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21st April 2015

Council for Mathematical Sciences (CMS) response to the call for evidence on the Nurse Review of Research Councils

The Council for the Mathematical Sciences (CMS) exists to develop, influence and respond to UK policy issues that affect the mathematical sciences in higher education and research, and therefore the UK economy and society in general. The CMS is glad to provide a response to the Nurse Review's call for evidence, agreed by senior representatives of its constituent societies: the Institute of Mathematics and its Applications (IMA), the London Mathematical Society (LMS), the Royal Statistical Society (RSS), the Edinburgh Mathematical Society (EMS), and the Operational Research Society (OR Society).

1. Strategic decision-making

1.1. How should the Research Councils take account of wider national interests including regional balance and the local and national economic impact of applied research?

1.1.1. Research Council budgets overall should not be depleted. Revenue spending since 2010 has been ring-fenced but decreasing in real terms. Evidence suggests that to be competitive with other advanced nations, the government should seek to increase overall expenditure on research and development from 1.7% (as last measured in 2012) to 3% of GDP. The average expenditure on R&D across the European Union (by government, business and charities) is between 2% and 3% of GDP and increasing, and this is also the case in the USA and in China (excluding Hong Kong).[1, 2, 3] The UK should step up its investment to remain competitive overall.

1.1.2. The mathematical sciences research infrastructure consists of its broad people pipeline from researchers to graduate students, who take roles in industry and act as vital conduits to economic growth. The quality and distribution of research units is key to developing skills and strengthening mathematical science across our research base.[4]

[1] Eurostat Gross Expenditure on R&D data.
[2] OECD (2014) *Estimates of R&D expenditure growth in 2012* [PDF]. Available from: http://www.oecd.org/sti/inno/Note_MSTI2013_2.pdf [Accessed March 2015]
[3] Allas, T. (2014) *Insights from international benchmarking of the UK science and innovation system* [PDF]. January 2014. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277090/bis-14-544-insights-from-international-benchmarking-of-the-UK-science-and-innovation-system-bis-analysis-paper-03.pdf [Accessed: April 2015]
[4] EPSRC (2010) *International Review of Mathematical Sciences* [PDF]. December 2010. Available from: https://www.epsrc.ac.uk/newsevents/pubs/international-review-of-mathematical-sciences/ [Accessed: April 2015]

1.1.3. The UK's universities play a critical role across a broad spectrum - supporting industry and employment, social policy and personal opportunity. Mathematical sciences enhance virtually all of these areas, and CMS believes it should be a strategic goal of the UK HE system to create structures to facilitate this. Provision in higher education for mathematical science of high and imaginative quality and well integrated into other cutting edge research areas adds substantial value. Where it is absent, it has real limiting consequences on other research areas through, for example, their limited ability to interpret and acquire interesting data. Some adjustment in dominant performance metrics may be needed, to reward constructive investments in collaborations that have other beneficial e.g. economic impacts, that are relatively poorly recognised.

1.1.4. EPSRC should attend to the balance of its support for research groups across regions, to improve the scope for diversity in research, appropriate teaching and training, and the formation of research and consultancy connections with local industry. We note that HEFCE is concerned about 'cold spots' in mathematical sciences provision across the country, so concentrating research while widening teaching would not be joined up thinking.

1.2. Is the balance of funding well-judged between the support of individual investigators, support of teams and support of equipment and infrastructure?

1.2.1. The mathematical sciences main infrastructure requirement is computing power. Its principal resource requirement is people's time. We will make progress in research and innovation by funding opportunities to collaborate, to compute, and to either take up studentships or post-doc opportunities, or mentor students or post-docs. The number of high quality research units needs to be increased, to underpin mathematical science across our research base. This is needed to train and retain the best researchers, and to raise the standard and competitiveness of our research base overall.

1.2.2. With regard to the UK science budget as a whole, the government's strategy for revenue spending should be coupled to plans for capital spending, so that spending plans as a whole can be assessed and appropriately balanced. Some of that balance is missing at the present time. For example, the relative lack of post-doctoral training and fellowship money is a serious concern in terms of bringing on the next generation of trained researchers for a wide range of disciplines and industries.

1.3. What are the gaps or holes in the funded portfolios of the Research Councils?

1.3.1. In 2013, the Council for Science and Technology praised the standing of UK universities' mathematics departments, alongside new investments in the Open Data Institute, the Digital Economy Catapult and the Hartree Centre. They noted however that "there remains an important gap … [in] the area of research and development of advanced computing science."[5] The new Alan Turing Institute, which was proposed as a means toward filling this gap, will drive forward and raise the profile of research and development in this field. However further accompanying steps are needed. UK investment in cutting edge facilities needs to be coupled to a holistic strategy to advance the mathematical sciences across our research base as a whole. To play its proper role in driving economic growth at national level and across the UK nations and regions, our intellectual capital needs to be built upon. Occupations that engage

[5] Council for Science and Technology (CST) (2013) The age of algorithms: algorithms, analytics modeling and data for growth and public sector efficiencies. *Letter to the Prime Minister from the CST*, 6 August 2013. Available from: https://www.gov.uk/government/publications/the-age-of-algorithms [Accessed: March 2015]

in mathematical sciences research, or that directly require the use of tools and techniques derived from such research, form a highly productive sector of employment in the UK. [6, 7] We need to have the capacity to innovate, to extend and develop mathematical science, and not solely to deploy existing techniques.

1.3.2. The rise of the data-led economy, and the worrying existence of major skills gaps in data-led industries, have drawn further attention to the need for statistical and data analytical skills in research and in industry.[8,9, 10] The UK's strategy for data capability recognised the need to address a deficit in data analytical skills, and commissioned a review by Universities UK on this topic. [11] The review's forthcoming findings include that mathematics and statistics support centres provide students, and sometimes staff, with much-needed guidance.[12] Consultation by the Engineering and Physical Sciences Research Council (EPSRC) has also found that the use of statistics in other disciplines can be very poor, that staffing for this remains an issue, and that post-doctoral and early career fellowships are essential for retaining talent in the UK.[13]

2. Collaborations and partnerships

2.1. *Are the right arrangements in place to ensure optimal funding for research that crosses disciplinary boundaries?*

2.1.1. The recent Triennial Review of Research Councils highlighted collaboration on interdisciplinary research funding as an area for improvement. CMS is in agreement that work is needed to more widely unlock the value of research in cross-cutting disciplines and themes, among which the mathematical sciences should form a key group. Mathematical sciences are cross-cutting and it is important to recognise and build on this, to advance quantitative research and methods across a wide range of disciplines. It is important to anchor cross-disciplinary leadership on mathematical science somewhere, whether in EPSRC, or more broadly under the aegis of Research Councils UK. Wherever leadership is located, it should be well placed to be cognisant of developments across disciplines and across Councils.

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[6] EPSRC / CMS (n.d.) *Mathematical sciences research: leading the way to UK economic growth* [PDF]. Engineering and Physical Sciences Research Council. Available from: http://www.ima.org.uk/_db/_documents/4_page_economic_impact.pdf [Accessed: April 2015]

[7] Deloitte (2012) *Measuring the Economic Benefits of Mathematical Science Research in the UK* [PDF]. November 2012. Available from: https://www.epsrc.ac.uk/newsevents/pubs/deloitte-measuring-the-economic-benefits-of-mathematical-science-research-in-the-uk/ [Accessed: April 2015]

[8] European Commission (2015) Commission workshop identifies skills gap for big data analytics and explores possible solutions [online]. Available at: http://ec.europa.eu/digital-agenda/en/news/commission-workshop-identifies-skills-gap-big-data-analytics-and-explores-possible-solutions [Accessed: March 2015]

[9] SAS / Tech Partnership (2014) *Big Data Analytics: Assessment of demand for labour and skills 2013-2020* [PDF]. Available at: https://www.thetechpartnership.com/globalassets/pdfs/bigdata_report_nov14.pdf [Accessed: March 2015]

[10] Bakhshi, H. Mateos-Garcia, J. & Whitby, A. (2014) *Model workers: how leading companies are recruiting and managing their data talent* [PDF]. London: NESTA. Available from: http://www.nesta.org.uk/sites/default/files/model_workers_web_2.pdf [Accessed: March 2015]

[11] Department for Business, Innovation & Skills (2013) *Seizing the data opportunity: a strategy for UK data capability* [PDF]. London: Crown Copyright. Available from: https://www.gov.uk/government/publications/uk-data-capability-strategy [Accessed: March 2015]

[12] Universities UK (2015) [Forthcoming, title to be confirmed]

[13] EPSRC Mathematical Sciences Theme (2015) *Statistics and Applied Probability Review Day, 18th June 2014: Report and Next Steps* [PDF]. Available from: http://www.epsrc.ac.uk/newsevents/pubs/statistics-and-applied-probability-review-day-18th-june-2014-report-and-next-steps/ [Accessed: March 2015]

2.1.2. The relatively small size of the mathematical sciences budget also has an impact on collaborations, as it seems that review panels view the budget allocated to the mathematical sciences as being too small to fund interdisciplinary work. It is felt that proposals for mathematical science +X should be funded by the panels which fund X. At the same time, it is not clear whether the panels for X have members who are comfortable with, or understand, the level of mathematical science required. A second related reason is the so-called "double jeopardy" in assessment, in that a mathematical science +X submission seems to need a top score in both the mathematical science aspects and X. When these problems are combined, there are obstacles to the inclusion of transformative mathematical science in applications for funding. A boost to funding for interdisciplinary work that is explicitly allied to the mathematical sciences may be necessary to sufficiently raise the profile of such work.

2.1.3. Mathematics of information, including big data, is predicted by many to be the next big front for the mathematical sciences. This is relevant to biology, astronomy, business, finance, social science, health service and other areas. CMS is of the view that RCUK needs a framework in which to take advantage of the UK's potentially leading position in this domain. In particular, research into Data Science, as opposed to research using it, is not adequately covered by existing structures.

2.1.4. With the ubiquity of mathematical thinking to analyse data, mathematical scientists should have a wider presence in research funding panels than at present. This would promote a more rational approach to mathematical science in RCUK-funded research, and help to avoid the mistaken notion that its applications consist solely of a fixed set of methods that can easily be deployed by staff with fairly low-level technical skills. Research collaboration with the mathematical sciences should develop theoretical and 'non routine' use of mathematics, statistics and operational research.

2.1.5. Structures and assessment methods should work for, and not against, research that is translational, interdisciplinary or simply highly innovative. While the core disciplines of mathematical sciences and many areas of mathematical inspiration and application lie within the Engineering and Physical Sciences, RCUK should develop an overview of how research in the mathematical sciences is funded on a broader base. This should take account of the needs of, and opportunities in, other communities for innovative mathematical ideas, and hence consider the mechanisms by which other areas interact with mathematical scientists to develop new and original approaches to their problems.

2.1.6. Using RCUK-wide strategy to embed collaboration, based on approaches that have been tried and tested by different Research Councils, would be preferable to reinvention and duplication. The EPSRC Mathematical Sciences team is addressing some opportunities outside the immediate Engineering and Physical Sciences remit, e.g. Maths in the Life Sciences, Maths in Social Sciences, Maths for Environmental Change, Maths for Big Data. But there is no built-in mechanism for highlighting the mathematical opportunities across the spectrum of the RCs. Approaches from other Research Councils that could be informative to cross-cutting research agendas is the policy of MRC and the National Institute for Health Research (NIHR) to collaborate on a cross-disciplinary funding strategy for the development of research methods that underpin discoveries in health.[14] The Economic and Social Research Council

[14] Medical Research Council (2015). Methodology research programme [online]. Available at: http://www.mrc.ac.uk/funding/browse/methodology-research-programme/ [Accessed: March 2015]

has also been working in partnership to raise the level of quantitative skills across the social sciences, in an approach that other disciplines might also benefit from.

2.2. *How should the work of the Research Councils integrate most effectively with the work of agencies funding innovation, such as Innovate UK?*

2.2.1. CMS' Submission to the Dowling Review (in collaboration with ICMS, the Isaac Newton Institute, the Smith Institute, and the Turing Gateway) considers the current under-representation of mathematical sciences in collaboration with industry. Our evidence to Dowling notes that EPSRC's industrial CASE programme places PhD funding with companies, however hardly any of these awards support collaborations with mathematical scientists. We also note that the Catapult Centres, focused on innovation in technology, have little awareness of the mathematical expertise to harness for this. Our submission identifies a need to boost dramatically the pipeline of collaborations, to address a knowledge gap both for industry collaborators and for our Research Councils and institutes, and recommends a large scale national programme for early career researchers in the mathematical sciences to have direct experience of how business R&D operates.

3. Balance of funding portfolio

3.1. Are the divisions of scientific subject areas between the Research Councils appropriate?

3.1.1. With regard to the mathematical sciences, it is CMS' view that the position of this set of disciplines within EPSRC, while not inappropriate, constrains the breadth of mathematical science research and applications.

3.1.2. While EPSRC is the lead Council for funding mathematical sciences projects, involvement of the other Councils is substantial and merits recognition in broader strategy. It would be valuable to consider the profile and distribution of funding for the mathematical sciences across Councils in this.

4. Effective ways of working

4.1. How can the RCs catalyse collaboration between institutions?

4.1.1. CMS wish to affirm very strongly the importance of research community representation on funding panels, in keeping with the Haldane Principle. Funding for the research community should never be led by civil servants acting alone. This point is made generally, and applies across all disciplines.

4.1.2. As we have discussed above, large programme grants and the Doctoral Training Centres could be used more to catalyse collaboration between institutions. When multi-site proposals are submitted this is, at present, likely to be regarded as a weakness. It could be viewed as a strength.

4.1.3. The development of data infrastructure will be crucial to effective working, and Research Councils have a key part to play in this. The ethical governance of data sharing should also be provided for in a manner accessible to all researchers, so that the benefits of opening up access to data are widely seen to outweigh any risks. The Cabinet Office, the Economic and Social Research Council (ESRC), and the UK Statistics Authority have been leading initiatives to improve data sharing for research and statistics. Agreed infrastructural approaches to this should be taken forward on a longer-term basis.

4.1.4. Mathematical scientists should have a wider presence in research funding panels than at present. We would then be better placed to develop theoretical and ‘non routine’ use of the mathematical sciences in collaborative research, which is a need that is under-addressed at present. This would in turn send an important signal to our institutions that there is the scope for cross-disciplinary work and that applications for this will be properly assessed and valued.