THE ROYAL SOCIETY

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Royal Society submission to Spending Review 2021

The Royal Society is the National Academy of Science for the UK. It is a Fellowship of many of the world's most distinguished scientists working across a broad range of disciplines in academia and industry. The Society draws on the expertise of its Fellows and Foreign Members to provide independent and authoritative scientific advice to UK, European and international decision makers.

This document contains the Society's submission to the 2021 Spending Review in support of Government ambitions to increase UK R&D investment and make the UK a global science and tech superpower. For further information or queries, please contact public.affairs@royalsociety.org.

Introduction: a long-term vision for science driving innovation and prosperity across the UK and a net zero economy

1. UK science, research and innovation have enormous potential to generate new knowledge, technologies and jobs, with a high rate of return on investment. When supported effectively, science can drive long-term growth and productivity, improve lives and opportunities, help us lead on global challenges including the transition to net zero and a more sustainable relationship with the biosphere, and play a vital role in the creation of strong and innovative public services. It will also enable the UK to prepare for and manage future threats to global health and wellbeing, building on the pivotal role of science and technology in tackling COVID-19.

2. The Government has already committed to increase public spending on R&D to £22 billion a year by 2024/5 and overall investment to 2.4% of UK GDP by 2027[1]. The 2021 Spending Review (SR) is an opportunity to put detailed plans in place for reaching 2.4% and maximising the UK's strengths in science, research and innovation to bring transformative and lasting benefits to people and places across the UK.

3. To realise that goal, a long-term vision for science is needed that matches the Government's ambitions in the Plan for Growth[2] and Integrated Review[3] and commands political consensus. This should focus on using research and innovation to improve lives, drive growth and level-up, supporting more people to become researchers and innovators in the UK, and shaping the UK's future as a responsible and visionary science and tech superpower, advancing the Global Britain agenda. In the short- to medium-term context of the SR, that requires:

    - Clarity on the Government's R&D spending profile up to and beyond the £22 billion it has already committed by 2024/25.
    - Strong foundations for R&D across the UK to create the capacity for reaching the 2.4% R&D investment target and beyond.
    - The capability and credibility to become a science and tech superpower through ambitious investment in international collaborations and assuming global leadership on key scientific challenges.

    Analysis of these priorities and policy recommendations are set out in the following sections.

Why is investing in UK science, research and innovation important?

- Estimated rates of return on investment in R&D are typically in the region of 20-30%, with some estimates as high as 85%[4].
- Research and innovation supports productivity growth and high value employment. Firms that persistently invest in R&D are 13% more productive[5]. The pharmaceutical industry in the UK employs around 67,000 people of whom 25,000 work in R&D[6].
- Research and innovation supports regional growth and levelling-up. In 2020, the compound semiconductor cluster in Cardiff contributed £172 million to the Welsh economy and supported

around 2,100 jobs[7]. The Centre for Secure Information Technologies in Belfast's Catalyst cluster supports an innovation ecosystem of 1,600 cybersecurity professionals across 40 companies and makes Northern Ireland a prime investment location for US cybersecurity development projects[8].

- Investment in R&D drives improvements in health and wellbeing. For example, the international RECOVERY trial discovered that the drug Dexamethasone improved survival in patients with severe respiratory complications from COVID-19.
- The UK has a higher level of foreign direct investment in R&D than any other G7 nation[9].
- Science enables the UK to lead on global challenges such as climate change, energy security, biodiversity loss, and ageing populations.
- Research and innovation can help the UK harness the benefits of data science and artificial intelligence (AI) unlocking discoveries and creating benefit for society and the economy.

Clarity on R&D spending profile up to and beyond the £22 billion committed by 2024/25

4. Rapid growth in global R&D investment makes it essential for the UK to have a clear and visible representation of the Government's R&D spending up to the £22 billion by 2024/25 towards its overall investment target of 2.4% of GDP by 2027. Reaching this milestone requires a substantial contribution from private R&D investors with sufficient confidence in the Government's commitments.

5. The risk that the UK will slip further behind other science nations is increasing. China, for example, is raising its annual spend on R&D by more than 7% over the next five years[10], while the USA is preparing to invest an additional $250 billion in core science and technology budgets[11]. France has announced that the budget of its National Research Agency will be trebled by 2023, as Spain lifts R&D spending by more than 80% in 2021 and Sweden by 10% up to 2024[12]. Across the OECD, investment in R&D as a proportion of GDP has already risen from an average of 2.4% – the UK's target for 2027 – to 2.5%[13] and is set to increase further as investment elsewhere accelerates.

6. Providing clarity in the SR on the Government's multi-year R&D spending profile will offer assurance to globally mobile talent on the seriousness of the UK's ambitions to become a science and tech superpower, act as a 'crowding in' signal to the private investors needed to grow the UK's overall R&D intensity, and support Government plans in the Innovation Strategy[14] to boost foreign direct investment in R&D by promoting the UK's investable strengths.

   Policy recommendations:

   - The Government should publish its R&D spending profile to keep on track to 2.4% and create the signals and confidence for the necessary private co-investment, at a ratio of at least two to one, to take place.
   - Public spending uplifts should be spread evenly across the four year period to 2024/25 to crowd in private investment in time to meet the 2.4% target by 2027.

Creating strong foundations for R&D across the UK

7. Growing the UK's capacity for R&D is critical to meeting Government ambitions and ensuring the long-term health and sustainability of science across academia and industry. Gaps in the UK's current approach appear in three broad areas – people, funding, and place – where effective intervention will generate the capacity for reaching the 2.4% target and beyond.

People: skills, training and talent

8. Firstly, increasing the volume of R&D undertaken in the UK requires more people working across the research base. To that end, the Government should act urgently to address weaknesses in the UK's skills, training and global talent offer at all levels of the system. Current challenges include:

   a. a shortage of suitably qualified science and mathematics teachers compounded by missed recruitment targets[15] and a high teacher attrition rate in key subjects such as physics[16] meaning

that fewer younger people are finishing school or college with the necessary foundational skills for R&D and other high value economic activity;

b. a bottleneck in the supply of exceptional researchers to jobs and prevalence of short-term funding at early to mid-career stage resulting in precarious employment and negative research culture;
c. underrepresentation of women and ethnic minorities in STEM highlighted in the Government's R&D People and Culture Strategy[17] and work by the Royal Society and others;
d. a lack of incentives for mobility and porosity between academia and industry with relatively little being done to prepare researchers for jobs in industry and at the interface with academia[18] or to drive innovation through intersectoral mobility more generally;
e. skills gaps and shortages in key sectors such as process and chemical engineering[19] where the decadal qualification and training cycle is too long for wage signals either to be visible or to balance the market effectively;
f. skills gaps and shortages within the R&D technical workforce with significant numbers approaching retirement age and data suggesting a fall in the number of younger workers being employed in relevant roles[20];
g. data skills gaps and shortages affecting businesses' ability to access data science skills, with Government commissioned research showing unmet demand for 178,000 to 234,000 data roles[21];
h. the UK being outcompeted on the upfront costs of work and study visas which are up to six times higher than the average of leading science nations[22];
i. beyond its participation in multilateral schemes such as Marie Skłodowska-Curie Actions, the UK offering limited opportunities for early career collaboration and mobility to attract globally mobile talent and increase the impact and reach of research.

Policy recommendations:

- Introduce a subject-specific continuous professional development (CPD) entitlement of 35 hours training per year for teachers[23].
- Establish an Office for Science Education Teacher Professional Development to lead on commissioning CPD to meet emerging policy needs, deliver an innovation grant-giving programme with themed calls for proposals, and oversee high quality policy, research and evaluation.
- Deliver against commitments in the R&D People and Culture Strategy including specific policies in the 'New Deal' for postgraduate research students and practical actions to address the precariousness of research careers and attract and retain a diverse research and innovation community.
- Review the incentives for mobility and porosity between sectors with existing initiatives, such as the Royal Society's Industry Fellowships and Entrepreneur in Residence scheme, used as models of best practice and/or upscaled to increase their impact. Supporting joint academia-industry appointments in high growth areas like AI will help to foster excellence in data science across sectors.
- Assess the future training and capacity needs of the technical workforce to ensure that the drive to meet the 2.4% investment target is not constrained by limited technical absorptive capacity.
- Develop new funded career opportunities for technical careers, such as Technician Fellowships, to raise the profile of technicians and enhance career opportunities.
- Address the need for data skills by building knowledge and skills from school to degree level and beyond including nimble options for upskilling and retraining.
- Significantly reduce the uncompetitive upfront immigration costs for visa holders and close family members to put the UK at least on par with other countries as a favoured destination for talented researchers.
- Develop and launch a UK Global Talent fund supporting collaboration and mobility for exceptional early career researchers

Funding: long-term support for R&D that creates the time and space for ground-breaking discoveries, technologies and innovations to emerge

9. Secondly, the Government should support a greater volume of R&D through long-term core funding and investigator-led grant and fellowship schemes. In addition to creating precarious employment for early to mid-career stage researchers, the current prevalence of short-term project funding tends to favour incremental science that builds on existing work. This encourages researchers to take fewer risks and at a system level inhibits the UK's ability to pursue ideas, technologies, and innovations that could deliver transformative change over time. While the launch of the Advanced Research and Invention Agency (ARIA) is a welcome development in this context, action is needed on a much wider scale.

   Policy recommendations:

   - Increase long-term core support for basic science in higher education and research institutions including uplifts in quality-related (QR) funding.
   - Develop and launch a fund to attract and retain the most talented early and mid-career researchers including an ambitious new mid-career programme of investigator-led grants and a funding uplift for existing UK Research and Innovation (UKRI) and National Academy schemes.
   - Invest in new and existing initiatives providing long-term support to research bold ideas.

Case study: Investing in basic science as the critical underpinning for innovation

To increase the overall performance and innovation potential of the research base, long-term support is needed for both basic science (the 'R' in R&D feeding the innovations of tomorrow) and applied science (the 'D' driving the innovations of today). The rapid development and deployment of the Oxford-AstraZeneca vaccine, for instance, was only made possible through years of investment in the underpinning science on coronaviruses, vaccine technology, and manufacturing processes. Similarly, it was only after decades of preceding medical research that scientists working on the RECOVERY trial were able to test multiple potential therapeutics concurrently. The drug Dexamethasone – which the trial found to be effective in treating patients with severe respiratory complications from COVID-19 – had been used since the 1960s to reduce inflammation in a range of conditions and was not only inexpensive due to being out of patent, but also well understood and widely available.

COVID-19 has also brought to light how applications can arise from basic research in unexpected ways, often over long timescales. For example, the polymerase chain reaction (PCR) process used worldwide for detecting the SARS-CoV-2 virus owes its development to a chance discovery of a microorganism *Thermus aquaticus* – the source of heat-resistant enzyme DNA polymerase – in the 1960s. DNA polymerase is used to amplify genetic material for a range of biomedical applications, from the early initial identification of viruses to DNA-based personalised medicine approaches which have huge growth potential.

Place: growing R&D capacity across the UK to support levelling-up

10. Thirdly, to complement excellence-based (or 'place blind') funding for R&D, the Government should develop a balanced portfolio of place-based investments aimed at improving regional productivity[24] and addressing geographical disparity in the UK's absorptive capacity for research and innovation. This should include an R&D focus within the UK Shared Prosperity Fund (UKSPF) as the successor to European Structural and Investment Funds (ESIF) which have been effective at supporting local R&D projects in areas such as skills development and SME competitiveness and by leveraging investment from other sources[25].

11. The Levelling-up White Paper should articulate a clear role for R&D in creating opportunity in regions that lag behind on productivity, innovation and skills, without setting an agenda that risks or 'levels-down' established and globally successful innovation economies in London, Oxford and Cambridge.

Rather than one approach supplanting the other, creating regional capacity for R&D must co-exist with protecting and growing the UK's international excellence in science.

Policy recommendations:

- To avoid a funding cliff edge that leads to a loss of R&D capacity, rapidly deliver UKSPF to replace ESIF contributions which are no longer being paid to the EU. While ESIF has brought significant benefits to many regions, its successor should avoid replicating burdensome EU regulations and reporting requirements and facilitate interregional knowledge exchange.
- Develop a broader programme of locally informed interventions around research and innovation capacity using data to target regional strengths and comparative advantages.
- Review existing models for promoting research collaboration, connectivity and capacity growth between different places. Research Innovation Scotland, for example, facilitates collaborative R&D through multidisciplinary research pools, networking, and equipment sharing across the Scottish higher education and research sector.

Case study: Using R&D capacity funding to drive growth in the Highlands and Islands of Scotland

The University of the Highlands and Islands (UHI) is an academic partnership of 13 institutions which interfaces with hundreds of local SMEs to build their capabilities and capacity. In the last two decades, the institution has delivered approximately £250 million of European Structural Investment Funds and currently has the largest EU Interreg grant of all universities in Scotland supporting research in rural health and marine energy. Funded by Framework Programme 7, UHI's successful Marine Energy Research Innovation and Knowledge Accelerator (MERIKA) project[26] was made possible by earlier ESIF investment which built the capacity for excellence-based research with direct benefits to the region. In 2019, research and knowledge exchange at UHI generated £43 million GVA and 590 jobs across the Highlands and Islands, Moray and Perthshire[27].

Establishing the capability and credibility to become a science and tech superpower

12. Becoming a global science and tech superpower requires sustained efforts to enhance the UK's collaborative capabilities and reputation for world-leading science. The Government can achieve progress towards this goal by creating more opportunities for UK-based scientists to collaborate and excel internationally and by demonstrating global leadership on key scientific challenges.

Supporting international collaboration

13. The UK's success as a leading science nation depends on being open to the rest of the world, with numerous studies showing that international collaboration increases the reach and wider benefits of research activity. In 2018, 55% of UK academic publications were the result of international collaboration, compared with 26% in 1998[28].

14. As well as maintaining a strong scientific relationship with the EU through association to Horizon Europe and other programme commitments in the Trade and Cooperation Agreement, the Government should broaden the range of instruments for collaboration with countries elsewhere and deploy these strategically alongside existing multilateral, bilateral, national and regional mechanisms. The absence of agile funding to support fast-moving opportunities for international R&D collaboration has been identified as a major gap in the current landscape[29].

Recommendations:

- Deliver the Smith-Reid Review recommendation for the creation of an international agility fund to invest in emerging programmes of significant potential and to capture opportunities that arise unexpectedly.
- Develop funding that fosters international collaboration and mobility.
- Ensure that UK contributions to Horizon Europe and other EU science programmes are part of the committed increase in public R&D investment.

- Restore Official Development Assistance (ODA) expenditure to support mutually beneficial growth in research excellence in partner countries.
- Develop a wider strategy for collaborating with established and emerging science nations in areas of shared research strength, innovation and technology, infrastructure and global challenges. This should build on the trade chapters and export support in the Government's Innovation Strategy, develop clear approaches and criteria for specific collaborative agreements on key science and innovation priorities, and target high value foreign direct investment in R&D.

Global leadership on key scientific challenges

15. Finally, using the strategic direction and convening power of the National Science and Technology Council and Office for Science and Technology Strategy[30], the Government should prioritise the following areas of scientific leadership to tackle global challenges and develop constructive relationships with other countries:

    a. **Drive a resilient net zero global economy** | The UK should exploit its scientific expertise to drive research and innovation in low carbon technologies, establish world markets for globally leading green growth technologies, and support the innovation needed to bring down costs for consumers. Current areas of strength for the UK, from research through to use and recycling, include the development and deployment of batteries; catalysis (a fundamental of chemistry vital in achieving a net zero chemicals industry and also underpinning the use of hydrogen for home heating); solar to fuel; the production of green ammonia for fertilisers and energy storage; biotechnology and genetic innovation to improve quality and yields in plants; and the synthesis of a new generation of zero carbon chemicals. Similar to the life sciences sector, scientists working in these areas are highly networked and able to respond rapidly to opportunities.
    b. **Reverse the unsustainable crisis from overexploitation of the biosphere** | Achieving a sustainable relationship with the biosphere is essential for humanity's survival and requires a step change in national and international policy development on a similar or greater level to net zero. The UK must show global leadership on this issue and on the pressing land use trade-offs and synergies – carbon storage, nature restoration, food, water and housing – that underpin sustainability. The Dasgupta Review[31] was an important first step toward the creation of an economic framework to internalise biodiversity in market-based mechanisms.
    c. **Embed the UK's leadership in well-governed use of data and AI |** The UK has significant strengths in the use of data-driven science to tackle everything from global health security[32], to reaching net zero[33], to unlocking new scientific discoveries as evidenced by DeepMind's work on AlphaFold[34].
    d. **Use science as a national security asset** | The Integrated Review recognises the essential role of science and technology in modernising the UK's defence and security capabilities and shaping international norms with allies and partners.
    e. **Promote a positive global culture and regulatory environment for research and innovation |** The key tenets of science – rationality, transparency and universality – are an important source of soft power for building constructive international relations. The UK is in strong position to uphold and promote core scientific values such as academic freedom and also take the lead in developing safe and ambitious regulations that set the global standard. For example, the International Commission on the Clinical Use of Human Germline Genome Editing[35], convened by UK and US science academies following the birth of twins whose embryonic genomes had been edited (an act widely condemned for violating ethical norms), is directly informing the activities of the World Health Organization.

    Policy recommendations:

- Establish an independent technology assessment body to oversee the creation of a technology roadmap to net zero – including on digitalisation of the net zero transition – and encourage other countries to follow suit. The use of published and living socio-technical technology roadmaps, co-created with industry with consideration of technology readiness level (TRL) and level of investment risk, will help create a highly visible technology investment landscape clarifying public (high risk) private (low risk) and public/private co-investment (near market) opportunities, and market barriers for policy development.

- Invest in R&D to support new net zero power, heat, industry and transport and natural resources in excess of £1 billion per annum.
- Strengthen the UK's leadership in responsible digital innovation through a mission-driven approach to AI with a key focus on the use of data and digital technology to achieve net zero.
- Invest in the essential data infrastructure including technologies for privacy preserving and ethical use of data and the skills needed to make best use of data for societal benefit.
- Drive action to address the biodiversity crisis including recognising and properly accounting for the true value of biodiversity.
- Adopt a strategic approach to land use planning which integrates the objectives for climate, nature, food and development under a coherent spatial framework which can inform place-based delivery by local stakeholders.
- Fund the Natural Capital and Ecosystem Assessment currently in pilot phase to provide the baseline for monitoring progress towards the environmental objectives set out in 25 Year Plan and forthcoming Environment Bill.
- Apply outcome and risk based regulatory approaches to genetic technologies used in agriculture, offering an approach to environmental regulation and protection that has greater consistency and sustainability than product or technique-based approaches.
- Take a lead role in developing regulations that have international utility and establish international norms including responsible innovation and good research governance.

Notes

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