THE ROYAL SOCIETY

Friday 11 September 2020

Royal Society submission to the House of Commons Science and Technology Select Committee inquiry into the role of technology, research and innovation in the COVID-19 recovery

Summary

- Research and innovation help us to understand our world. This knowledge allows us to improve people's lives. Investment in research over many decades and the commitment of an army of scientists collaborating openly and widely across the globe have enabled us to respond to the COVID-19 pandemic. Technology, research and innovation will be crucial to our recovery.
- The pandemic has exacerbated existing fragilities in the research and innovation system in the UK. These include interdependencies between funding for research and for teaching, deficits in our strategic capability and the precarious employment conditions of many researchers and innovators.
- The actions that Governments of the UK have taken to support the research and innovation system are welcome, though it is too early to fully assess their efficacy. It is also important to recognise that there are further challenges ahead. In particular, the uncertainty over our future engagement with European science programmes and the impact of this on the attractiveness of the UK research and innovation system as a partner, destination for talent and target for investment.
- As part of a drive to increase the UK's comparatively low research intensity the UK government has committed to increase its investment in research and development (R&D) to £22 billion a year by 2025, and increase overall investment in R&D to 2.4% of gross domestic product by 2027. This is as an opportunity to make ambitious changes to the way that we do research and use its findings to benefit our economy and society. The government should ensure that the UK research and innovation system:
    - Remains an active participant in European Science. Association to Horizon Europe is necessary to prevent a cliff-edge that causes further damage to the UK system.
    - Is an attractive destination for those working in research and innovation. The proposed Office for Talent is a welcome recognition of the need for further action to deliver this. Further information and engagement by Government is needed to ensure that it is connected to the needs of the system.
    - Supports our transition to Net Zero and enables the UK to deliver on the potential for green growth. UK science offers enormous potential increase resilience and mitigate crises such as climate change, degradation of the biosphere, and other major societal challenges.
    - Is central to plans for driving sustained economic growth across the UK. UK science and technology capability is world class. The many centres of expertise across all regions of the UK should be exploited to maximise the mobile R&D investment that will help to create jobs, improve people's lives, and improve national resilience.
- The COVID-19 crisis is not over. Continued support from Government is necessary to ensure the sustainability of our research and innovation system going forward. This is an important investment that we must make now to enable the country to build the resilience required to meet future challenges.

Introduction

1. The Royal Society welcomes the opportunity to submit written evidence to the House of Commons Science and Technology Select Committee's inquiry into the role of technology, research and innovation in the COVID-19 recovery.
2. The Royal Society is the national academy of science for the UK. It is a self-governing Fellowship of many of the world's most distinguished scientists working across a broad range

of disciplines in academia, industry, charities and the public sector. The Society draws on the expertise of the Fellowship to provide independent and authoritative scientific advice to UK, European and international decision makers.

3. This submission consists of six sections, corresponding to the points identified in call for evidence:
    a. What role can technology, research and innovation play in supporting the UK's economic recovery from COVID-19 and how can it best be supported in this?
    b. Does the current or post-COVID situation lead to any particular opportunities or challenges for economic growth driven by technology, research and innovation?
    c. What lessons can be learnt from the role of technology, research and innovation in recoveries from previous economic downturns, and how relevant are these to the current situation?
    d. How have research and innovation in UK universities, businesses and other settings been affected by the COVID-19 pandemic, and how might they be affected by any lasting changes post-COVID?
    e. How effective have measures adopted by the Government to support research and innovation, such as the support packages for innovative firms and university researchers, and the 'Ministerial University Research and Knowledge Exchange Sustainability Taskforce', been?
    f. In the context of the Government's 'Research and Development Roadmap', what shorter-term measures can best support UK research and innovation in recovering from the disruption of the COVID-19 pandemic and adapting to the post-COVID environment?

What role can technology, research and innovation play in supporting the UK's economic recovery from COVID-19 and how can it best be supported in this?

4. Science provides us with new knowledge and concepts which can take us in new, often unforeseen, directions. The successful application of this knowledge has led to more effective medical treatments, and the creation of the technologies that enabled parts of our economy to continue to work effectively during the COVID-19 crisis. Research and innovation are interrelated and complementary endeavours that take place within a shared ecosystem, though they are often distinct from each other. Support for both will be critical to our immediate recovery.
5. Maintaining the UK's position as a global leader in science is crucial to our long-term economic strength. Underpinning this status is a diverse and internationally competitive workforce able to generate new knowledge and new applications of that knowledge. Innovation in areas such as biosciences, energy science and optoelectronics could contribute to future economic growth and help us to face long-term challenges including climate change and an aging population.
6. **Universities are at the core of the UK research and innovation system. They depend on considerable cross-subsidy to perform research. This may not be sustainable in the future climate, meaning that support/investment from government and elsewhere is required.** The pandemic has exposed the dangers inherent in the current higher education funding system in which funding for research is cross subsidised by tuition fees[1]. This cross subsidy is necessary as public funding does not cover the full economic cost of university research. Consequently, research is undertaken at cost to universities. It is unclear whether a commensurate increase in student recruitment, particularly of international students, is possible or desirable. Public sector research organisations are an important part of the research landscape, that undertake grant funded research. However, unlike universities they do not receive Quality Related (QR) block grant funding or tuition fees and so rely on other, often short-term, sources of funding to make up the shortfall. Provision of a greater proportion of the

[1] https://www.hepi.ac.uk/wp-content/uploads/2017/11/HEPI-How-much-is-too-much-Report-100-FINAL.pdf

full economic costs of research would assist with the sustainability of the organisations performing publicly funded research and so better enable them to contribute toward realising the Government's ambition of making the UK a 'Science Superpower.'

7. **Greater investment is needed in commercialisation.** In future, it will be essential for the UK to better leverage its research strength to underpin long-term economic strength. In the context of a real term uplift in public funding for research and innovation, there should be greater investment in interventions that support the commercial application of academic research and enable individuals and public and private sector organisations to innovate in products and services. The National Academies have commissioned work to understand, 'the conditions needed to translate research and drive innovation[2]' This work identified a 'lack of clarity about user needs and [the absence of] stable access to capital throughout the innovation process' as general barriers to translating research and driving innovation. Interventions that seek to overcome these challenges should be supported. This will be particularly crucial for encouraging private sector investment in the context of an economic recession. Current initiatives such as the Industrial Strategy Challenge Fund and British Patient Capital Programme operate in this space.

8. **Finally, to protect any recovery, we need to ensure that we are prepared for future challenges**. The UK's four national academies have played a key role in the response to the pandemic, reacting to multiply Government's abilities to rapidly access and utilise large numbers of diverse scientists, economists, and engineers from both public and private sectors to provide actionable evidence to support our response to the crisis. However, this has been an unplanned reactive effort. It is important to consider whether these processes should be formalised to support rapid responses to any future crises. The Comprehensive Spending Review provides an opportunity to address this.

Does the current or post-COVID situation lead to any particular opportunities or challenges for economic growth driven by technology, research and innovation?

9. This is a challenging time for the UK and its citizens. There are economic challenges as we enter recession, and many people have experienced deep personal tragedy. The Prime Minister has stated his ambition to "use this crisis to tackle this country's unresolved challenges" and to "unite and level up"[3]. Research and innovation have enabled us to respond rapidly to the COVID-19 pandemic and will be key to building better jobs and opportunities for everyone in the future. The UK government has committed to increase its investment in research and development (R&D) to £22 billion a year by 2025 and increase overall investment in R&D to 2.4% of gross domestic product by 2027. This investment is intended to support the Government's ambition for the UK to become a 'Science Superpower.' The UK research and innovation system is globally competitive. Additional investment could allow the UK to build on existing strength and deliver ambitious changes to our economy and society. If delivered judiciously alongside complementary interventions, this investment could help to achieve net zero emissions, assist in the better use of data and support the development of equitable technology-led growth.

10. **The UK has committed to achieving net zero emissions by 2045, ending its contribution to global warming. Action is required now to ensure that this goal is met. The COVID-19 crisis is a disruptive event. The response to this event should be used as an opportunity to introduce policies that will help to achieve net zero.** To achieve net zero emissions, reductions will be required from all sectors of the economy. Beyond the reduction of emissions, we will need to actively remove greenhouse gases from the atmosphere. Government should use this opportunity to examine how we travel, heat our homes, what we eat and how we reduce waste with increased reuse and recycling. There must also be a focus on investing in new technologies in a range of sectors including:

[2] https://royalsociety.org/topics-policy/publications/2018/a-fresh-case-for-investment-in-uk-research-and-innovation/
[3] https://www.gov.uk/government/speeches/pm-economy-speech-30-june-2020

a. *Power*: Further development of renewables, large-scale long-term energy storage and smart systems, carbon capture and storage (CCS) infrastructure and research into the potential use of the captured carbon.

b. *Transport*: Continued improvements in batteries and an early move to alternative fuel sources such as biofuels for sectors such as aviation, HGVs and shipping. Alternative fuels need to be researched further, including hydrogen, ammonia and synthetic fuels.

c. *Agriculture, forestry, land use and protecting biodiversity*: Developing solutions for more sustainable livestock farming, increased soil carbon storage, afforestation, restoration of wetlands to store more carbon, and decreased mineral nitrogen fertiliser use, and demonstrating global leadership in how biodiversity is valued economically.

d. *Residential and commercial heat:* improved insulation, use of heat pumps and research to improve their efficiency, and potential use of hydrogen to replace natural gas. In the face of consistent policy failure over decades in failing to stem the tide of unprecedented global biodiversity losses, the Government should also act internationally to push for radical new policy measures to properly value and account for biodiversity, to incentivise good global stewardship of the resources future generations will depend on.

e. *Industry*: shift to low, zero, or negative carbon emissions, for example by using heat more efficiently, developing alternate power and fuel sources, using more efficient processes and building with low or negative emission carbon-negative building materials (wood, carbonated aggregates). Further, capturing CO2 from industrial processes and storing it underground or in economically viable products will be essential.

f. *Adaptation*: Adapt infrastructure in preparation for environmental changes, and increased frequency of extreme weather events to improve safety and minimise economic harm, including through improved return on investments on more climate resilient infrastructure

11. **Digital technologies will be crucial to supporting the UK's transformation to net zero.** Combining digital sensors, wireless networks and computer algorithms can help farmers shift to precision agriculture, where the amount of water, fertiliser and energy they need to grow their crops can be improved. Offices and our homes can be better monitored to ensure they are only heated and cooled as needed. Using technology in new ways also brings challenges. Further action is needed to create an environment of careful stewardship, where the benefits of digital technology are shared across society. Safe and rapid deployment of digital technologies will require action to:

    g. *Create an amenable data environment*: Realising the potential of digital technologies will require access to well-governed data, but large-scale data analysis may be constrained by important legal, reputational, political, business and competition concerns. An amenable data environment would draw from open standards and frameworks or behaviours to ensure data availability across sectors.

    h. *Build skills at all levels:* There is a high demand for people with data science skills, with specialists in the field being highly sought after across organisations, from government departments to technology start-ups. Developing foundational skills by ensuring our education system provides all young people with data science knowledge and skills, advancing professional skills by offering nimble and responsive training opportunities, and enabling the movement and sharing of talent by addressing barriers to mobility between sectors will be vital.

    i. *Encourage the development of trustworthy technology interfaces:* Digital technologies could become powerful decision-support tools. By integrating data from across different sources or organisations and identifying points of intervention to increase the efficiency of a system, these tools could enable more effective human management of complex systems – whether transport, land use, or energy networks. This requires careful design of the interfaces between people and technology, with implications for the underlying technical architecture.

j. *Manage carbon emissions from digital technologies:* Digital technologies rely on a complex infrastructure of cables, fibres, computers, data centres, routers, servers, repeaters, satellites, radio masts and energy needed to perform their functions. Operating these systems requires energy, and – if computing systems are to be widely deployed as digital infrastructure for managing activities across sectors – the energy demands and emissions from them will need to be understood and managed.

k. *Support digital technologies that have proven critical to effective operation during the pandemic***:** Highly digitalised logistics have been central to the impressive resilience of the food sector, supply chains in other critical sectors, and home delivery. Digital tools have instantly transformed entire businesses and sectors that were location dependent, to effective remote operations. Given that the service sector dominates the UK economy, exploiting and enhancing digital tools and innovations will be central to future growth.

12. **R&D may offer opportunities to address regional inequalities and further work should be undertaken to ensure that place-based investment deliver regional growth.** R&D investment is concentrated in three regions of the UK: the East of England, London, and the South East. This concentration of investment reflects a broader disparity in regional economic performance. The pandemic has triggered an economic recession[4]. The economic repercussions will cut across industries and individual in ways that are complex and do not neatly align with geography. It is likely to entrench existing regional inequality. While pre-COVID 19 employment levels in the UK were high, overall productivity growth in the UK has been flat since the 2008 financial crisis, though this varies massively within and between regions. The 'levelling-up' agenda is focused on addressing this regional inequality. Investment in R&D in one means of achieving productivity-led growth: "The creation and application of new ideas is critical for long-run productivity growth. There is clear and robust evidence of a link between R&D spending and national productivity"[5].

13. The Government's commitment to increase funding in R&D and ensure that the benefits of this investment are more widely felt is welcome. Care is needed to ensure that this increase is delivered judiciously. Further work to better understand the role of R&D in supporting regional economic development may be beneficial to ensure that 'place-based' investments deliver regional growth. Specifically, to understand the relative importance of public R&D investment alongside other factors such as investment in skills and infrastructure.

What lessons can be learnt from the role of technology, research and innovation in recoveries from previous economic downturns, and how relevant are these to the current situation?

14. The severity of the global economic recession precipitated by the pandemic represents the deepest recession since the Second World War[6]. The relevance of any lessons learnt from previous economic downturns, including the 2008 financial crisis, should be considered in this context. Still, our understanding of the role that technology, research and innovation play in economic growth and providing resilience provide some direction in the current context. Specifically, with regard the dangers of short-termism and the need for foresight by policymakers.

15. Historically, technology, research and innovation have been crucial to economic development. For example, significant investments by governments in East Asia after the Second World War, contributed to the period of high and sustained economic growth known as the 'East Asian

[4] https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/articles/coronaviruscovid19roundupeconomybusinessandjobs/2020-07-02

[5] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/443897/Productivity_Plan_print.pdf

[6] https://www.worldbank.org/en/news/press-release/2020/06/08/covid-19-to-plunge-global-economy-into-worst-recession-since-world-war-ii

Miracle.'[7] In Taiwan, public investments in the 1970s contributed to the creation of a technology cluster at Hsinchu whose turnover now accounts for approximately 6% of GDP[8].

16. In 2010, the Royal Society published, 'The Scientific Century: securing our future prosperity'[9]. This document, written in the aftermath of the 2008 financial crisis, set out a bold vision with science and innovation at the centre of the UK's future growth. While the domestic circumstances have changed, the vis.ion set out in The Scientific Century remains compelling, as do its two central messages: the need to place science and innovation at the heart of the UK's long-term strategy for economic growth and the fierce competitive challenge from countries investing at a scale and speed that the UK may struggle to match. The six overarching recommendations of the report are repeated below for consideration:

    a. Recommendation 1: Put science and innovation at the heart of a strategy for long-term economic growth
    b. Recommendation 2: Prioritise investment in excellent people
    c. Recommendation 3: Strengthen Government's use of science
    d. Recommendation 4: Reinforce the UK's position as a hub for global science and innovation
    e. Recommendation 5: Better align science and innovation with global challenges
    f. Recommendation 6: Revitalise science and mathematics education

17. In the intervening ten years, progress against these six recommendations and a subset of more detailed actions, has been variable. Austerity policies during the 2010s led to, and accelerated, disinvestment in specific areas of the UK's science capacity. For example, DEFRA's R&D budget fell from approximately £250m in 2006 to approximately £100m in 2014[10], diminishing the Government's scientific capability in areas of direct relevance to the current pandemic. Conversely, the creation of the Industrial Strategy Challenge Fund in 2016 is a positive intervention and signal, as something that seeks to better align science and innovation with global challenges.

18. The current Government's commitment to increased investment is a significant positive step. It is important that this investment be sustained in order to support the long-term generation of scientific knowledge and accompanying economic and social benefits. To illustrate, the emergence of a successful life sciences cluster in Cambridge is in large part a product of sustained public funding for research, specifically through the Laboratory of Molecular Biology (LMB). The LMB was established, first as the Medical Research Council 'Unit for the Study of the Molecular Structure of Biological Systems' in 1947. Advancements in scientific knowledge are the product of years of sustained effort. This effort requires support through long-term funding for people, institutions and infrastructure. Translating the research outcomes into the creation or improvement of products and services requires complementary sources of support. Both require an understanding by politicians that investments in research and innovation may have positive uses and results in the future that cannot be articulated today. The current pandemic has shown the need for spare capacity and resilience in the research and innovation system.

How have research and innovation in UK universities, businesses and other settings been affected by the COVID-19 pandemic, and how might they be affected by any lasting changes post-COVID?

19. Research and innovation in UK universities, businesses and other settings – including public sector research establishments – have been severely affected by the COVID-19 pandemic. The impacts vary in both type and severity. As will the extent to which these organisations and the people that they employ are able to recover from the damage.

20. A high volume of university research and knowledge exchange has been suspended. The sustainability of institutions, and therefore their ability to resume activities, will be reduced by the impacts of a weakened economy and by fewer international students with the desire or

[7] https://documents.worldbank.org/en/publication/documents-reports/documentdetail/975081468244550798/main-report
[8] https://www.sipa.gov.tw/english/file/20190617135632.pdf
[9] https://royalsociety.org/-/media/Royal_Society_Content/policy/publications/2010/4294970126.pdf
[10] https://www.sciencecampaign.org.uk/news-media/case-comment/departmental-r-d-2016.html

ability to come to the UK. A London Economics report published in April[11] suggested an average loss of income per higher education institution of approximately £20m, with some potentially losing £100m. This could lead to approximately 30,000 job losses in the sector. While the impact will be variable across institutions, all will be affected. Four key risks to universities have been identified:

a. *Impact of a reduction of international students and other financial pressures*: Universities UK estimate the fall in income at approximately £790m[12]. This is likely to be compounded in 2020/21 by an anticipated significant fall in international students and a rise in undergraduate home student deferrals.

b. *Impact of lower levels of charity funding for university research*: Universities are reporting significant challenges in certain disciplines. In medical research, the diversity of funding sources, high dependence on charitable funding, high cost of research and clinical responsibilities of researchers pose specific challenges. In 2018, over 40% of publicly funded medical research was funded by charities, with 87% of charitable funded research taking place in universities[13]. Cancer Research UK have already announced a £44 million cut to their research expenditure.

c. *University staff reductions*: The capacity of universities to operate has been reduced directly through the diversion and redeployment of staff and resources to support the national effort and indirectly by the necessity for home working and the furloughing of staff. In the context of the medical sciences, many clinical research staff have returned to frontline clinical duties and cannot fulfil normal research responsibilities.[4]

d. *Reduced levels of business funding for R&D*: The impact of the crisis on the economy will reduce the ability of the private sector to directly fund research at universities. More broadly reduced private sector investment in R&D will reduce the demand for skilled employment and so affect graduate prospects as well as the strength of the wider UK research system

21. The following impacts have also been identified:

a. *Impact on the research workforce*: Financial impacts on universities are having knock-on effects on researchers, particularly students and those on fixed-term contracts. Postdoctoral researchers, who are a vital layer in the research infrastructure but are often on fixed term contracts tied to time-limited grants, and PhD students (whether funded or not) are at particular risk. They must be protected to ensure the long-term sustainability of the system. Without steps to address the effects of the pandemic on career progression, the UK risks a 'lost-generation' of early career researchers.

b. *Differentiated impact across individuals and disciplines:* The capacity of individuals to continue to conduct research effectively during the current crisis is affected by a range of factors that include the nature of their research and their personal circumstances. Work that requires large teams and/or cannot easily be conducted remotely may have suffered more than research that can be conducted with limited access to specialist equipment and materials. With regard personal circumstances, individuals with caring responsibilities, those at the beginning of their careers and those in vulnerable groups may have had their ability to undertake research, publish and submit grant applications disproportionately affected by the crisis, thereby exacerbating existing inequalities.

c. *Disruption to capital and estates plans:* The immediate crisis and economic impact will create disruption to university capital and estates plans. This could lead to a long-term diminution in research infrastructure.

22. The capacity of universities to avoid lasting damage from the pandemic is in large part tied to their ability to their ability to recruit a sufficient level of students to enable a return to pre-pandemic levels of activity. Predictably, those institutions that were experiencing financial

[11] https://londoneconomics.co.uk/blog/publication/impact-of-the-covid-19-pandemic-on-university-finances-april-2020/
[12] https://www.universitiesuk.ac.uk/news/Documents/uuk_achieving-stability-higher-education-april-2020.pdf
[13] https://www.amrc.org.uk/position-statement-on-supporting-research-in-universities

difficulty before the crisis are facing the greatest challenges. In the context of research, the differentiated impact on disciplines and individuals is likely to continue as long as some degree of necessary lockdown measures are in place, though some adaptation is taking place. As mentioned earlier, this crisis has exposed the frailty inherent in the current system in which research activity is cross subsidised by tuition fee income. While institutions are able to extract efficiencies and can, to varying degrees, draw on their QR block grant a reconsideration of the optimal level of FEC supported by public grants is timely.

23. Approximately two-thirds of spending on R&D in the UK comes from the private sector[14]. In 2017, the four largest sources of private investment in R&D by sector were pharmaceuticals (£4.34bn), motor vehicles and parts (£3.60bn), computer programming and information service activities (£1.92bn) and aerospace (£1.52bn)[15]. Private investment in critical to the health of the UK R&D system. The ongoing impact of the pandemic on the world economy is severe[16]. While the impact has varied for sectors or regions, many businesses in the UK have been negatively affected[17]. As with the 2008 financial crisis[18], a decrease in private sector investment in R&D is expected. Government action to incentivise the private sector to support the diffusion, adoption and application is vital.

How effective have measures adopted by the Government to support research and innovation, such as the support packages for innovative firms and university researchers, and the 'Ministerial University Research and Knowledge Exchange Sustainability Taskforce', been?

24. The Royal Society participated in the Ministerial University Research and Knowledge Exchange Taskforce as a representative of the National Academies. The Royal Society is also administering additional Government funding to support for researchers related to COVID-19.

25. It is too soon to assess the long-term efficacy of specific measures adopted by the Governments of the UK to support research and innovation.". However, we welcome the intent of Government and recognises that action has been taken relatively quickly to try and address the impact of the pandemic. In time, proper evaluation of the efficacy of the measures taken by Government is necessary.

26. It is important to note that uncertainty regarding our association to Horizon Europe is another immediate challenge for the research and innovation system. We must work to avoid a damaging cliff edge for UK research as the UK exits the EU at the end of the year by securing a positive outcome for science with the EU, including association to Horizon Europe. European connectivity has ensured that science, innovation and knowledge is not held up at state borders. Scientists working together in European research projects have helped to make our continent a leading scientific destination. Whatever our future relationship with the EU, we need to remain part of European science.

In the context of the Government's 'Research and Development Roadmap', what shorter-term measures can best support UK research and innovation in recovering from the disruption of the COVID-19 pandemic and adapting to the post-COVID environment?

27. The publication of the UK Research and Development (R&D) Roadmap is a positive statement of intent. We have welcomed 'the vision for UK science that is forward and outward looking. With its focus on investment, talent – whoever they are and wherever they are from – and international collaboration it can provide a basis for confidence in the future.' The Roadmap contains a useful analysis of the current research and innovation landscape and provides a coherent framing for Government research and innovation policy. As it acknowledges, it is 'the

[14] https://royalsociety.org/-/media/policy/projects/investing-in-uk-r-and-d/2019/investing-in-UK-r-and-d-may-2019.pdf
[15] https://royalsociety.org/-/media/policy/projects/investing-in-uk-r-and-d/2019/investing-in-UK-r-and-d-may-2019.pdf
[16] https://www.worldbank.org/en/news/press-release/2020/06/08/covid-19-to-plunge-global-economy-into-worst-recession-since-world-war-ii
[17] https://www.ons.gov.uk/businessindustryandtrade/business/businessservices/bulletins/coronavirusandtheeconomicimpactsontheuk/latest
[18] https://www.nature.com/articles/d41586-018-06634-4

start of the conversation.' Further work is required to identify the solutions to the challenges that the Roadmap describes. The Royal Society has written a letter to the Secretary of State in response to the publication of the Roadmap which included a response to the accompanying online survey[19].

28. In terms of shorter-term measures to best support UK research and innovation to recover from the disruption of the pandemic, the Roadmap closes by describing its 'Next Steps', which includes engagement with a range of stakeholders and work over the coming months to develop a comprehensive R&D plan. Sustained stakeholder engagement is vital. This should provide Government with a mechanism to gain input on both the immediate challenges and any remedial short-term action required, as well as input to help shape the 'comprehensive R&D plan'. Short-term actions should include steps to address the effects of the pandemic on the career progression of researchers – not just those funded by UKRI. Without intervention, the UK risks a 'lost-generation' of early career researchers. The latter 'comprehensive R&D plan' will need to have regard to both the immediate context as well as a clear and compelling vision for the role of technology, research and innovation at the centre of the UK's economy and society. This is an opportunity for the necessary discussion of how best to fund research, including the optimal proportion of full economic cost support by public grants.

29. The Roadmap includes reference to new groups, interventions and organisations at various stages of development. These include UK ARPA, the R&D People and Culture strategy, an Innovation Expert Group, the R&D Place Advisory Group, and the Office for Talent. It is vital that stakeholders across the research and innovation landscape are engaged with the detail of these to ensure coherence at a time of significant disruption. For example, the thinking behind the proposed new Office for Talent is welcome but we know very little about how it will operate in practice. The Royal Society has first-hand experience of these issues within our Fellowship. We want to engage and support this body to help address known challenges in the UK research and innovation system.

30. Finally, the Roadmap states that, 'following the COVID-19 crisis, we want to build a future which is greener, fairer, healthier, more resilient and more innovative that ever before.'[20] To achieve this we need:

    a. **A positive outcome for science with the EU**, including association to Horizon Europe, avoiding a damaging cliff edge for the UK.

    b. **An outward looking, international approach**. Science is global, as well as European. We must be ambitious to create new deals with leading and established science nations around the world, in addition to Europe. To do this, we need wider support for mobility – both into and out of the UK, working overseas can form an important part of a global scientific career - and incentives to drive this. The Royal Society is making a bid to the Comprehensive Spending Review currently underway to significantly increase our grant and non-grant international collaboration offer in attempt to support this.

    c. **A competitive immigration regime to ensure that the UK is an attractive destination for those able to contribute to building this future.** The new Global Talent Visa route is welcome, but high visa costs in comparison to international competitors remain a significant barrier, particularly to postdocs. Upfront visa costs here are four to six times higher than in other leading science nations.

    d. **The skilled people to do R&D.** To remain a world leading destination for science, research and business, the UK needs to invest in its own workforce, including ensuring that all young people have a broad and balanced education that includes science, arts and humanities education up to age 18 - while continuing to attract the best international talent.

[19] https://royalsociety.org/topics-policy/publications/2020/consultation-response-letter-to-alok-sharma-in-response-to-r-and-d-roadmap-survey/

[20] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/896799/UK_Research_and_Development_Roadmap.pdf

e. **A stable system with a clear long-term plan**. This can provide the continuity that is needed to pursue potentially transformative lines of scientific enquiry over long timeframes. It will also give confidence to investors in the UK and overseas.

f. **A major targeted strategic campaign to exploit the UK**'s world class science capabilities and assets to attract globally mobile R&D investment.

For further information, please contact public.affairs@royalsociety.org