THE ROYAL SOCIETY

Response to 'One Nation Labour's Plan for Science'

Introduction

The UK is an attractive and productive place to conduct world class research. The potential of this research to transform society, revitalise the economy, improve health and enhance wellbeing has been demonstrated in recent studies, and in the years to come research and innovation will play an even more central role in our knowledge-driven economy.[1] As the UK reaps the benefits of past investment in science, and the economy begins to recover from the recent stagnation, continued investment must be ensured for future prosperity.

The Royal Society believes that science and innovation are crucial to the future social and economic prosperity of the UK, as outlined in the statement *Fuelling prosperity*[2] published jointly by the UK national academies. A long-term plan for science and innovation, building on and supporting the already strong system in place, is necessary, as decisions made today will have a long-lasting impact on the future prosperity of the UK.

The Society welcomes the opportunity to comment on Labour's green paper on science[3]. This response is based on reports and analyses previously carried out by the Society, and on work being prepared for future spending reviews. The response is structured around the questions outlined in the Labour green paper and is publicly available on the Society's website.

A successful plan for science and innovation should:

- Build on the existing strengths of the UK science system.
- Provide a flexible long-term framework that enables the UK to collaborate and compete internationally.
- Be broad in scope to encompass the UK's richly diverse and integrated science and innovation system.
- Have excellence as the primary guiding principle for decision-making in research investment.
- Assign Government an active role in encouraging business investment in research.
- Promote the use of evidence in policy-making, both nationally and internationally.
- Include concrete proposals to develop, retain and attract the skilled individuals the UK will need.

Science Investment

How can we make better use of the UK's resources to support science and innovation?

The Society strongly supports a long-term plan for science and innovation, consisting of an ambitious and flexible framework covering a period of at least 10 years. [4] The framework should aim to maintain a

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[1] See for example Haskel et al. (2014), *The Economic Significance of the UK Science Base,* http://www.sciencecampaign.org.uk/UKScienceBase.pdf; and Glover et al. (2014), *Estimating the returns to UK publicly funded cancer-related research in terms of the net value of improved health outcomes, http://www.wellcome.ac.uk/About-us/Publications/Reports/Biomedical-science/WTP056596.htm*

[2] UK national academies (2013), *Fuelling prosperity: Research and innovation as drivers of UK growth and competitiveness*. https://royalsociety.org/policy/publications/2013/fuelling-prosperity/

[3] Byrne (2014), *One Nation Labour's Plan for Science*. http://liambyrne.co.uk/one-nation-labours-plan-for-science-24-june-2014/

[4] UK national academies (2013), *Fuelling prosperity: Research and innovation as drivers of UK growth and competitiveness*. https://royalsociety.org/policy/publications/2013/fuelling-prosperity/

broad research base that provides the UK with the capacity to address current, emerging and as yet unknown challenges. A long-term framework would provide the stability needed by industry, charities and academia to attract investment and talent from overseas, allow the training of skilled professionals, and reflect the time needed to tackle long-range scientific challenges. Structuring the plan as a periodically reviewed framework would allow flexibility with direction.

An essential interdependence exists between one-off investments (capital) and recurring expenses (resources). While capital investment has now been restored to pre-2010 levels and protected in real terms for the next five years, a flat-cash arrangement since 2010 has led to the erosion of the science budget due to inflation. Both budgets should be protected in real terms to create maximum value from their interaction. A ring-fenced science budget for both resources and capital, which at the very least should be protected in real terms to keep pace with inflation, is an essential component of a stable investment framework.

The Society, jointly with the other UK national academies, has recently submitted a joint response to the Government consultation on science and research capital investment.[5] Excellence should be the primary guiding principle for decision making within a wider strategic vision of investment in research capital, and investment is required across the whole spectrum of research projects. The response also highlighted the need for comprehensive operational planning to support research infrastructures. Any new initiatives will require ongoing funding for maintenance, staffing, refurbishment, insurance and upgrades. These requirements, alongside a description of how they will be provided, should be clearly detailed at the outset in a business plan.

A successful plan for science and innovation should take into consideration the full breadth of publicly and privately funded research to ensure the two are complementary and to leverage additional investment from other sectors and abroad. The UK's research landscape extends beyond universities and those institutions supported by the 'science budget' in BIS. Across Government, the Department of Health (through the National Institute of Health Research (NIHR)), the Ministry of Defence, the Department for International Development, the Department of the Environment, Food and Rural Affairs and other public bodies also invest heavily in research and innovation. In addition, there is an important international dimension to UK science, as outlined below.

Beyond the public sector, businesses and charities play an important role in the research landscape. However, private sector investment in R&D in the UK is significantly lower than in most other advanced economies.[6] As highlighted in a recent study, private and public sector research expenditures are not interchangeable but act in a complementary way that contributes to economic growth.[7] The Government can play an active role in encouraging business investment in research. This will necessitate a broadening of focus from the supply-side measures controlled by BIS to encompass similar measures in other departments, such as the NIHR, and demand-side measures across Government and the research and innovation system as a whole, such as procurement.

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[5] UK national academies (2014), Response to BIS Consultation on Proposals for Long-Term Capital Investment for Science and Research. https://royalsociety.org/policy/publications/2014/consultation-response-long-term-capital-investment-science-research/

[6] Allas T (2014) Insights from international benchmarking of the UK science and innovation system https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277090/bis-14-544-insights-from-international

[7] Haskel et al (2014), *The economic significance of the UK science base.* http://www.sciencecampaign.org.uk/UKScienceBase.pdf

The Technology Strategy Board has been a welcome addition to the funding landscape in the UK and can help translational research to have high impact. For example, each £1 that the TSB invests in collaborative R&D between business and researchers typically returns around £7 in Gross Value Added.[8] The positive role played by the TSB in supporting industrial collaboration with the academic research base, which relies on the strength of the UK research and innovation system as a whole, should be recognised. The TSB should be adequately resourced to fulfil this role, without redirecting funds away from other parts of the research and innovation system. A successful plan for science and innovation should also reflect the importance to the UK's science and innovation performance of regulation, taxation, procurement, immigration, education and foreign policy (see below).

Do you believe the previous Labour government's 10 year approach was a success and how can we learn from this in the future?

The Society supports a long-term approach to science and innovation. Specific policy measures developed in recent years are addressed under the relevant sections of this response.

How can we unlock greater levels of private sector investment?

Business and charitable decisions about R&D investment take account of the whole research and innovation system in which they take place. The scarcity of private sector investment is an obstacle to the growth of the UK science and innovation system, and the government should play an active role in encouraging it. Public investment in research underpins and attracts private and charitable investment in R&D, and a strong public research base supported by stable, long-term investment is therefore a key foundation for business investment.[9] [10] A plan for science and innovation should be linked to the UK's Industrial Strategy to ensure a coherent approach across Government, with science and innovation sitting at the heart of plans for growth.[11]

Innovation and research in the private sector are increasingly open, and therefore opportunities to collaborate with academic talent are a crucial factor in business R&D investment decisions (see below). [12] Following the 2003 Lambert Review, considerable efforts have gone into increasing the supply and quality of commercial ideas from universities into businesses through a range of policy measures such as the successful Higher Education Innovation Fund (HEIF).[13] This has paid some dividends. The World Economic Forum's ranking of the UK's university-industry collaborations has improved from ninth in 2008/2009 to fifth in 2013/2014.[14] [15] [16] The Society therefore supports the recommendation of the Witty

[8] See https://www.innovateuk.org/documents/1524978/1866950/Press+briefing+-+The+Technology+Strategy+Board+at+a+glance/d03376c9-e7f5-4fe8-b658-6bc2e9b1653e

[9] Falk (2006). What drives business research and development intensity across OECD countries? Applied Economics 38

[10] Haskel et al. (2014), *The Economic Significance of the UK Science Base*. http://www.sciencecampaign.org.uk/UKScienceBase.pdf

[11] UK National Academies (2013), *Fuelling prosperity: Research and innovation as drivers of UK growth and competitiveness.* https://royalsociety.org/policy/publications/2013/fuelling-prosperity/

[12] Royal Society (2012), *Science as an open enterprise*. https://royalsociety.org/policy/projects/science-public-enterprise/Report/

[13] Lambert R (2003). The Lambert Review of business-university collaboration. http://www.eua.be/eua/jsp/en/upload/lambert_review_final_450.1151581102387.pdf

[14] World Economic Forum (2008). Global competitiveness report. http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2008-09.pdf

[15] World Economic Forum (2013). Global competitiveness report. http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2013-14.pdf

Review to make an explicit long-term commitment to the HEIF and an increase of funding through this mechanism.[17] Nevertheless, gaps remain. For example, the UK has relatively low levels of academic corporate co-authored publications, and collaborations between universities and SMEs, although the latter are growing.[18] [19]

The overall financial and tax environment is also important for business. The Society supports R&D tax credits as a means to stimulate private sector investment in science and innovation. The newly introduced Patent Box has the potential to attract internationally mobile business R&D investment to the UK, but needs to be carefully monitored to ensure value for money.[20] [21] Simple ways exist to increase business investment in collaborative research. For example, removing the 5% limit on the amount of commercially sponsored research that can be carried out in a building before VAT has to be paid on the entire building, which discourages universities and business from working together at present.[22] This for example has been a major issue for the operation of the Francis Crick Institute.

The past 20 years have also seen a number of beneficial tax measures to encourage 'angels' and venture capitalists alike to take the enormous financial risks which are often necessary to start an innovative company. These include the establishment of Venture Capital Trust and Enterprise Investment Schemes. However, the abolition of the 10% business assets capital gains tax (CGT) rate in the 2009 Finance Bill almost doubled the exit tax rate for founder entrepreneurs who subsequently sell their businesses. Taxation incentives are an important factor in the passage over the 'valley of death'. The Society recommends addressing the issue of CGT in the first instance, and investigating other ways in which taxation might be used to stimulate entrepreneurship. The incentive competition from other countries is serious.

Emerging innovative companies often struggle to find the funding to progress beyond the start-up stage. One financing opportunity would be to attract funds that hold portfolios of other investment funds (known as funds of funds) rather than investing directly in bonds, stocks or other securities directly. This

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[16] Innovation indexes such as that produced by the World Economic Forum do have limitations such as the use of survey data as a proxy for direct measure of outcomes, which can be difficult to directly quantify. Also in this case the time series is quite short and the parameters of the survey questions changed slightly between reports.

[17] Witty A (2013). *Encouraging a British invention revolution: Sir Andrew Witty's review of universities and growth.* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/249720/bis-13-1241-encouraging-a-british-invention-revolution-andrew-witty-review-R1.pdf

[18] Allas T (2014) Insights from international benchmarking of the UK science and innovation system https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/277090/bis-14-544-insights-from-international

[19] BIS, HEFCE, Scottish Funding Council, Department for Employment and learning Northern Ireland and HEFCW 2013). Higher education –business sand community interaction survey. http://www.hefce.ac.uk/media/hefce/content/pubs/2013/201311/Higher%20Education%20-%20Business%20and%20Community%20Interaction%20Survey%202011-12.pdf

[20] Royal Society (2010), *The Scientific Century: securing our future prosperity*. https://royalsociety.org/policy/publications/2010/scientific-century/

[21] Levy and O'Brien (2013), Will the Patent Box boost the UK innovation ecosystem? Policy Briefing. *http://www.biginnovationcentre.com/Assets/Docs/Patent%20Box%20Final.pdf*

[22] Royal Society (2014), Response to the House of Commons Business, Innovation and Skills (BIS) Committee consultation on business-university collaboration. https://royalsociety.org/~/media/policy/Publications/2014/response-to-bis-consultation-business-university-collaboration-20140430.pdf

might be achieved with matched or partly matched investment from the public sector. Successful mechanisms, such as the Research Partnership Investment Fund (RPIF), that leverage investment from industry might be used to attract this finance or act as a model to achieve this goal. Another option might be to attract longer term investors such as pension funds, sovereign wealth funds, insurance companies and livery companies, although regulations can sometimes restrict the ability of these investors to fund some innovative endeavours.[23]

Finally, SMEs can be very innovative, but may have limited capacity for understanding and taking advantage of Government initiatives. The TSB has a number of initiatives in place that support SMEs and should aim to increase awareness and uptake of them.[24] Maintaining stable initiatives is important to allow time for companies to become familiar with them. The Small Business Research Initiative has had some success in leveraging the Government's substantial procurement budget to support SMEs, and should continue to aim to do this to the fullest possible extent.[25] There should be stronger recognition in such schemes that many SMEs are part of a supply chain headed by larger companies.

Strengthening British science

Science can lead to great benefits for society and the economy, but the routes to impact for curiosity-driven research are complex and unpredictable. The distinction between 'basic' and 'applied' research should not be over-emphasised, as often each supports the other in an iterative and non-linear process.

What more can be done to improve the way science is driven by British universities?

Our world-class higher education system underpins the UK's success in drawing the brightest talent from across the world, producing a first class workforce, attracting business, driving knowledge creation and innovation, and enabling us to be a leader in a competitive and inter-connected global economy. Research and innovation are essential to the future success of the UK economy, and business-university collaboration is important for research and innovation, particularly as many contemporary scientific challenges are so complex and involve considerable risk.[26]

The value of business-university collaboration goes far beyond simply generating external revenue for higher education institutions and can benefit all the partners. These alliances foster the development of skilled people who are vital to the UK's knowledge economy and whose formal and tacit knowledge can help the absorption of ideas from abroad.[27,28] Universities are a cornerstone of the UK science base, and Government has an important role to play in facilitating business-university collaboration for both private

[23] House of Commons Science and Technology Committee (2013). Bridging the valley of death: improving the commercialisation of research. http://www.publications.parliament.uk/pa/cm201213/cmselect/cmsctech/348/348.pdf

[24] Royal Society (2014) Response to the House of Commons Business, Innovation and Skills (BIS) Committee consultation on business-university collaboration. https://royalsociety.org/~/media/policy/Publications/2014/response-to-bis-consultation-business-university-collaboration-20140430.pdf

[25] Tredgett and Coad (2013). The shaky start of the UK Small Business Research Initiative (SBRI) in comparison to the US Small Business Innovation Research programme (SBIR). *http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2205156*

[26] Sainsbury D (2013). *Progressive capitalism*. Biteback publishing, London.

[27] Allas T (2014) *Insights from international benchmarking of the UK science and innovation system* 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

[28] The Royal Society (2010). *The scientific century. Securing our future prosperity.* https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2010/4294970126.pdf

and public benefit as an active partner in a dynamic research enterprise alongside industry, charities, academia and the public.

Mobility between academia and industry promotes effective knowledge exchange, and bi-directional and prolonged exchanges are crucial for building mutual understanding, trust and a shared language. Improving mobility of individuals and permeability between different sectors would improve collaboration. Informal knowledge exchange is also important, but is typically underplayed in policies.[29] [30]

Evidence has emerged that the increased interest from universities in IP might, in some cases, have proved a barrier to business-university collaborations.[31] The commercial value of some intellectual property may be overestimated and rights exercised too early in the process of knowledge generation. By being less protective of their IP, universities have the opportunity to harness increasing interest in open innovation from companies that are now looking outwards for ideas.[32] This model is in contrast to the large in-house research laboratories of the past. Open innovation is about more than just openness. More important are the underpinning mutually beneficial collaborations and personal relationships. However, open innovation does not remove the need for corporate in-house R&D. If a company is to gain from external ideas, internal R&D skills are needed to develop and maintain 'absorptive capacity' – the ability of companies to assimilate and use knowledge.

Clusters play a key role in fostering business-university collaborations as they provide economies of agglomeration through an ecosystem of different-sized companies, universities and investors that stimulates the exchange of people and ideas.[33] Evidence shows that companies, especially those from abroad, often choose to site their R&D labs near the best universities.[34] There is also a strong correlation between the research assessment results for a University and the number of venture backed companies and R&D companies that surround it.[35,36] When considering supporting clusters, governments need to be careful to ensure that this is done at the right time in the development of an industry/technology. This is demonstrated by repeated unsuccessful attempts to emulate Silicon Valley.[37] Successful clusters are characterised by a critical mass of academic and commercial endeavour with exchange of people across

[29] Royal Society (2009), *Hidden Wealth: the contribution of science to service sector innovation.* https://royalsociety.org/policy/publications/2009/hidden-wealth/

[30] Royal Society (2014) Response to the House of Commons Business, Innovation and Skills (BIS) Committee consultation on business-university collaboration. https://royalsociety.org/~/media/policy/Publications/2014/response-to-bis-consultation-business-university-collaboration-20140430.pdf

[31] Parker R (2013). 2003 Lambert Review: seminal and pragmatic. http://blogs.royalsociety.org/in-verba/2013/07/15/2003-lambert-review-seminal-and-pragmatic/

[32] The Royal Society (2010). The scientific century. Securing our future prosperity. https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2010/4294970126.pdf

[33] Academy of Medical Sciences (2011). *Submission to the Innovation and Research Strategy.* www.acmedsci.ac.uk

[34] Abramovsky L, Harrison R and Simpson H (2007). *University research and the location of business R&D.* Economic Journal 117, 519.

[35] Sainsbury D (2013). *Progressive capitalism.* Biteback publishing, London.

[36] Sainsbury D (2007) *The race to the top. A review of Government's science and innovation policies.* http://www.rsc.org/images/sainsbury_review051007_tcm18-103118.pdf

[37] PricewaterhouseCoopers (2010). Government's many roles in fostering innovation. http://www.pwc.com/gx/en/technology/pdf/How-governments-foster-innovation.pdf

these sectors, strong capital and financial infrastructure, and a highly educated local population.[38] To compete with world-leading clusters in places such as Boston, Shanghai and Bangalore, UK clusters will need to be on a similar scale.

The Society supports the concept of institutions to harness local research and innovation to facilitate local growth. This is particularly important outside the Greater South-East and following the closure of Regional Development Agencies (RDAs). Local institutions need to form part of national and regional strategies that recognise regional distinction without complete fragmentation. However, at the present time local investment is not on the scale of that recommended in the Heseltine Review. [39] Another challenge is that innovators and entrepreneurs looking to partner with academic researchers are sometimes swamped by a confusing array of different initiatives and institutions. Measures to encourage local growth through science and innovation should be simple and clearly communicated to all relevant stakeholders.

Impact, which comes in many forms, should always be an aim of research, and should be one of a set of broad and flexible measures used to judge research success. Impact is not always easy to define, evaluate or predict, and it is too early to offer a firm conclusion about the effect of including impact criteria in the most recent REF assessment. As discussed above, one route by which research can, and often does, achieve significant impact is through business-university collaboration.

UK universities have made effective efforts in achieving efficiencies, for example through regional equipment sharing initiatives such as the N8, M5, SE5 and GW4 groups, and partnerships such as the Midlands Physics Alliance and the National Marine Equipment Pool. These initiatives are resulting in the pooling of capabilities and intelligence on asset management, and in time will have the power to change procurement practice. Public funders are increasingly evaluating the impact of their schemes and in 2010-11 the higher education sector saved £462 million through efficiency measures. The Society welcomes initiatives to encourage equipment sharing, but the impact of efficiency savings must be closely monitored to avoid harm to the research base.

What more can the UK do to ensure that science is embedded in our international relationships?

The UK is a global hub for science and innovation, attracting talent and investment and successfully collaborating internationally. The UK is second only to the USA in attracting international students. Overseas funding made up 20% of R&D expenditure in the UK in 2012 and UK bodies received 15% of the European research budget, much more than the 11% it contributes.[40] [41] In the same year, 47% of

[38] Academy of Medical Sciences (2011). *Submission to the 2011 innovation and research strategy.* http://www.acmedsci.ac.uk/viewFile/publicationDownloads/Contribu.pdf

[39] Heseltine M (2012). *No stone unturned.* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/34648/12-1213-no-stone-unturned-in-pursuit-of-growth.pdf

[40] Office of National Statistics (2014), *UK Gross Domestic Expenditure on Research and Development 2012.* http://www.ons.gov.uk/ons/dcp171778_355583.pdf

[41] See http://europa.eu/rapid/press-release_SPEECH-14-83_en.htm

the UK's scientific publications had a non-UK co-author, up from 33% in 1999. The impact of these publications, measured by citations, is significantly higher than the UK average.[42]

International activities and collaboration should form an integral part of a framework for science and innovation, so that the UK research base is better placed to benefit from the intellectual and financial leverage of international partnerships. Research funders should provide greater support for international research collaboration through research and mobility grants, and other mechanisms that support research networks such as the 'Science Bridges' scheme.[43] The UK is also a thought leader on science policy (see below). Promoting the principles and practice of evidence-informed policymaking in governments, regional and multilateral policy fora should be a primary objective for the UK.

European engagement should form an explicit part of an international plan for science and innovation. The global influence of the European Union, the degree to which it legislates for the UK, and the progressive development of the European Research Area provide imperatives and opportunities for the UK to continue to help shape European policy. The UK should also engage with emerging scientific powers such as China, which play an increasing scientific and economic role on the global stage. These countries offer significant potential for collaboration and often look at the UK as a role model. Initiatives such as the Newton Fund are very welcome, as they allow for long-term partnerships that are beneficial for both countries involved.

Science is a source of soft power and science diplomacy should feature in the plan, building on the UK's research strengths and the reputation of its scientific institutions.[44] The scientific community often works beyond national boundaries on problems of common interest, so is well placed to support emerging forms of diplomacy that require non-traditional alliances of nations, sectors and non-governmental organisations. If aligned with wider foreign policy goals, these channels of scientific exchange can contribute to coalition-building and conflict resolution. Interactions between UK and European scientists and institutions are strong and provide a useful, but presently underexploited, source of soft power[45]. The geographical reach of the UK Science and Innovation Network (SIN) should be extended, particularly across the Middle East, Africa and South America.[46] National science academies and learned societies are also an important means of deploying science for soft power.

There are also considerable leadership opportunities for UK research to shape the research trajectories in other countries and to help develop human capital in those other countries in ways that offer scope for recurrent collaboration. International capacity building is crucial to ensure that the benefits of research are shared globally. Researchers and funders should commit to building research capacity in less developed countries to help improve their ability to conduct, access, verify and use the best research, and

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[42] Elsevier (2014). International Comparative Performance of the UK Research Base – 2013 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263729/bis-13-1297-international-comparative-performance-of-the-UK-research-base-2013.pdf

[43] Royal Society (2011), Knowledge, Networks and Nations. https://royalsociety.org/policy/projects/knowledge-networks-nations/report/

[44] British Academy (2014), The Art of Attraction: Soft Power and the UK's Role in the World, by Christopher Hill and Sarah Beadle. *http://www.britac.ac.uk/intl/softpower.cfm?frmAlias=/softpower/*

[45] Royal Society (2013) Response to the House of Lords Select Committee on Soft power and the UK's influence.

[46] Royal Society (2010), *The Scientific Century: securing our future prosperity*. https://royalsociety.org/policy/publications/2010/scientific-century/

to ensure that they can contribute to global scientific debates and develop local solutions to global problems.[47]

Systematic monitoring and analysis of developments in overseas research investment, output and policy are essential to inform both domestic and international policy decisions. Government should work closely with UNESCO (and other agencies such as the OECD) to investigate new ways in which trends in global research can be captured, quantified and benchmarked. This can help to improve the accuracy of assessments of the quality, use and wider impact of research, as well as to gauge the vitality of the research environment.

What does the UK need to do more to place science at the heart of government and policy making?

Public policy is increasingly dependent on complex science, and both emerging challenges and the everyday business of government demand constant input from scientists and other experts. Science offers broad and deep expertise to inform evidence-based policy, which Government should ensure is fully incorporated into its work. Many of the challenges facing society, such as climate change and food security, require broad, multidisciplinary approaches, and supporting a breadth of excellent research across different disciplines is therefore crucial. Scientific advice needs to be based on the best available knowledge and be independent of political pressures. National academies, with their independence and broad range of in-depth expertise, are well placed to assist with this process.

In the UK, a substantial proportion of strategic research is funded through Government departments and Public Sector Research Establishments (PSREs). As well as helping to inform Government's decision making, this research can be world class in its own right and underpin innovation in other areas. Cross-government research coordination and an appropriate level of funding are necessary to maximise the impact of this strategic research.

Recognising the interconnectedness of global challenges, the UK should use its experience to promote its principles and practice of evidence-informed policy-making in governments, regional and multilateral policy fora. The European Union in particular has an increasing influence on policy-making, both within its borders and internationally, and straightening the role of scientific advice in the EU government should be a priority for the UK. National science academies and their networks, such as the European Academies Science Advisory Council, have an important role to play in providing independent scientific advice to national and international policymakers.

What steps would help deliver a joined-up approach to science that plans for the world of 2030?

Scientifically the UK is one of the most productive nations in the world.[48] This strength is due in part to its characteristic features, such as the 'Haldane Principle' and the dual support system. The reputation of UK research internationally relies on the strong emphasis on quality within the dual framework of regular and rigorous research assessment combined with competitive bidding for project-based funding. The UK

[47] For example, Academy of Medical Sciences (2012), *Building institutions through equitable partnerships in global health: Conference report*. http://www.acmedsci.ac.uk/viewFile/53d79ed38b19a.pdf

[48] Elsevier (2014). International Comparative Performance of the UK Research Base – 2013 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/263729/bis-13-1297-international-comparative-performance-of-the-UK-research-base-2013.pdf

should build on its strengths and excellence should remain the primary criterion for investment in science for the country to retain its place in the world.

Investment in research has been demonstrated to have long-term economic and social benefits, and recent evidence indicates that research activity scales with the level of investment.[49] [50] The UK's international competitors are increasingly recognising the opportunities presented by research and innovation, and are increasing their investment. In the UK in 2012, overall R&D expenditure from government, businesses and charities was 1.72% of GDP, a decrease from 1.77% in 2011 and 1.79% in 2000. That contrasts with our international competitors such as the US (2.79%), Germany (2.98%) and Korea (4.36%), where investments have been steadily increasing since 2000.[51] A report published by BIS in 2014 stated that a level of overall R&D spend consistent with securing future economic success in the UK is likely to be closer to the 2.9% average of comparator countries, and that public sector expenditure may need to rise more sharply in the short-to-medium term.[52] The Government should commit to increased investment in research and innovation to keep pace with other leading scientific nations.

A flexible approach is needed when defining priorities for future research, as they need to be able to adapt to new knowledge and challenges. There can be tensions between basic discovery science and science closer to translation and application. The former is unpredictable and serendipitous, generally thriving in a bottom-up funding system led by researchers. The latter requires funders to identify priorities and allocate funding more top-down. Policies that pick winners and prescribe solutions are rarely successful.[53] Establishing well-defined challenges can be a useful means by which to pull research towards shared goals, but should be very generally scoped without prescribing a specific route. This requires an existing broad research base maintained by a long-term flexible framework. Society should be involved in defining and prioritising these challenges (see below).[54]

The Rungs on the Ladder

What additional policy measures are needed to ensure the UK has a strong pipeline of STEM skills?

Science and mathematics are at the heart of modern life. They are essential to understanding the world and provide the foundations for economic prosperity. The UK is a world leader in science and engineering and, to maintain and capitalise on this position, it needs to strengthen its science, technology, engineering and mathematics (STEM) education. The Society recently published its report *Vision for*

[49] For example, Health Economics Research Group at Brunel University, King's College London and RAND Europe (2014) *Medical Research: What's it worth?* http://www.acmedsci.ac.uk/download.php?f=file&i=29924

[50] Office of Health Economics and the Science Policy Research Unit at the University of Sussex (2014) *Exploring the interdependencies of research funders in the UK.* http://news.ohe.org/2014/07/02/interdependence-funding-medical-research-uk/

[51] Data refer to overall Gross Expenditure in R&D (GERD), which includes expenditure by government, businesses, charities and direct foreign investment. OECD, *Main science and technology indicators*. http://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB

[52] Allas (2014), *Insights from international benchmarking of the UK science and innovation system.* https://www.gov.uk/government/publications/science-and-innovation-system-international-benchmarking

[53] European Commission (2009). The Role of Community Research Policy in the Knowledge-Based Economy: Report of an Expert Group to the European Commission. http://bookshop.europa.eu/en/the-role-of-community-research-policy-in-the-knowledge-based-economy-pbKINA24202/

[54] Stilgoe et al. (2013), *Developing a framework for responsible innovation.* http://www.sciencedirect.com/science/article/pii/S0048733313000930

science and mathematics education, which aims to raise the general level of mathematical and scientific knowledge and confidence in the population.[55]

Scientific discovery and technological innovation can provide solutions to emerging challenges, but they also raise social and ethical dilemmas. All citizens need the skills and knowledge to be able to make informed decisions about how society handles these issues. As well as offering insight into the wonders of nature, a sound education in scientific subjects is essential to achieving progress as a modern democracy, one that is capable both of developing creative scientists and engineers and astute citizens. In addition, science and technology open doors to jobs in many sectors where the analytical and problem-solving skills acquired by studying mathematics and science are greatly prized. A plan for science and innovation should include concrete proposals to develop, retain and attract the skilled individuals the UK will need. It will need to align with the broader skills agenda in the UK to ensure a pipeline of future research and technical staff.

Students should study mathematics and science to age 18 alongside the arts and humanities as part of a new baccalaureate that provides a broad education. This means changing our current educational framework and gradually replacing the current A-level system with a broader framework that places emphasis on vocational and academic learning. Alongside this change there is a need to support the teaching profession through measures such as a requirement for subject-specific continuous professional development (CPD) and long-term funding of national infrastructures providing training.[56]

While academic qualifications can be a gateway to a research career, many who undertake such studies eventually work in other professions such as financial services, heritage or information technology. Transferable skills gained from academic study are among the research base's most important contributions to society and the economy. To ensure that academic courses are responding to the requirements of employers beyond research more emphasis could be given to a collaborative approach to learning between universities and non-academic employers. Transferable skills programmes could also be further developed and become an integral part of researchers' career development.

The UK higher education sector is a major source of earnings worth almost £60bn in jobs, exports, innovation and added value that has historically performed well in attracting talent from overseas.[57] The UK is a centre for talent development, but is competing in an increasingly global market for both international and domestic students and researchers. Global competition for excellence makes it essential that the UK remains an attractive place for the most talented individuals and teams to work, whether they are from home or from elsewhere in the world. It is essential to minimise real and perceived barriers to the flow of talented people by broadly articulating and supporting the need for inward researcher migration, and ensuring that migration and visa regulations do not prevent researchers from accessing the best research across the world.[58]

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[55] Royal Society (2014), *Vision for science and mathematics education.* https://royalsociety.org/education/policy/vision/

[56] Royal Society (2014), *Vision for science and mathematics education.* https://royalsociety.org/education/policy/vision/

[57] Figures quoted by Lord Mandelson, The Future of Higher Education', Dearing Lecture, Nottingham University, 11 February 2010. Full text available at: webarchive.nationalarchives.gov.uk/+/http:/www.bis.gov.uk/News/Speeches/mandelson-dearing-lecture

[58] Royal Society (2011), *Knowledge, networks and nations. Global scientific collaboration in the 21st century*. https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2011/4294976134.pdf

How can the UK ensure there are inclusive routes into STEM careers?

The Society is concerned with excellent science wherever and by whomever it is done. A lack of diversity across the scientific community represents a potential loss of talent to the UK, and a plan for science and innovation should ensure access to scientific careers is open to the most talented regardless of background. The Society, together with the Royal Academy of Engineering, is currently running a BIS-funded programme of work to address the issue of diversity in the STEM workforce.

The Society's work on diversity is investigating ways to remove barriers to entry, retention and progression within the scientific workforce. It focuses on gender, ethnicity, disability and socio-economic status in the first instance and aims to cultivate leadership in the scientific community towards removing barriers to increased diversity. As part of this programme, the Society recently published a report providing a picture of the scientific workforce in the UK. The report concludes that future analysis of demographic datasets should be improved to better understand the diverse makeup of the scientific workforce in the UK in order to better target initiatives to address underrepresentation. [59]

To promote the uptake of STEM disciplines, students need to be provided with the tools and opportunities early on to understand the vast range of careers that are linked to the study of STEM. This includes career awareness and exposure to role models from primary school and careers information, advice and guidance from secondary school onwards, as well as clear pathways to work from vocational and technical education. This also involves strengthening links between schools, colleges, industry and the STEM community, both on a local and national level, as well as increasing parents' understanding of how STEM offers many and varied employment opportunities for all children, regardless of their social or economic status.[60]

About the Society

The Royal Society is a self-governing Fellowship of many of the world's most distinguished scientists drawn from all areas of science, engineering, and medicine. The Society's fundamental purpose, as it has been since its foundation in 1660, is to recognise, promote, and support excellence in science and to encourage the development and use of science for the benefit of humanity.

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[59] For further discussion see Royal Society (2014), *A picture of the UK scientific workforce*. https://royalsociety.org/policy/projects/leading-way-diversity/uk-scientific-workforce-report/

[60] Royal Society (2014), *Vision for science and mathematics education.* https://royalsociety.org/education/policy/vision/