve the performance of the UK research base is to continue to fund excellence wherever it occurs, determining excellence through free and open competition. Government should support funding councils to determine excellence through competitive process. As previous studies have also shown, this will help sustain the diverse and complementary network of research activity that will ensure the sector remains dynamic and is able to respond with agility to the fast-paced changes in the future research system.[28]

Recommendations

Government and funders should continue their commitment to funding excellence wherever it is found, determined through a competitive process

The dual support funding system is essential to the health of the research and innovation ecosystem and must be retained

Open innovation means open competition – funders should ensure that the leverage of private investment is not curtailed by closed funding schemes

27 www.epsrc.ac.uk/skills/students/coll/icase/Pages/intro.aspx [Accessed July 2014]

28 Evidence Ltd (2010) The Future of Research

3 | Nurturing talent future-proofs UK capability

Postgraduate research (PGR) students are essential to the UK's future capability and competitiveness. As well as contributing to the national and international knowledge base, doctoral-level research and skills play a crucial role in driving innovation and economic growth, attracting global businesses to the UK, and remain in strong demand in the labour market.[29] A strong research culture is vital for research-informed learning and innovation activities: it is the essence of an enquiry-led, academic university learning environment that delivers the high postgraduate-level skills needed for the economy, with further trickle-down benefits for students at all levels.

Despite wide acceptance of the value of postgraduate students and the need to nurture and retain talented future researchers and innovators, recent funding trends for postgraduate study are affecting the UK's ability to achieve this. Sustainability, concentration and relevance are key issues which threaten the ability of the ecosystem to nurture talent and meet future capability needs.

3.1 Demand for the next generation of researchers and innovators may not be met under current funding criteria

Despite increases driven by international students, growth in uptake of PhD courses has slowed in the UK due to recent funding squeezes.[30] Universities UK analysis has shown that although demand for PGR study at UK institutions has remained strong over the last decade, it showed signs of stagnating in 2012–13, which 'may be a sign that demand for PGR study may taper down over the next few years, particularly if funding opportunities from the research councils (RCs) continue to shrink and demand for postgraduate taught (PGT) qualifications (which are increasingly often a stepping stone to a doctoral degree) continues to weaken.' There has been a continued upward trajectory in the number of entrants to doctoral training courses with a previous Masters degree (from less than one third in 2002-03 to 59 per cent in 2012/13).[31] The effects of declines in take-up of PGT courses in the last two years may be felt, although are yet to be realised.

At the same time that supply of PGR and doctoral students is threatened in the UK, there is also sustained and increasing demand for doctoral graduates in the labour market, as evidenced by secure employment levels and wage premiums relative to other highly qualified individuals, including other postgraduates.[32] Doctoral graduates have proven to be more 'recession-proof' in recent years than other graduates in the UK; doctoral graduates were less likely to be unemployed and retained the same level of full-time paid work between 2008 and 2010, during which period Masters and good first degree holders saw a 5 per cent decline in the same.[33] Demand for doctoral skills from a range of disciplines is reflected across sectors, with nearly 60 per cent of doctoral researchers working in sectors outside higher education following graduation.[34]

Given strong demand for doctoral graduates both within the research base and from industry, it is essential that financial opportunities are provided to all those with the talent and drive to undertake advanced research programmes. Similarly, funding systems must evolve to support training that meets the needs of the changing landscape of PhD employability, a landscape in which PhD graduates are increasingly less likely to work in a university-based research role post-study. Less than one third (29 per cent) of 2010 leavers were in pure research roles 3 years after graduating, fewer than the 2008 cohort (32 per cent).[35]

29 Adrian Smith (2010) One Step Beyond: Making the Most of Postgraduate Education; Christine Halse and Susan Mowbray (2011) The Impact of the Doctorate, Studies in Higher Education, 36, 513–25 http://dro.deakin.edu.au/view/DU:30035145 [accessed 28 October 2014]
30 David Cyranoski and others (2011) Education: The PhD Factory, Nature, 472, 276–79 http://dx.doi.org/10.1038/472276a
31 Universities UK
32 OECD (2013) Making the Most of Knowledge. Key Findings of the OECD-KNOWINNO Project on the Careers of Doctorate Holders; Laudeline Auriol, Max Misu and Rebecca A Freeman (2013) Careers of Doctorate Holders: Analysis of Labour Market and Mobility Indicators, OECD Science, Technology and Industry Working Papers, 2013/04 http://dx.doi.org/10.1787/5k43nxgs289w-en
33 Vitae, (2013) What Do Researchers Do? Early Career Progression of Doctoral Graduates 2013
34 Vitae (2013)
35 L DHLE data 2008 and 2010

3.2 New models for doctoral training have resulted in concentration of funding

In an environment of declining resource, changes to funding systems have increased the concentration of public funding for doctoral training through block grants and studentships into fewer universities and around fewer research areas. These trends carry significant implications for the future capacity of the research base, the economy and society.

The effects of fiscal pressures and real-terms declines of research spending in recent years have been felt in the funding environment for PGR study: a decrease in resource has resulted in overall reduction of 18 per cent in PhD studentships available through research councils, although this was not across the board: provision by the ESRC and NERC has increased.[36]

Overall funding for HEFCE's block grant through the research degree programme (RDP) supervision fund also increased in England, as a result of the redistribution of £34 million from mainstream QR funds released as a result of a decision to cease funding for 2* rated research. This extra funding was received by the top 20 universities whilst 56 universities saw a decrease in support. Professor Mick Fuller of the UK Council for Graduate Education (UKCGE) has analysed this and other effects of the new algorithm, noting that the resulting concentration of RDP funds has 'redress[ed] the funding allocations back to where they were pre-RAE 2008' and creates contradictions where lower quality profiles are given higher quality scores, penalising universities with higher proportions of 2* research than 1* and unclassified research.[37]

Funding has also been concentrated into fewer universities as a result of other allocation reforms. The introduction of 'fewer, larger, longer' awards through Doctoral Training Partnership (DTP) and Centres for Doctoral Training (CDT) mechanisms have been compounded by alignment with priority areas and have been coupled with the removal of PhD researchers as a viable cost in the vast majority of research grants.[38] The 20 institutions at the top of the funding distribution trained 75 per cent of all research council-funded studentships in 2012-13 compared to 51 per cent in 2010-11, and over a fifth of institutions who had previously trained research council students no longer had any.[39]

Likewise, recognised excellent research units now have no publicly-funded studentships: 36 institutions with 4*-rated research currently receive no research council CDT funding. The implication is that some research students who could have worked with specialists in peaks of excellence are now not able to work in those environments as they lie outside the distribution of RCUK PGR funding.

Whilst research funding has been concentrated into fewer institutions, PhD uptake has in fact increased elsewhere in the sector. NUS analysis submitted to this review shows that Alliance universities showed the most growth in their share of UK PGR capacity, more than doubling (134 per cent) the number of PhD graduates between 2002/3 to 2012/13, whilst their collective share of research grants and contracts declined during the same period (Figure 8). The highest earning universities have seen an overall increase in their research income at the same time as a decrease in their total share of PhD graduates.

Figure 8 Increases in PGR share have been inversely correlated with research funding over the last decade

Source: NUS/University Alliance analysis of HESA Finance Returns / HESA Student Qualifiers

	University Alliance	Highest-earning 20 Universities for Research Income
% change in Doctoral graduates (2002-03 to 2012-13)	134%	41%
% change in share of UKHE Doctoral graduates (2002-03 to 2012-13)	2.8%	-2.8%
% change in total research income (in cash terms 2002-03 to 2012-13)	63%	92%
% change in share of UKHE research income (in cash terms 2002-03 to 2012-13)	-0.3%	4.9%

36 Universities UK
37 Mick Fuller (2014) The Consequences of the HEFCE Change in RDP QR Calculation, UKCGE
38 The MRC and NERC have retained separate, if small, funds for supporting PhD researcher training as part of large grants, programmes or institutes. The ESRC has recently announced it will allow those outside the DTP network to include studentships in large grant applications as part of its Postgradute Training Strategy for 2017-2022.
39 Universities UK

Whilst cross-subsidy has allowed this growth thus far, it is not a sustainable model and brings problems related to accessibility and finance. As the Higher Education Commission has pointed out, over-concentration of research funding curtails opportunities to develop early career researchers.[40] A recent report for the ESRC on their Doctoral Training Centres Network has highlighted 'significant issues' with the DTC model, particularly with regard to the concentration of resources, exclusion of excellent research units, diversity and widening access, sustainability of funding, and industry engagement.[41]

3.3 Collaboration and cohort-learning can add value to a training environment

The DTP and CDT schemes have refocused debates about value added in UK doctoral training and early indications suggest there are some benefits. Unlike the US, which embeds PhD students within larger research grants as research apprenticeships, UK funding councils have preferred a cohort training model supported by separate funding for studentships.

As there is a need to improve the robustness of the evidence base for the strengths, weaknesses and successful structures of cohort PhD training, we welcome the ESRC's recently commissioned independent and comprehensive review of their DTC Network. It found that DTCs have improved the quality and flexibility of training, fostered greater interdisciplinarity and helped to build a strong sense of a national cohort of highly-skilled and motivated researchers although, other drawbacks and problems were raised.[42] The EPSRC's mid-term review also described how the cohort model reduces isolation through the support network and opportunities for peer-to-peer learning and development, increases student satisfaction, strengthens operational management, increases flexibility, and provides better resourced (if fewer) studentships – all considered to lead to a richer training experience.[43] The embedded network and peer support benefits of bringing together cohorts of PhD students in CDTs has added value to training environments and has been adopted by other funders including the EU through Marie Curie, the Leverhulme Trust and Wellcome Trust.

In the context of cohorts, critical mass may therefore be a viable consideration for a training environment. But this mass in excellence can be, and often is, created between institutions. As many existing CDT models have demonstrated, the cohort mass for training environments does not exist solely within a single institution. Many CDTs are based on multi-institutional consortia and the true value of the network effect is to bring together a diverse and far reaching group.

Research councils have taken different approaches to consortia bids in recent allocations. The AHRC positively encouraged collaborative bids, supporting 75 institutions across 18 DTPs and CDTs, and the ESRC funded 21 DTCs comprising 12 individual institutions and nine consortia (including 46 institutions in total). The EPSRC funded 80 DTCs across 34 institutions. Cohorts of doctoral students provide an important and valuable opportunity to encourage early stage researchers to work with the best throughout the system; funding should incentivise excellence-seeking across the research base through multi-institutional and collaborative doctoral training.

3.4 Accessibility, social mobility and diversity has been reduced by over-concentration of postgraduate funding

The success of the UK's society and economy depends on widening participation to higher education at all levels. The Rt Hon David Willetts MP, when Minister for Universities and Science, recognised that postgraduate study is 'the new social mobility frontier'. Social mobility restrictions at undergraduate level are compounded further at postgraduate study.[44] The growth in self-financed PGR students increasing from 37.6 per cent in 2010-11 to 39.1 per cent in 2012-13 suggests this trend is worsening under the current funding system.[45] Therefore University Alliance has welcomed the new provisions for taught postgraduate student finance announced as part of the 2014 Autumn Statement and, as this system develops, hope that similar opportunities will be extended to research postgraduates in the future.

40 Higher Education Commission
41 Bartholomew and others
42 Bartholomew and others
43 EPSRC Mid Term Review outcomes: http://www.epsrc.ac.uk/newsevents/news/cdtoutcomes/; Universities UK.
44 HEFCE (2013) Trends in Transition from First Degree to Postgraduate Study: Qualifiers between 2002-03 and 2010-11
45 Universities UK. Analysis of HESA 2014 data

The NUS noted the following in their response to the consultations behind this report:

> 'The figures suggest that the traditional research intensive universities are not expanding their PGR numbers as quickly as the rest of the sector, despite research funding being increasingly concentrated in them. The research intensives continue to house the majority of PGR students, but relying on a small number of highly selective research universities to provide the bulk of PGR provision poses questions over access and diversity.
>
> One of the issues is the high number of students who stay at the same institution when transitioning to a postgraduate research degree. HEFCE research on trends in transition showed that in 2010-11, 60 per cent of full-time first degree graduates entering PGR study at high average tariff English HEIs stayed at the same institution[46]. The stickiness of student mobility in the postgraduate market means that trends in gender, class, and ethnic underrepresentation at undergraduate level and PGT level in highly-selective research intensives is replicated and often intensified at PGR level.'

Funding which restricts access to some universities and subjects therefore has consequences for widening participation, affecting who can study at post graduate level,[47] with similarly damaging effects for the economy as is observed in limiting access to undergraduate courses. Inclusivity agendas include broadening access to all underrepresented groups including those from lower socio-economic backgrounds, and this must be extended to the PhD training environment. Alliance universities, largely excluded from Research Council funded DTCs, are sector-leading in their support for improving outcomes for a wider range of students.[48]

The effects of fewer studentships and concentration into smaller numbers of universities has however raised concerns about a 'two-track' system which sets a worrying precedent for the future. The report on the ESRC DTCs noted that the new structure 'is a very strongly two tier one with relatively impermeable boundaries between the two', and that the barriers to entry for those outside the existing network are 'formidable and discouraging'. It recommends that smaller centres of excellence currently outside the DTC Network, especially as indicated in the results of the REF, 'should be included in future DTC commissioning processes as part of consortia bids'.[49]

3.5 Dynamism and responsiveness in the future ecosystem cannot be achieved through over-concentration in PhD funding

The House of Lords' Science and Technology Committee 2012 report into higher education in STEM subjects noted the importance of maintaining a diverse complement of training mechanisms, recommending that a variety of PhD delivery models be utilised to ensure that the UK's current breadth of expertise in science and technology is maintained.[50]

Yet shifts and concentration in the funding environment for doctoral students and consequent capacity within UK higher education have a narrowing effect. Not only are five-year cycles of funding for subjects and institutions restrictive, the exclusion of some universities with other valuable attributes, including strong industry expertise and entrepreneurial environments, from holding or bidding for publicly-funded studentships hinders the development of the next generation of researchers in areas of UK research excellence. It also prevents these institutions from experiencing and demonstrating high quality training, with implications for future funding rounds.

46 HEFCE
47 Bartholomew and others
48 University Alliance (2014) Closing the Gap. Unlocking Opportunity through Higher Education.
49 Bartholomew and others
50 www.publications.parliament.uk/pa/ld201213/ldselect/ldsctech/37/37.pdf

Similarly, senior academics with relevant expertise and skills (including those from outside academia) may be prevented from taking supervisory roles for PhD students. Given the new employment trajectories for PhD students which lie principally outside pure research roles, it is increasingly important for doctoral graduates to be widely formed in research and knowledge exchange capabilities in a way that is responsive to workforce needs. Although doctoral training funding tends to be concentrated in high-research intensive institutions, these institutions attract relatively lower proportions of their staff from private sources than other parts of the sector (see also 5.2).[51] Analysis of the ESRC DTCs noted that, although 22 per cent of studentships have non-academic collaborators, only 3 per cent were from the private sector.[52]

The closer alignment of public funding for the future generation of researchers with long-term defined research priorities should also be complemented by support for the newer research excellence (which may be riskier for institutions to invest in, although still necessary) which underpins the dynamism of the UK research base. This flexibility is essential to future-proofing the research system and will help ensure the UK remains a top destination for PGR students in a global and rapidly changing research market.

51 Ulrichsen, p. 6
52 Bartholomew and others pp. 4-5
53 Universities UK
54 Bartholomew and others p. 23
55 HESA Student number returns, 2014.

3.6 Funding implications for nurturing future researchers and innovators

Funding for postgraduates needs to be more sustainable, and less concentrated. Applications for DTPs and CDTs represent a financial risk for universities, as the required matched studentships funded by the institution may or may not materialise, dependent on the outcome of their bid.[53] Many holders of these awards are using QR and other 'in-house' monies to match fund these schemes, diverting money away from research and teaching activities.[54]

Alliance universities realise that postgraduate students are essential to the UK's research and labour force capability, and a strong doctoral community is recognised as strategically important to their institutions' research capacity and integral to university culture. They, like many other universities, are therefore willing to cross-subsidise to invest in postgraduate research - nearly 20 per cent of all PGR students are now financed directly by institutions.[55] The long-term sustainability of this approach is questionable however; the consequences may seriously affect the future capacity of the research base, and its ability to respond to the fast-paced changing requirements of research and industry.

The concentration of funding has also excluded many 'peaks of excellence' from receiving public funding for postgraduate training. Those institutions that fall outside public funding models for postgraduate research are therefore increasingly relying on investment with other funding for nurturing the next generation of researchers. These must be recognised in future cohort-based funding allocations, via consortia.

Recommendations

Funders should recognise and support the training of future researchers and innovators within peaks of research excellence

Research councils should support consortia of universities to deliver doctoral training to ensure excellence is funded wherever it is found

Case study

Mathematics

Oxford Brookes' mathematics expertise brings Sony-funded PhD students

Oxford Brookes' researchers shared their computer vision expertise to help enhance interactions in augmented reality systems, directly contributing to the development of Sony's Wonderbook™. Through the understanding and utilisation of the complex mathematical theory behind computer vision, the partnership was able to create a robust human hand tracker and segmenter that could calculate the position of the player's hand and segment it in a live video in real-time. The resulting display enables books to 'come to life' in dramatic new ways that can be used for entertainment and education.

Sony Computer Entertainment Europe reported that their partnership with Oxford Brookes saved a significant amount of time and money in development and research efforts and have funded three PhD students at the university, as well as creating a hand tracker through a KTP with the university.

Case study

Assistive technology for healthcare

University of Hertfordshire PhD start-up improves sociability for children with autism

Researchers at the University of Hertfordshire developed the humanoid robot Kaspar to help children with autism learn about human communication and interaction. This research led to the development of human-robot interaction technology, interaction scenarios and methods, and stimulated national and international public discourse on robot-assisted therapy for children with autism.

The research also helped to provide knowledge on how to use robot technology in austism therapy. Results have showed positive impact in helping children improve their ability to interact socially. It has also helped change public perceptions about the utility of robots as assistive technologies for autism.

This expertise allowed a former Hertfordshire PhD student to establish an international robotics start-up business Que Innovations through development of QueBall, marketing toys for children with autism.

A New Doctoral Training Alliance

Alliance universities are committed to maintaining the pipeline of relevant and diverse future high level skills for the research ecosystem. Recognising the value of cohort-based learning and employer co-designed training programmes, Alliance universities are working collaboratively to deliver a new doctoral training scheme. The Doctoral Training Alliance will be built around joint research strengths and embed close relationships with industry from design to delivery.

4 | Collaboration optimises the system

As we have seen, selectivity and specialisation - driven by healthy competition - are an essential part of the research and innovation ecosystem. These result in a biodiversity represented through a plurality of skills, expertise and activities throughout the ecosystem.

This biodiversity is optimised at the system level through collaboration – a vital interdependency which drives innovation and progress. Existing capacity in the ecosystem is made more productive in this way, and the importance of collaboration has been enshrined in the Government's science and innovation strategy for the next decade.[56] Elsevier analysis suggests that UK researchers are 'highly collaborative' but that the country fits a pattern of 'high and rising rates of international co-authorship with moderate and falling institutional co-authorship rates'.[57]

Universities are used to switching from collaborative to competitive mode, a healthy 'coopetition' made necessary by funding demands and striving for excellence. But the switch from competitive to collaborative mode is not always that smooth, and certain systemic disincentives work against it, creating an atomised landscape that fails to maximise the full capacity and potential across the ecosystem.[58]

The optimal equilibrium of competition and collaboration is therefore essential to get right. Connectivity, collaboration and openness are essential to the future of world-leading science: teams of people, not individuals, have driven the advances of the modern technological age.[59] Similarly, whilst strong public funding for research is essential, in times of straitened public spending there also needs to be greater efficiency, smarter deployment of resources and leverage of other sources of funding for research. Collaboration helps deliver cost efficiencies, reduces duplication and maximises capacity throughout the ecosystem. The UK's evaluation and funding structures need to respond.

Over 100 years of partnership working

Collaboration with industry and with other university partners' complementary strengths is essential to the missions of Alliance universities, as demonstrated in the case studies throughout this report. Having built strong strategic partnerships with businesses for over a hundred years, Alliance universities know that multi-disciplinary and multi-partner approaches are key to problem solving and innovation, and that the connectivity they provide with local, national and international partnerships act to bring real value to society.

University Alliance is also undertaking and supporting efforts to extend existing geographically organised equipment sharing schemes nationally and to business, bringing the benefits of sharing resources to the wider research ecosystem.

4.1 Collaboration and plurality improve the impact and value for money of UK research

Connectivity and collaboration are essential. This report examines various elements of this in practice. Connectivity is the reason why the very smallest research units grow in quality as they expand.[60] Connectivity also underlies the advances made by cohort training of PhD students across consortia of universities. Collaborative working with partners inside and outside universities allows specialists to combine their expertise to create new and innovative advances. As one expert has put it: 'Many great innovations … have been driven by strengthening cross-disciplinary and cross-sectoral communication – many more innovations are possible if we work at fostering these interfaces and unconventional partnerships.'[61]

56 HM Treasury and Department for Business Innovation & Skills
57 Elsevier and BIS p. 59
58 As described by Rt Hon David Willetts: Chris Havergal, 11 December 2014, 'Universities Need More Collaboration, Less Competition,' Times Higher Education, http://www.timeshighereducation.co.uk/news/universities-need-more-collaboration-less-competition/2017464.article
59 Walter Isaacson (2014) The Innovators: How a Group of Hackers, Geniuses, and Geeks Created the Digital Revolution
60 See n. 19
61 Ralph Rayner (2014) Connectivity – the Glue that Drives Innovation, FST Journal, 21, pp. 5–6

Other benefits of collaborative working include funding by network, ensuring that funding reaches the best delivery partners and helping to fund excellence wherever it is found.[62] This can achieve complex outcomes through multi-partnered responses: creating a critical mass of the best across the system, not restricted to unit level.

Yet the importance of collaboration often gets lost in the highly competitive world of research funding. Unpublished HEFCE analysis has found that at least 25 per cent of papers submitted to REF 2014 were co-authored by staff from two or more UK universities. Compared to Elsevier's latest benchmarking analysis for BIS,[63] where at least 15 per cent of all papers are written with authors at other UK institutions, the message is clear. Collaborative UK research is a valuable part of this ecosystem and improves quality. Likewise, interdisciplinary collaborations often prove to be the most innovative.[64]

This is not to mention the many other collaborations with non-academic partners which are not represented in 'outputs', although the tip of the iceberg is described in the thousands of impact case studies. Collaboration with research partners outside academia also ensures benefit to wider society, the spread of ideas and value for money.

Most business challenges need multidisciplinary responses. Wider changes in the relationship between business and academic worlds, moving from transactional to strategic relationships, are helping to realign ambitions. Case study examples throughout this report show how important end-user access into the research base can be directed through entry points into multi-disciplinary research. Portals and open doors are essential to ensure all sectors have access to world-leading research, an approach which University Alliance institutions have embedded across their activities.

4.2 Funding implications for supporting essential collaboration

At the level of the individual researcher, there is considerable drive to collaborate with excellent complementary partners. Funding principles should create an environment which encourages networked collaboration, through increasing opportunities for collaborative, inter-institutional working, including for example multi-partner doctoral training schemes.

But whilst Science 2.0, the open access agenda and open innovation are steering policy discourses, there remain systemic disincentives to these agendas, creating barriers to the switch from competitive to collaborative mode. One way to address these barriers is to recognise collaboration better. The USA measures and captures collaboration by counting R&D expenditures passed through to other academic institutions or received by institutions as subrecipient funding. Nearly 90 per cent of these 'pass through' funds in the financial year 2009 were federal (public) funds.[65]

Similar attempts in the UK to measure collaborative pursuits would recognise the institutions who already prioritise them, as well as help to incentivise collaborative activities further. Currently, funding councils do not track with consistency 'pass through' funds. In many cases, holders of large grants choose to work with other providers who are better placed to deliver elements of their project. Recognising the contribution of these institutions who receive funds 'second hand' would help public funders understand better where excellence lies throughout the system, as traced through the investment preferences of collaborators. It would also allow any funding mechanisms reliant on algorithms of previous award levels to reflect more accurately where these public funds were spent.

Other simple tweaks such as recognising co-investigators and their home institution as well as principal investigators in funding audits (the AHRC are leading the way with this practice), and considering systems of transitive credit which can help give appropriate recognition to all individuals in a team for their work,[66] should also be considered.

The Government's request for HEFCE to lead a programme enhancing collaboration which includes the recognition of collaborating institutions, and involving Research Councils UK and other partners, should therefore be much welcomed.[67]

Recommendations

Funders should encourage more collaborative and interdisciplinary research pursuits through open competition, including doctoral training schemes

Funders should recognise the contributions of collaborating institutions through tracking 'pass through' funds and recognising Co-Investigators

62 David Watson, 3 April 2008, 'Getting it together', Times Higher Education: http://www.timeshighereducation.co.uk/401289.article
63 Elsevier and BIS
64 See for example the role of design with other disciplines in solving challenges: University Alliance and Design Council (2014) Design& Education: Creating the Future
65 National Science Foundation (2012) Science and Engineering Indicators
66 Daniel S Katz (2014) Transitive Credit as a Means to Address Social and Technological Concerns Stemming from Citation and Attribution of Digital Products, 2, 1–4
67 Department for Business Innovation & Skills (2015), Grant Letter to HEFCE, n. 18

Case study

Computer Science

University of Salford-led virtual reality research drives creative collaboration at Jaguar Land Rover

Researchers at the University of Salford have developed the first virtual reality system capable of communicating eye gaze between moving people, helping Jaguar Land Rover to improve and simplify its design process and open a new visualisation facility which has led to highly innovative car designs.

Salford led the multi-partner EPSRC-funded 'Eye-catching' project, working with colleagues at UCL, and the Universities of Reading and Roehampton to drive advances in understanding of the balance between visual and spatial qualities of shared simulations. The collaborators found that the best teamwork and conversations taking place in virtual reality environments were related to how well they were spatial matched to the task and display, and that using fine detail improves the quality of users' experience. The result was the first communication system capable of communicating eye gaze between moving people.

Jaguar Land Rover (JLR) explored with Salford's researchers how virtual reality technology could be used in the automotive industry, employing these principles to design JLR's Virtual Reality Centre at its Gaydon Design and Engineering Centre in 2008, before further investing in a new Virtual Innovation Centre (VIC). The new VIC provides a more flexible and sophisticated range of functions, which are being used by more departments across the business. Employees use the virtual reality tools to work faster and smarter, achieving higher levels of quality, durability and reliability in their vehicles with less reliance on expensive and time consuming prototypes.

The opening of the VIC in July 2013 reinforced JLR's position as an auto industry leader in harnessing the benefits of virtual reality and high-end visualisation. Already it has played a crucial role in the delivery of the Range Rover Evoque – internationally acclaimed as one of the most exciting design concepts of its age – the new Range Rover and Range Rover Sport, and the Jaguar F-Type sports car.

Case study

Manufacturing

Northumbria collaboration generates profit from improved performance of metal cutting tools

Research undertaken by the University of Northumbria in close collaboration with SNA Europe has resulted in the development of new tooth design for metal cutting tools, new coating techniques and new production technologies.

The collaboratively designed research focused on understanding the fundamental mechanisms of material removal and evaluating the optimum performance, efficiency and lifespan of existing tools, with special attention to the cutting performance for wear-resistant and difficult-to-cut materials such as ball bearing steel, stainless steel, Ni–Cr–Mo steel and titanium alloy (Ti-17, which is widely used in aerospace industry).

These results fed into new products which are marketed and sold internationally, and include well known retailers such as B&Q, Homebase and Screwfix. The collaboration has led to 140 per cent per annum return on the research investment, new sales revenue of £2m, reduced manufacturing time and costs and improved life of products.

Case study

Healthcare

Lincoln research pioneers imaging technology in the fight against cancer

An award-winning EPSRC-funded consortium led by the University of Lincoln with the Institute of Cancer Research, University College London and The Royal Marsden Hospital has created DynAMITe: the world's largest radiation-tolerant silicon imager. Designed primarily for medical imaging and 200 times larger than the processing chips in current PCs and laptops, its image clarity shows the impact of radiation on tumours, as well as assisting detection in the earliest stages of disease progression.

Spin-out company Image Sensor Design and Innovation Ltd has signed agreements with a global medical technology company for the exclusive design and provision of all future large area imagers and three international patents have been submitted as well as attracting extra translation funding from the Wellcome Trust.

A new collaboration with the University of Liverpool will combine the imaging techniques from Lincoln with detectors produced at Liverpool to develop unique medical imaging technology that will provide accurate proton therapy doses and 3D images of where radiation is absorbed at a tumour site.

Case study

Mathematics

Manchester Metropolitan University research improves energy generation through wave modelling

Advanced computational fluid dynamics models and software developed by Manchester Metropolitan University researchers and their collaborators are helping the UK to meet ambitious government targets to deliver 15 per cent of energy from renewables by 2020.

Researchers working within Manchester Metropolitan University's Centre for Mathematical Modelling and Flow Analysis have developed advanced computational fluid dynamics models and software, applied to hydrodynamics following their original development for aeronautical research. Their work is helping to increase understanding of future impact of climate change such as sea level rises and increased storm activity. These can have critical implications for the safe deployment of existing and future offshore structures for both wind and wave power.

MMU researchers developed the AMAZON suite of flow codes, which examine different properties of waves such as generation, steepening, overturning and breaking over a structure.

Funded by the EPSRC, the team also collaborated with partner laboratories at Bath, Edinburgh, Hull, Lancaster, Manchester, Oxford, Plymouth and Queen's Belfast universities, to develop and deploy technology to push the boundaries of wave energy generation. Experimental studies in these labs allowed the team to construct a detailed, validated, computational model in the form of a so-called numerical wave tank that can simulate both laboratory-scale and full-scale devices in realistic wave climates.

The researchers also developed, with QUB, OYSTER wave energy converter technology which has been deployed in almost 30,000 homes after the Scottish Government granted a license to Aquamarine Power Plc to develop the world's largest grid-connected commercial wave power array.

4.3 Openness and efficiency drive productivity from existing capacity

Efficiency savings, for example those made through asset sharing and open data, are another important benefit of collaboration, and will help drive productivity amongst existing capacity in the ecosystem. Opening up access to the national research infrastructure is a crucial element of maximising existing capability within the research and innovation ecosystem. Connectivity and collaboration therefore need to be embedded within all national capital projects, as well as those of individual institutions.

The UK boasts a wide-ranging and valuable innovation resource in its cutting edge research equipment. Assets exist across the country, often residing in universities and research centres, many of which are funded by public money in the first instance. These assets are incredibly valuable at all stages of the research and innovation cycle, for proving, testing and scaling up – for academics and industry developers alike. But these assets are numerous, dispersed and – all too often – not visible. New initiatives by Innovate UK and the National Centre for Universities and Business (NCUB) to develop national brokerage systems to improve connectivity within the research and innovation ecosystem should therefore be warmly welcomed. These will help integrate and connect different actors within the research and innovation ecosystem and help direct access to relevant equipment, data and research, as well as business expertise.

Alliance universities consider their research assets to be part of this national research infrastructure and, like many universities throughout the ecosystem, have proven that they are keen and willing to share resources to maximise their use and reach, in all types of all assets (including data and even 'shelved' IP). Good progress is being made towards a more efficient system following the Wakeham and Diamond reviews, and will be driven further by the latest report on efficiencies by Professor Sir Ian Diamond and Universities UK.[68] Certain key principles will ensure maximum efficiency is achieved.

Alliance universities believe that their research equipment should be available to and easily accessible by local and national industry users as well as academics, and are working collectively to improve information sharing and simplify access arrangements to research assets. They are already ensuring their significant capital research assets are available and productive for a wider cohort of users, including industry of all sizes, as examples here show. SMEs need support to increase their R&D investments, which lag behind international comparators. Opening university research facilities to these businesses is an essential element in the integration of the research and innovation ecosystem and realising the benefits of the UK's world-leading research environment.

4.4 Funding implications for maximising existing capacity

Efficiency and collaboration drives need to recognise valuable research assets wherever they exist. Geographical locality in sharing research assets matters to a greater or lesser degree, depending on the uniqueness of the asset – researchers and industry developers would travel far and wide to reach a uniquely powerful microscope, or the only testing facility of its kind. Yet many existing asset sharing schemes have been set up on an exclusive basis, both in geographic terms, and with restrictions on partner organisations. These pioneering schemes have created useful learning and best practice models in sharing equipment. But there is still a long way to go to a national system, particularly in terms of extending these benefits more widely amongst universities and business. For example, restricting sharing schemes to research intensive universities automatically and senselessly excludes a wide range of unique and valuable assets and business partners.

Where national and international-level investments are made in capital projects, for example the Catapult Centres and large national centres, these must be neutral. They should seek to work with – and be accessible by – excellent researchers and research teams throughout the UK's research and innovation ecosystem, wherever this excellence is found. Through this collaborative and excellence-seeking approach, resources will be shared for maximum benefit to the ecosystem.

Recommendations

Universities should continue to work proactively to share research assets with each other and industry

National bodies should work with universities towards an open, accessible and inclusive national asset sharing system, to make best use of the national innovation capability

National and international-level research facilities should be open to all researchers

68 W. Wakeham (2010), Financial Sustainability and Efficiency in Full Economic Costing of Research in UK Higher Education Institutions; I. Diamond (2011). Efficiency and Effectiveness in Higher Education

Case studies: Asset sharing with other universities and industry

The **University of Salford**'s Energy House and Lab is the world first and only full size house within a fully environmentally controllable chamber, in which climatic conditions (rain, snow, wind and temperature) can be specified to high levels of accuracy and patterns monitored. Salford Energy House therefore provides a unique testing and development facility in which leading researchers can work collaboratively with industry to develop and test new technology and solutions to improve the energy efficiency of existing projects and processes.

Manchester Metropolitan University has assembled a unique aircraft exhaust measurement facility (Alfa) with the Universities of Sheffield and Manchester. The joint facility includes a gas and aerosol-sampling rake capable of traversing the core of the aircraft plume; high-resolution time of flight mass spectrometer system for incorporation into an existing Aerodyne aerosol mass spectrometer at the University of Manchester; and a fully equipped mobile combustion laboratory at the University of Sheffield. Elements of the Alfa joint facility have been used by the three partners in a number of programmes. These include work for Shell and Rolls Royce on aircraft engine exhaust emissions composition.

The £19 million Marine Building at the **University of Plymouth** contains the Coastal Ocean and Sediment Transport (COAST) laboratory and the Marine Navigation Centre. The COAST laboratory contains cutting-edge wave tank testing facilities that are unmatched in Europe, allowing researchers and businesses to design, conduct and report on bespoke experiments, particularly in offshore renewable energy. The wave tank facility is co-located with the Marine Innovation Centre, which aims to make the South West's marine and maritime businesses globally competitive; accelerating growth by creating intelligent connections between organisations, world-class knowledge, technologies, people and infrastructure.

Oxford Brookes University holds a new £1 million Zeiss 3D scanning electron microscope – currently the best in the UK – which is regionally shared (with the University of Oxford). Following original funding from BBSRC, Oxford Brookes are developing plans to build a new lab around the microscope to improve performance and researcher accessibility.

The **University of Portsmouth** is part of the South-East Physics Network (SEPnet), an alliance of ten physics departments across the south of England and holds the SEPNET Computing Infrastructure for Astrophysical Modelling and Analysis (SCIAMA) supercomputer. Over 30 per cent of the computing time on the £350k SCIAMA-I supercomputer goes to other SEPnet partners. Another shared SEPnet facility at Portsmouth is the Low Frequency Array (LOFAR) telescope, now funded by STFC.

Nottingham Trent University opened the £4.4 million Rosalind Franklin Building in October 2012, providing customised research space for external users to access X-ray imaging/diffraction, multinuclear NMR, new chemistry research laboratories, and other analytical equipment complementing its wider existing provision for Smart Materials and Human Interface Technology laboratories; providing a showcase of research capability and expertise as part of the University's industrial engagement strategy.

Assets are also made available for other users, including community based and practitioner users. **Cardiff Metropolitan University**'s National Centre for Product Design and Development Research underpins collaborative research in partnership with Abertawe Bro Morgannwg University Health Board funded through the Advanced Surgical and Technologies Network. Three-Dimensional scanning devices allow community-based users to acquire anatomical data in a non-invasive accurate way for the production of medical prostheses.

5 | Responsiveness delivers the greatest benefit from research

A healthy ecosystem is one that can adapt flexibly to an ever-changing environment. The responsiveness of an ecosystem relies on different agents within it engaging in a highly networked manner. For researchers, this means engaging with, being informed by and having an impact on the users of research, leading to smarter exploitation of this knowledge. It also relies on an attitude of willingness to work with the needs of users or partners to deliver solutions, rather than simply pushing out knowledge created without reference to these partners.

5.1 The impact agenda is helping drive broader benefits from publicly funded research

This element of responsiveness within the ecosystem is not measured by many traditional research indicators, like data on research outputs and citation analysis. Assessment of research excellence has traditionally looked inwardly to the scholarly community for validation of quality. Frequently-cited bibliometric statistics are used to underline the efficiency and quality of the UK's research base: the UK is responsible for 9.5 per cent of downloads, 11.6 per cent of citations and 15.9 per cent of the world's highly cited articles, and is now ranked first in the world for field-weighted citation impact.[69]

But these evaluative frameworks for research are no longer sufficient on their own. In the first instance citations are a poor predictor for quality as determined by peer review, as a recent comparison of the h-index and REF 2014 shows.[70] Bibliometric analyses also tell us only about outputs and the reach of research within academia, and not about its outcomes more widely – about the value of UK research to global and local society.

The impact agenda is helping to change this. Research impact is, simply put, any non-academic outcome to which research was essential. Those within academia understand that research is best understood as a complex and inter-related spectrum of activity, from exploratory and curiosity-driven research to research aimed at industry solutions. Complex feedback loops continually inform all parts of the spectrum and can create impact at any stage.

The impact agenda has begun to tackle the mismatch between the societal and economic objectives of publicly-funded research and the much narrower view of research excellence taken by some evaluation systems. Impact is now a substantial (20 per cent) part of Research Evaluation Framework criteria and a key element of research council bid valuations in the form of Pathways to Impact and Impact Summaries. Other countries are watching closely as funding bodies in the UK pioneer impact criteria as a substantive element of research assessment. Increasingly knowledge exchange and impact activities are being rewarded by institutions in terms of appraisals and promotions.[71]

The thousands of impact case studies submitted to the REF 2014 and examples throughout this report demonstrate just a small amount of the value that long-term investment in research brings to society. Demonstrating this utility and value of university research is an imperative for policy makers and academics alike. The impact agenda places this aim at its heart, widening the accountability of researchers and their publicly-funded activities.

69 Elsevier and BIS

70 O. Myrglod and others (2014) Predicting Results of the Research Excellence Framework Using Departmental H -Index, arxiv, 1411, 1–13; O. Myrglod and others, 'Predicting Results of the Research Excellence Framework Using Departmental H -Index – Revisited', Forthcoming.

71 Vitae (2013) HR Strategies for Researchers: A Review of the HR Excellence in Research Award Implementation Activities across Europe, p 13. Vitae (2010) The Engaging Researcher. Vitae (2012) A Career Development Perspective of UK Researcher-Business Interactions 2012. Laura Fedorciow and Julie Bayley (2014) Strategies for the Management and Adoption of Impact Capture Processes within Research Information Management Systems, Procedia Computer Science, 33, 25–32 http://dx.doi.org/10.1016/j.procs.2014.06.005

5.1.1 Limited correlation between impact and output ratings in the REF highlight the shortfalls of inward-looking indicators of research quality

Importantly, analysis of the REF 2014 results demonstrates that highly-rated impact case studies and highly-rated research outputs correlate moderately over the period of the REF, as the charts in Figures 9 and 10 show. This correlation should be expected due to the selection of the strongest submissions. However, a good output score does not necessarily translate into strong impact: whilst both activities are important, output score is a poor predictor of impact – around two thirds of the variation in impact is not explained by output.[72]

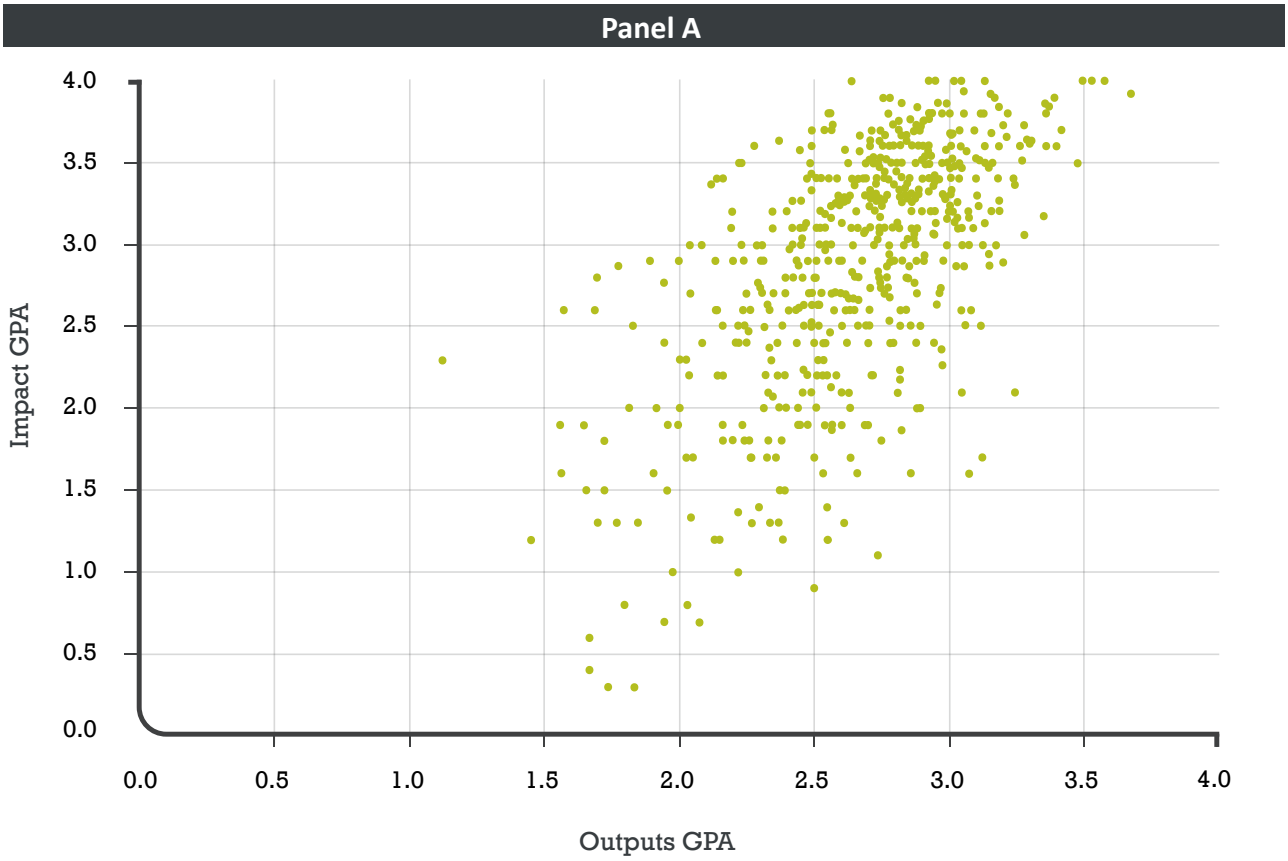
Figure 9 Outputs are a poor predictor of impact - many high impact ratings have low output ratings and vice versa

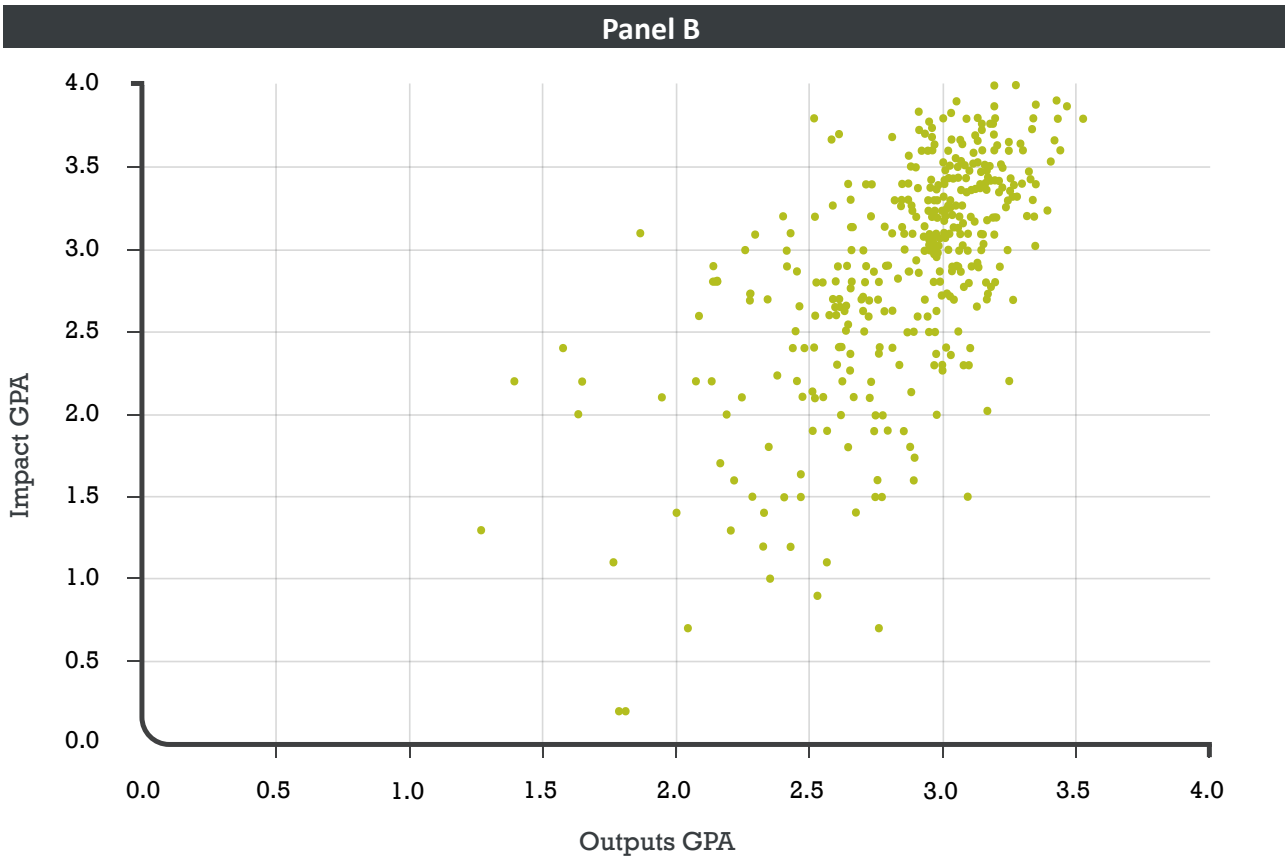
Source. HEFCE REF 2014 results data – all UoAs

72 The coefficients of determination for a simple linear regression of outputs on impact in Panels A-D are, respectively, 0.361, 0.404, 0.393, 0.235

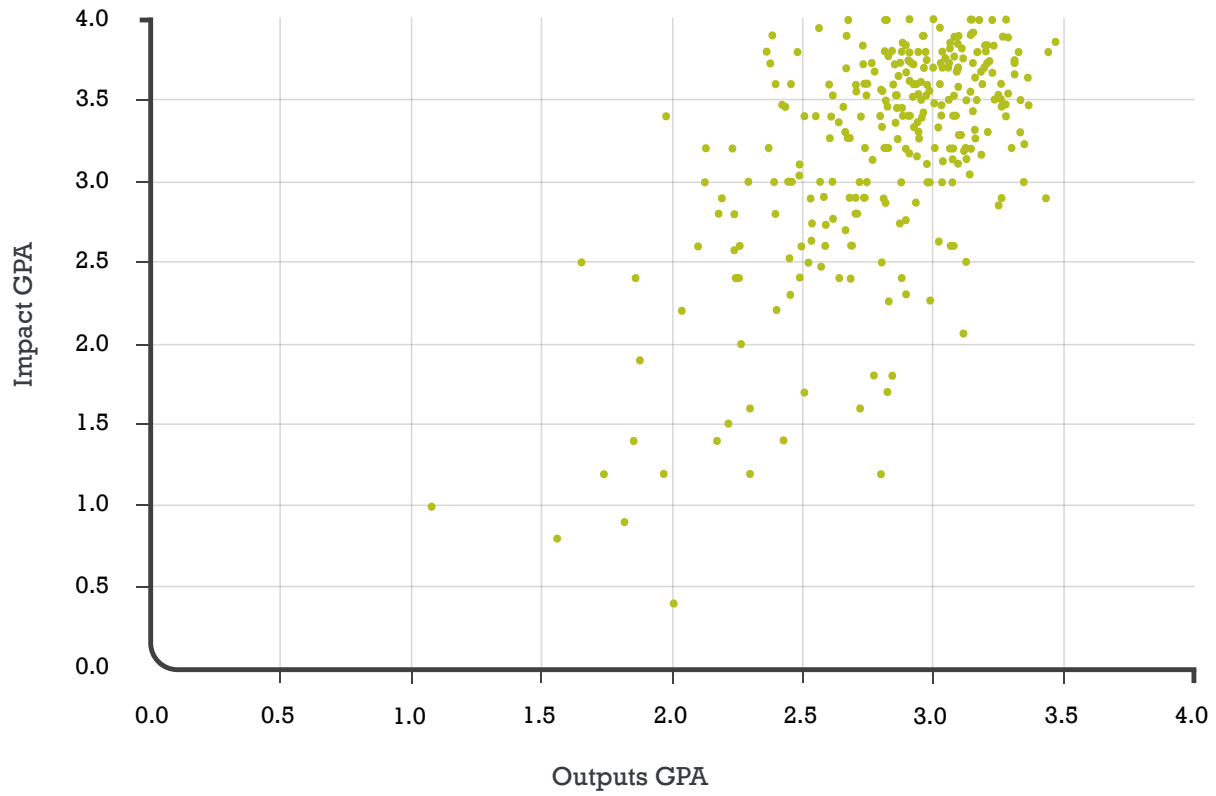
Figure 10 Correlation between impact and output ratings are moderate but vary between subjects

Source. HEFCE REF 2014 results data

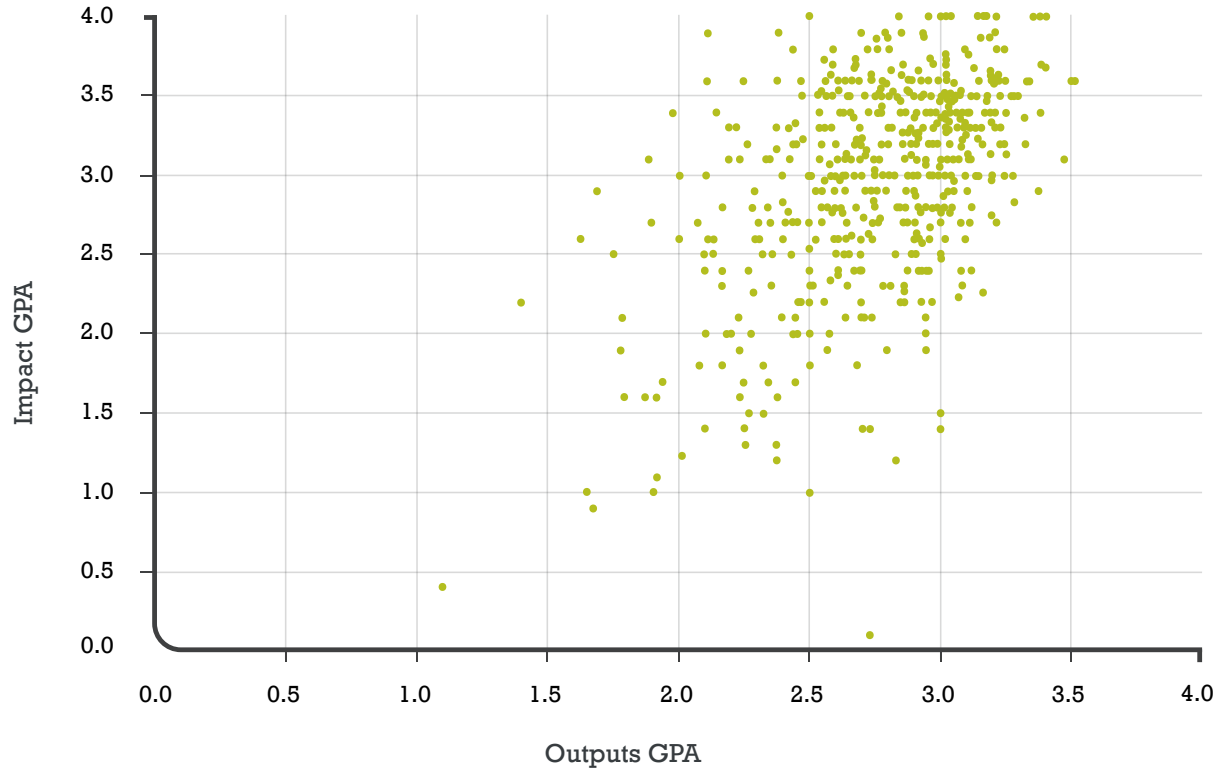




Panel C



Panel D



One explanation for this is that staff concentrating on impact work may not necessarily be the same people who produce 3* and 4* research, partly due to time constraints. This highlights the need for research clusters that cover a full range of activities: effective team collaborations are needed to maximise the REF return.

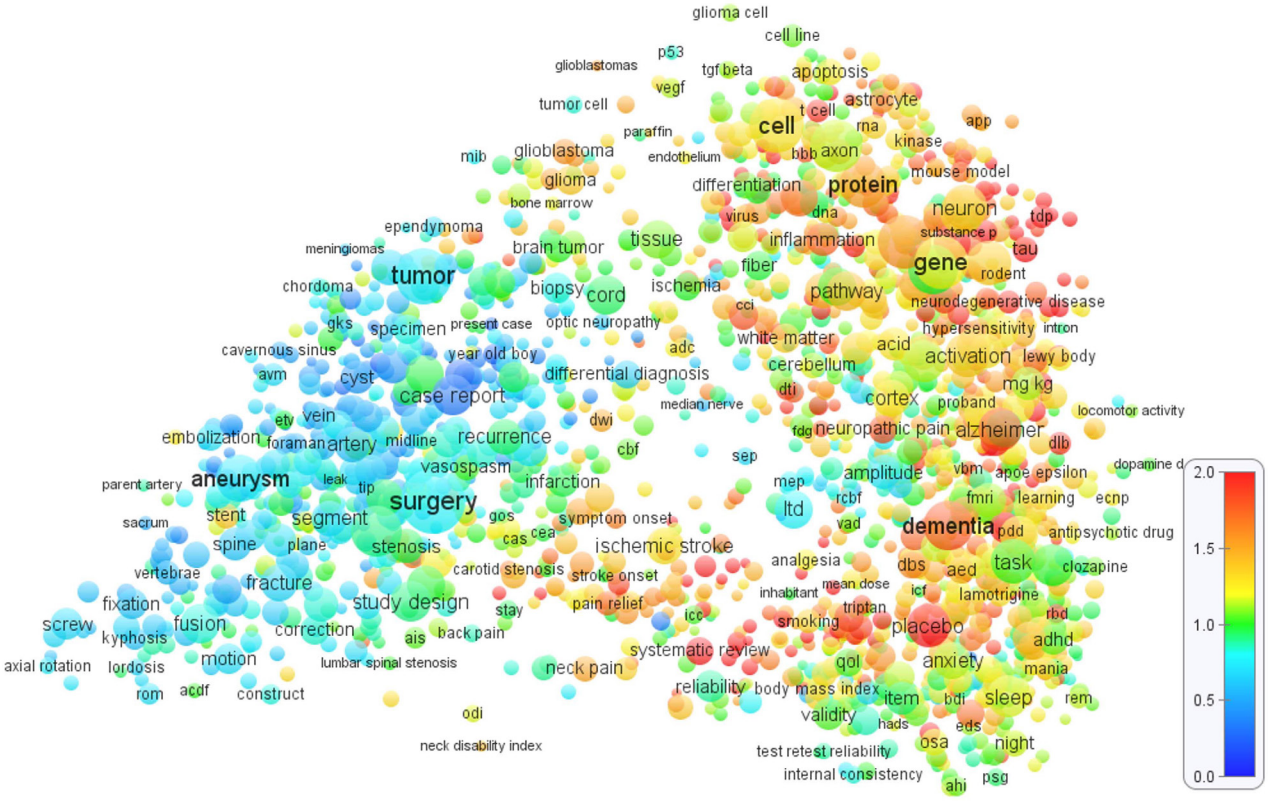
Other issues including time lags to impact and inherent biases within citation practices which can under-prioritise work with more immediate societal impact. A recent study of bibliometrics has shown how the citation impact of clinical intervention research may be substantially underestimated in comparison with basic and diagnostic research.[73] Figure 11 shows a term map for Clinical Neurology, based on natural language processing of 2,000 terms from publications in the Web of Science. Size and colour indicate (respectively) the number of publications in which the term occurs and the average citation impact of these publications (blue represents a low citation impact, green a normal citation impact, and red high citation impact).

As is evident, the most common terms relating to clinical practice (towards the left) have a lower (blue) citation impact than those on the right, representing basic research. The implications for researcher behaviour, if performance assessments were based on citation metrics, may be to discourage research in clinical intervention in favour of fundamental research. Certainly more money is spent on the latter, and further studies have found that clinical research has a greater impact than basic research. Both activities are essential for society, existing on a co-dependent spectrum, but current evaluative structures may not have the balance quite right in encouraging research with impact.

The importance of measuring research impact in evaluations of research quality is therefore essential for the responsiveness of the ecosystem.

Figure 11 Research with more immediate impact may be disadvantaged by output-only evaluations

Term map for Clinical neurology, from Van Eck et al.



73 Nees Jan van Eck and others (2013) Citation Analysis May Severely Underestimate the Impact of Clinical Research as Compared to Basic Research., PloS one, 8, e62395 http://dx.doi.org/10.1371/journal.pone.0062395

5.1.2 Systems for measuring, recognising and rewarding impact should be optimised

Research impact is achieved in many ways and by various knowledge exchange interactions that can be hard to capture. Any system of measurement and evaluation must be responsive to the subtleties of the variety of forms research brings value to society. In the UK and elsewhere, including Australia, the question of how to identify and assess the impact of research has been the subject of extensive consultation.[76]

These international consultations have shown that the case study approach is the most useful for analysing this element of research quality, confirmed by feedback from REF 2014 panel members. Narrative approaches to impact description allow the subtlety and variety of impacts to be captured, as testified by the rich resource of nearly 7000 impact case studies submitted to HEFCE for the REF 2014. Detailed analysis of these is underway to improve understanding of the impact of university research on society, and will help develop future evaluation systems.[77]

Because of this multiplicity of routes and types of impacts created, doubts have been raised about using metrics to act as a proxy measure for research impact,[78] although these are being used and developed as performance and behaviour tools as much as for assessment.[79] Even the economic impacts of university research are difficult to capture by standard econometric evaluation: the value that training brings, both for the researcher and to partners is one example of this.[80] In some subjects, including health-related subjects, it is possible to undertake high-quality analytical research to measure the monetary value of research,[81] but routinizing this across all disciplines and impacts in a cost-effective way is much more challenging.

Metrics-based measurements of impact are one element of the current independent review chaired by Professor James Wilsdon, which will report later this year.[82] It is unlikely that the diversity of the research base and the impact that arises from that research will ever be captured by a set of impact metrics, and that case studies, qualitative approaches and narratives will dominate. The technological challenge will be to see how far automated text mining approaches could be employed to ease the cost of assessment and analysis: analysis by the Policy Institute at King's College London due later this year will shed further light on this.

Innovative dual electric/hydrogen fuel cell technology developed by researchers at Coventry University underpins the work of spin-out Microcab Ltd, delivering the eco-friendly car of the future.

Powered by Microcab's most advanced 3kW fuel cell, the lightweight zero-emission vehicle H2EV combines hydrogen with oxygen to create electricity. Unlike a battery-powered electric vehicle, there is minimal 'recharge' time: H2EV can be refilled with hydrogen in minutes to run for 100 miles.

The West Midlands has excelled in the field of low emissions automotive technology for years, but Coventry University's research has put it on the global low carbon industry map. Technical collaborations with automotive and motorsport industries, including Delta Motorspot and Lotus, allowed production-ready versions of small economical hydrogen fuelled cars to be delivered several years ahead of larger competitors and enabled a number of organisations to benefit economically through the potential to diversify into this new market.

Case study

Green automotive

Spin out company MicroCab brings Coventry research and cleaner air to our roads

74 Matthew Glover and others (2014) Estimating the Returns to UK Publicly Funded Cancer-Related Research in Terms of the Net Value of Improved Health Outcomes, BMC Medicine, 12, 99 http://dx.doi.org/10.1186/1741-7015-12-99; Jonathan Grant, Liz Green and Barbara Mason (2003) Basic Research and Health: A Reassessment of the Scientific Basis for the Support of Biomedical Science, Research Evaluation, 12, 217–24

75 Warnings have been sounded about the integration of impact factors into research assessment: B. R. Martin (2011) The Research Excellence Framework and the 'Impact Agenda': Are We Creating a Frankenstein Monster?, Research Evaluation, 20, 247–54 http://dx.doi.org/10.3152/095820211X13118583635693

76 Molly Morgan Jones and others (2013) Assessing Research Impact An International Review of the Excellence in Innovation for Australia Trial.

77 http://www.hefce.ac.uk/news/newsarchive/2014/news88461.html

78 Molly Morgan Jones, Jonathan Grant and RAND Europe (2013) Making the Grade: Methodologies for Assessing and Evidencing Research Impact, in 7 Essays on Impact, ed. by Andrew Dean, Michael Wykes, and Hilary Stevens (University of Exeter), pp. 25–35

79 Such as the system developed at Coventry University: http://blogs.lse.ac.uk/impactofsocialsciences/2014/02/07/eric-impact-management-tool-for-academics/

80 Ammon J. Salter and Ben R. Martin (2001) The Economic Benefits of Publicly Funded Basic Research: A Critical Review, Research Policy, 30, 509–32 http://dx.doi.org/10.1016/S0048-7333(00)00091-3

81 Glover and others

82 http://www.hefce.ac.uk/whatwedo/rsrch/howfundr/metrics/

Case study

Marine SMEs

Marine SMEs benefit from collaboration with Plymouth's world-class research

The University of Plymouth is harnessing its marine expertise for economic growth through its new Marine Innovation Centre (MarIC), established to optimise the interface between the University and Marine Sector SMEs. The Centre promotes the industrial uptake and commercialisation of the University's research and world-class facilities, links businesses to the Growth Acceleration and Investment Network (GAIN) and improves SME performance by stimulating innovation and the successful exploitation of new ideas.

The £1.97m project has drawn on investments from industry, ERDF and the University. MarIC expects to deliver a gross increase in GVA of £3.726m and a gross safeguarded GVA of £1.674m through business assists and the creation of new jobs, additional firms involved in business clusters or networks, SMEs launching new or improved products, and gross jobs created in environmental sectors.

Case study

Advanced manufacturing

Sheffield Hallam research is transforming the life span of materials

After Sheffield Hallam University upgraded its high power magnetron sputtering (HIPIMS) technology to industrial production grade with an automated system, it was in a unique position to transfer its research to the industrial sector. HIPIMS uses a powerful plasma discharge to generate an ionised vapour to pre-treat surfaces of target components, or to deposit a range of coatings such as 'fully dense' hard coatings.

The University has licensed the technology to a series of manufacturers worldwide looking to enhance the surface properties of a wide range of materials. This has led to more than £5 million worth of sales for these manufacturers and brought in more than £200,000 in licence income for the university.

The researchers collaborated in 2011 with the Gillette Company (USA) on work which led to a patent for a new HIPIMS-based process for manufacturing razor blades with a high aspect ratio cutting edge and improved shaving properties. A partnership with the Space Science Technology Department of the Rutherford Appleton Laboratory (UK) overcame a long-standing issue with their cryo-coolers for satellite applications, leading to their satellites being judged flight worthy and superior to competitor technologies. In 2013 they began a three-year R&D contract with Rolls Royce to develop HIPIMS technologies to improve the performance of aero-engine turbine blades.
The research group have also established in 2010 a joint Sheffield Hallam University-Fraunhofer HIPIMS Research Centre – the first such centre in the UK. The centre is working on a large EPSRC-supported collaboration to develop high efficiency solar-cell glass panels with Pilkingtons (UK), Gencoa (UK) and Von Ardenne (Germany).

5.2 Knowledge exchange activities are essential to delivering societal and economic value from research

The contribution of excellent research to society and economic growth includes 'creating new businesses, improving the performance of existing businesses, delivering highly skilled people to the labour market, and attracting investment from global businesses.'[83] Universities play an important bridging role in achieving these types of impact.

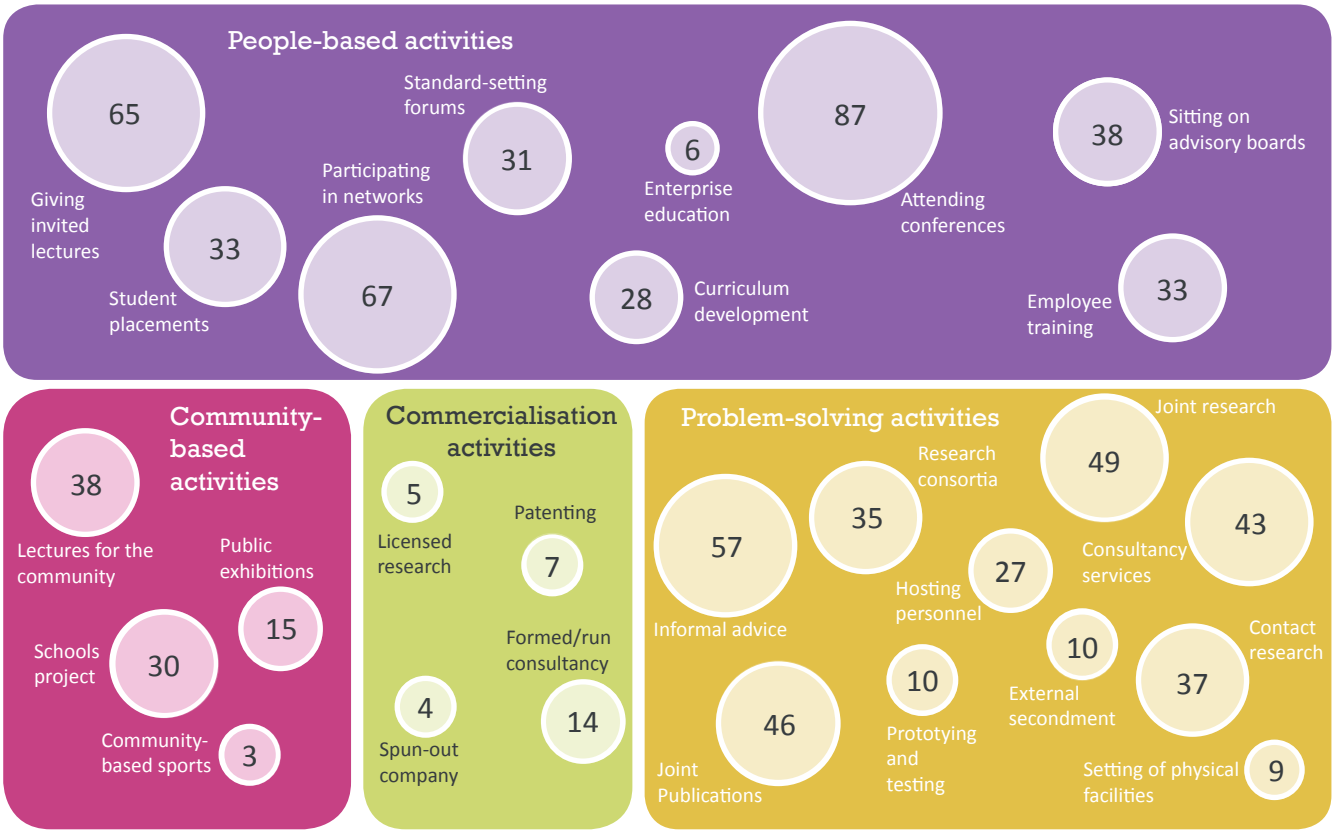
But direct research impact is in fact just one of the many achievements of a range of knowledge exchange channels and interactions (Figure 12).

Knowledge exchange

Knowledge Exchange (KE) is an umbrella term that describes all two-way processes between academics and non-academic individuals and groups with the purpose of creating cultural, societal, economic and research benefits. Although sometimes referred to as 'third mission' activities, Alliance universities see knowledge exchange as part of their core mission.

There are a variety of mechanisms and modes of interaction which constitute most KE activities, but the common theme is the sharing of learning, ideas and people between research and the private, third and public sectors, and the wider community. The aim of KE is to improve research, and its influence on policy, practice and business; therefore, an identifiable mutual benefit is an implicit requirement. Given the broad remit of KE activities and the diverse constituencies involved, their impact can measured by a variety of metrics, both economic and otherwise.

Figure 12 Knowledge exchange is achieved through a variety of channels
Source: Hughes and Kitson (2012) Pathways to Impact and the Strategic Role of Universities.



83 Department for Business Innovation & Skills (2014) The Allocation of Science and Research Funding 2015/16. Investing in World-Class Science and Research

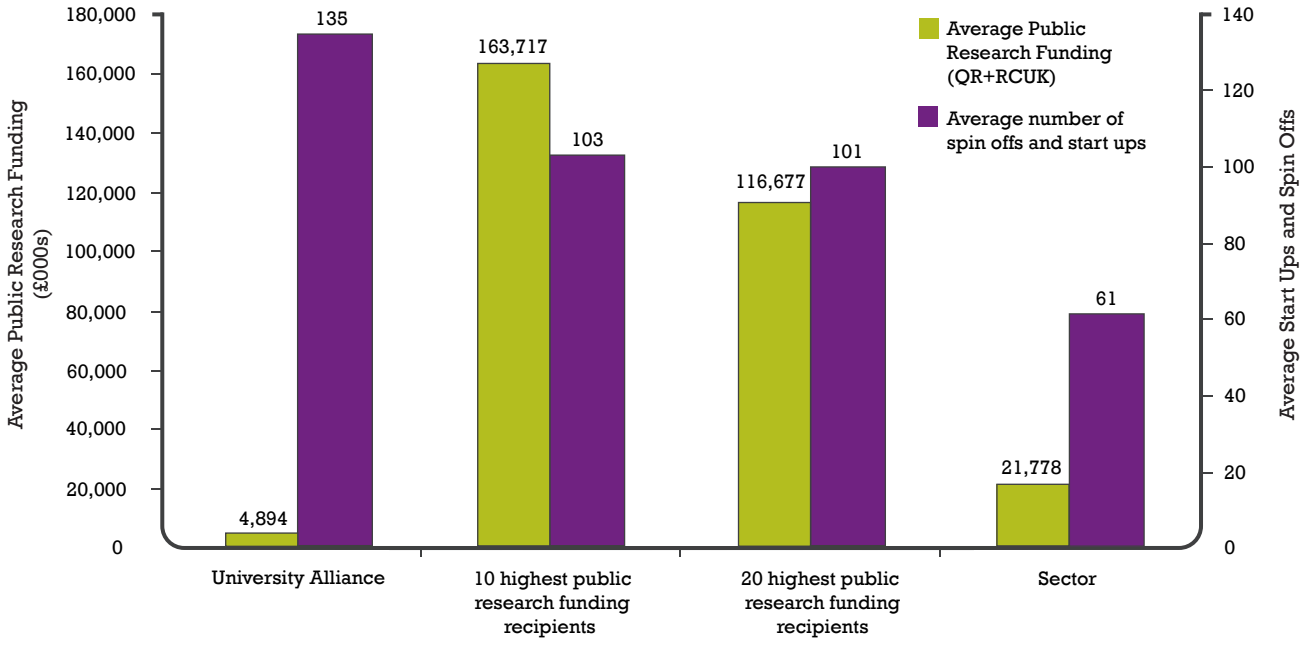
Taking a specific look at economic contributions to society, it is clear that certain types of impacts from research environments – such as spin offs and start-ups – are not achieved via the usual routes of research funding, as Figure 13 shows.

Informal interactions with businesses are more difficult to capture but of equal significance, and often greater economic importance, than patenting and licensing.[84] Evidence repeatedly suggests that the human factor is crucial in helping with absorptive capacity and knowledge exchange and research impact in business.[85] Support systems that promote the movement of people between industry and academic environments should be encouraged. This approach is a central focus of Alliance universities, who have successfully embedded business links and engagement across a range of university activities, not least through their staff who have a powerful combination of industry and academic experience. Alliance universities welcomed 20 per cent of their new staff in from industry in 2012-14 (compared to 14 per cent in 'Golden Triangle' institutions and a 17 per cent sector average).[86]

Alliance universities generate 44 per cent of the £376 million generated from graduate start-ups

HEFCE's Higher Education - Business and Community Interaction Survey (HE-BCI) captures the economic traces of a broad range of informal interactions. As Maps 1-4 show, analysis of this data shows the important and diverse role that universities play in delivering economic growth and the Industrial Strategy, particularly through the SME constituency which is vital to the UK economy. This includes creating new businesses through graduate start-ups, consultancy and contract research interactions with other economic stakeholders, and knowledge transfer partnerships in key sectors including life sciences and aerospace, automotive & construction. Peaks of excellence in societal and economic contribution also exist throughout the sector, as they do in research: diversification and specialization have been shown to be successful strategies for growing knowledge exchange income.[87]

Figure 13 Success in creating start-ups and spin offs is not achieved by usual research funding routes
Source: HE-BCI 2012/13



84 P. D'Este and P. Patel (2007) University–industry Linkages in the UK: What Are the Factors Underlying the Variety of Interactions with Industry?, Research Policy, 36, 1295–1313 http://dx.doi.org/10.1016/j.respol.2007.05.002; Maria Abreu and Vadim Grinevich (2013) The Nature of Academic Entrepreneurship in the UK: Widening the Focus on Entrepreneurial Activities, Research Policy, 42, 408–22 http://dx.doi.org/http://dx.doi.org/10.1016/j.respol.2012.10.005; Rudi Bekkers and Isabel Maria Bodas Freitas (2008) Analysing Knowledge Transfer Channels between Universities and Industry: To What Degree Do Sectors Also Matter?, Research Policy, 37, 1837–53 http://dx.doi.org/http://dx.doi.org/10.1016/j.respol.2008.07.007

85 See for example AHRC (2011) Hidden Connections: Knowledge Exchange between the Arts and Humanities and the Private, Public and Third Sectors; CIHE (2010) Absorbing Research: The Role of University Research in Business and Market Innovation

86 HESA Staff Data, 2012-2014

87 Adrian Day and Rosa Fernandez (2015) Strategies for Sustaining Growth of Income from Knowledge Exchange across Higher Education Institutions (HEIs) in the UK, National Centre for Universities and Business

A 'revolving door' with business

Alliance universities welcomed 20 per cent of their new research staff in from industry between 2012-2014 (including 14 per cent from the private sector) according to HESA staff data. This compared with 14 per cent from industry (5 per cent from the private sector) in 'Golden Triangle' institutions and 17 per cent (10 per cent) for the sector as a whole. They work closely with employers to provide 48 per cent of in-course work placements, and lead over one-third of all UK Knowledge Transfer Partnerships (KTPs).

By operating a 'revolving door' attitude towards business, staff and students are encouraged to move between different environments throughout their careers, creating T-shaped employees and researchers and relevant, impactful research. Businesses choose to work with Alliance universities precisely because they are responsive and flexible to business need.

Case study

Pain Management

University of Greenwich researchers develop novel tools to assess and treat chronic pain in the elderly

Researchers at the University of Greenwich worked with patients to develop ways to give older people the knowledge, skills and confidence to live independently at home with self-managed pain. Working in collaboration with the University of Teesside, the study involved service users and patients to search and grade the literature available for them. This led to improved self-help tools and recommendations that these tools be made accessible in printed leaflet format rather than online and better provision of information about drugs and the role of exercise and relaxation in pain management.

Alongside this project, researchers also led the launch of Guidance on the Management of Pain in Older People – the first such national document in the UK – in 2013. The document, commissioned by the British Pain Society and British Geriatric Society, aimed to inform health professionals who work with older adults in any care setting on best practice for pain management and identify gaps in the evidence that require further research. Widely adopted by the UK, the guidelines have gained international attention, particularly in the US.

The British Pain Society and British Geriatric Society also jointly funded the researchers to convert pain assessment guidelines into an iPhone/Android app for health professionals. After collaborating with the University's Computing and Mathematical Science Department, the South East Coast Ambulance service tested the app. The service's Clinical Lead reported the vast majority of its 2,000 operational staff benefitted from the work, concluding that in 90% of cases, patients' pain was better managed. The service has since adopted the app for everyday use.

Case study

Marine Conservation

University of West of England Bristol: Creating marine reserves to tackle overfishing

The Community of Arran Seabed Trust (COAST) was set up to protect marine life near the Isle of Arran after drawing on the findings of UWE Bristol legal research which showed that the Scottish Government had a duty to coastal communities in managing fishing rights. This work helped COAST to create Scotland's first fully protected marine reserve in the island's Lamlash Bay to strike a balance between fishing and conservation.

The researchers have worked with organisations interested in setting up similar reserves, which led to the establishment of a conservation agency, the Blue Marine Foundation (BLUE). In 2010, BLUE used UWE Bristol's research to argue that the Foreign and Commonwealth Office could create a reserve in UK overseas territory much more easily than in domestic waters. Supported by a multi-million pound grant from the Bertarelli Foundation, the agency negotiated the huge Chagos Islands marine reserve in the British Indian Ocean Territories which, at nearly 640 000 km2, is the world's largest marine reserve.

The Marine Conservation Society, acting with environmental lawyers, also used UWE research to successfully challenge the UK government on its failure to regulate fishing according to the EU Habitats Directive. This protects wildlife and their habitats in a network of so-called 'Natura 2000' areas within member states which each regulate activities within their own sites. However, they have not typically regulated fishing. As a result, UK sites will for the first time be protected against harmful fishing operations. It is likely that other EU member states will now follow suit.

Map 1. Top 20 for Graduate Start-ups

(By estimated current turnover of all active firms since 2008)

1. University of the West of England, Bristol (£145m)
2. Kingston University (£100m)
3. The University of Central Lancashire (£57m)
4. The University of Northumbria (£54m)
5. Bournemouth University (£44m)
6. Cardiff University (£43m)
7. University for the Creative Arts (£32m)
8. The University of Southampton (£27m)
9. The University of Edinburgh (£26m)
10. The University of Bradford (£25m)
11. University of Bedfordshire (£22.3m)
12. University of South Wales (£22.2m)
13. Liverpool John Moores University (£20.4m)
14. Coventry University (£20.3m)
15. University of St Mark & St John (£20.1m)
16. Royal College of Art (£18m)
17. The Nottingham Trent University (£17m)
18. The University of Sussex (£16.6m)
19. De Montfort University (£16.5m)
20. Edinburgh Napier University (£14m)

Data from HE-BCI, 2008-2012

Map 3. Top for Life Sciences sector KTPs

(By number of projects since 2008)

1. The University of Manchester (16)
2. Queen's University Belfast (11)
2. Cardiff University (11)
3. University of Leeds (9)
4. University of Central Lancashire (8)
5. London South Bank University (7)
5. University of the West of England Bristol (7)
6. Bangor University (6)
6. University of Bath (6)
6. University of Plymouth (6)
7. Aston University (5)
7. Bournemouth University (5)
7. King's College London (5)
7. Newcastle University (5)
7. University of Aberdeen (5)
7. University of Bradford (5)
7. University of Hertfordshire (5)

Data from HE-BCI, 2008-2012

Map 2. Top 20 for Consultancy & Contract Research

(By estimated current turnover of all active firms since 2008)

1. Coventry University (36,310)
2. The University of Liverpool (29,542)
3. SRUC (10,968)
4. The Queen's University of Belfast (3,742)
5. The University of Salford (3,695)
6. Leeds Metropolitan University (3,669)
7. The University of Central Lancashire (2,744)
8. Cardiff University (2,719)
9. The University of Lancaster (2,600)
10. The University of Northampton (2,595)
11. The University of Wolverhampton (2,232)
12. The University of Bristol (2,138)
13. University of Ulster (2,037)
14. Queen Mary, University of London (1,427)
15. The University of South Wales (1,320)
16. Cardiff Metropolitan University (1,145)
17. The University of Cambridge (1,114)
18. University of Derby (1,112)
19. Buckinghamshire New University (934)
20. The University of Newcastle (896)

Data from HE-BCI, 2008-2012

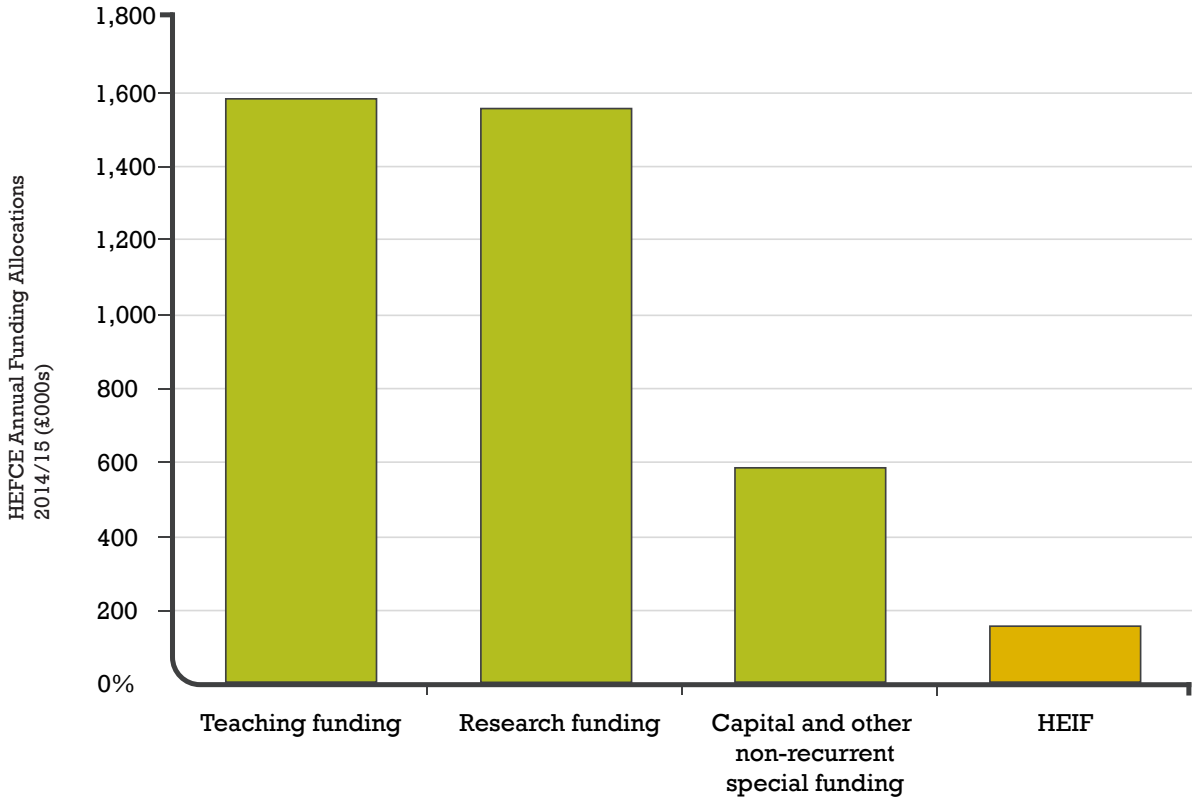
Map 4. Top for Aerospace, Automotive & Construction sectors KTPs

(By number of projects since 2008)

1. Queen's University Belfast (31)
2. The University of Sheffield (29)
3. Sheffield Hallam University (26)
3. University of Wolverhampton (26)
4. University of Hertfordshire (21)
5. University of Leeds (20)
6. Glyndwr University (19)
7. University of Bath (18)
8. The University of Nottingham (17)
9. Cardiff University (15)
9. Staffordshire University (15)
10. University of Bradford (14)
10. Birmingham City University (14)
11. The University of Reading (13)
11. University of Brighton (13)
12. University of Portsmouth (12)
12. University of South Wales (12)
12. The University of Liverpool (12)
12. The University of Manchester (12)

Data from HE-BCI, 2008-2012

Figure 14 Funding supporting 'third mission' knowledge exchange activities is much lower than for the other core missions



5.2.1 Targeted investment should support more costly SME knowledge exchange activities

Knowledge exchange activities are therefore a key element of delivering impact from university research, but this is not the only contribution they make. Inevitably the structures of support for knowledge exchange existing within a university can also help researchers deliver impact, but the routes to achieving this can be quite different. Each interaction that universities have with the wider world, internationally, nationally or regionally, helps to broaden knowledge and share the value of university research across the spectrum of research activities. Yet these activities are as resource-heavy as they are valuable.

Greater investment is needed to deliver these societal and economic objectives of universities. At £160 million Higher Education Innovation Funding (HEIF) is a relatively small – but critical – stream of funding, and its impact far outweighs its size. As the principal dedicated funding stream that allows universities to work innovatively with local SMEs, HEIF has enabled universities to support innovation in growth sectors and it provides an excellent return on government investment. Every pound of HEIF gives a gross return of £6.30 in additional knowledge exchange income, a proxy for the impact on the economy,[88] although this is likely to underestimate the total economic and social benefits.

As Figure 14 shows, knowledge exchange funding through HEIF is currently significantly under-funded and needs to be brought more closely into line with that for the other core missions: research and teaching, but not at the expense of these missions. Sir Andrew Witty recommended that HEIF should be increased to £250 million,[89] which should be directed from other areas of innovation funding.

HEIF should also include greater weighting for SME interactions. Innovative SMEs are the driving force of innovation in the UK economy,[90] and the UK's innovation performance showed a marked increase thanks to increases in innovative SMEs collaborating with others during 2009 and 2010.[91]

88 Ulrichsen
89 Sir Andrew Witty (2013) Encouraging a British Invention Revolution: Review of Universities and Growth, (Recommendation 4)
90 NESTA (2010) Rebalancing Act
91 European Commission (2014) Innovation Union Scoreboard, p. 70

The research base and anchor institutions have an important role to play in increasing the innovative capacity and investment of SME private funds in research and development.[92] The examples cited throughout this response demonstrate how Alliance universities' connectivity and expertise are driving economic growth through increasing local SME innovativeness and investment in R&D, in processes and services as well as technology and products.

As anchors in their regions and with over 20,000 interactions with SMEs each year, Alliance universities understand that collaboration and partnership working brings huge value to local economies and societies, but is resource-heavy and can be high risk. Engaging with numerous SMEs, for example, uses more resource than fewer collaborations and contracts with large businesses and whilst the impacts of engaging with small businesses (in terms of human resource, percentage increases to profits, and so on) may not equal those with large corporations in purely financial terms the societal and economic benefits may be more significant.

As high levels of engagement and innovation with SMEs do not necessarily translate into high levels of income, there are implications for HE-BCI results and, subsequently HEIF which currently only double weights interactions with SMEs. There is also a need for greater transparency in HEIF expenditure, to ensure it is invested in capacity that specifically supports knowledge exchange: this should take into consideration the quantity of SME partners and interactions, which would be a strong indicator of commitment to impact on the local society and economy.

5.3 Funding implications for a responsive research and innovation ecosystem

The responsiveness of the research and innovation ecosystem relies on a broad interaction between researchers, users of research and other agents in the ecosystem. Science remains responsive when user-inspired feedback loops are able to inform research questions. An organic and constant interplay between researchers, industry and the community is created especially by institutions who operate a revolving door for staff and students.

The nature of the broader spectrum of knowledge exchange actions and their contributions to society must be recognised compatible with, but not the same as, direct research impact – often sitting outside 'REF-able' activities. The implications for funding are to ensure recognition for research impact through the REF and to support valuable knowledge exchange activities by a dedicated and well-resourced funding stream.

Non-hypothecated funding streams like QR and HEIF are critical to the responsiveness of the ecosystem. They allow universities to spend research and knowledge exchange funding in the most appropriate way for local societal and economic circumstances, and can act nimbly as demands for research and structures of innovation evolve and change.

Recommendations

Funding councils should continue to recognise and reward impact in indicators of research quality, using a case study approach

Funders must continue to prioritise funding streams like QR and HEIF, which build in agility and responsiveness to research and knowledge exchange activities

Government should invest more in a dedicated funding stream for Higher Education innovation activities

92 University Alliance (2011) Growing the Future: Universities Leading, Changing and Creating the Regional Economy

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