September 2018

Balance and Effectiveness of Research and Innovation Spending

A response from the Royal Society of Chemistry to the House of Commons Science & Technology Select Committee.

Summary & Recommendations

Effectiveness and Rationale for Public Spending on Research and Development

1. **The government's commitment to increase the UK's investment in research and development to 2.4% of GDP by 2027 is welcome. In considering how best to maximise the impact of this investment, UKRI must ensure that investment in fundamental research is a significant part of this.** Support for fundamental, curiosity-driven research must be sustained, alongside challenge-based and applied research. Evidence shows that supporting fundamental, curiosity-driven research results in long-term impacts that bring benefits beyond pushing the frontiers of science – delivering economic growth and solutions to challenges that the world faces with regards to health, energy and environmental sustainability.
   a. **Fundamental research delivers these longer-term benefits by providing transformative leaps in knowledge and by directly enabling developments in challenge-based or applied research. In order to ensure effectiveness through mechanisms such as the Industrial Strategy Challenge Fund (ISCF), there needs to be robust support for fundamental research to develop the knowledge base to advance science and ensure a strong research base that can lead to the transformational breakthroughs to support challenge-led research.** Evidence shows that the knowledge gained from fundamental research has a range of broader impacts, including often providing the advances that are then used to enable developments in applied research.
   b. **As part of UKRI's review of long-term funding allocations, there must continue to be appropriate funding for core disciplines, alongside interdisciplinary and challenge-driven research.** Evidence shows that advances in core disciplines underpin and enable interdisciplinary and challenge-driven research, as well as leading to the step changes in basic knowledge that can have broader impacts in the future.
   c. **Quality-related (QR) funding allocated in the Research Excellence Framework (REF) should continue to serve as baseline funding for institutions to invest in infrastructure and fund curiosity-driven or early-stage research.** The dual support system, which combines project based funding (through the research councils and other sources) with quality-related (QR) funding, is highly valued and contributes to the strength and long term health of the UK research system.

Levers for Encouraging Private Spending & Innovation

2. **Public investment in research can enable wider growth in the UK economy. This is particularly valuable in settings like small and medium enterprises (SMEs), where sharing the risks of innovations can yield wider gains in terms of growth and jobs around the UK.**
3. **When considering the levers available to encourage innovation, there are a number of non-financial elements which need to form part of an overall approach. Evidence from our community shows that support in the form of mentorship, advice and guidance can be just as critical to supporting a business to grow and thrive in a competitive environment as financial support.**

Main text

Effectiveness and Rationale for Public Spending on Research and Development

Long-term Impacts of Fundamental Research

As we have stated previously, support for fundamental research must be sustained, alongside challenge-based and applied research. This is vital because, whilst the impacts of fundamental research are often long-term, the history of science demonstrates that curiosity-driven research delivers the ground-breaking discoveries that open completely new avenues for research and for innovation.[1] This can result in novel applications that cannot be foreseen at the outset of the research, yet can deliver both societal and economic benefits.

Recommendation: The government's commitment to increase the UK's investment in research and development to 2.4% of GDP by 2027 is welcome. In considering how best to maximise the impact of this investment, UKRI must ensure that investment in fundamental research is a significant part of this.

Case studies developed as part of the Research Excellence Framework (REF) 2014[2] demonstrate the impact of fundamental research, showing its role in providing new knowledge that can, over time, contribute solutions to real-world challenges and deliver economic benefits from commercialising these solutions.

For example, research by Professor Jas Pal Badyal into new plasmachemical techniques at the University of Durham initiated in the early nineties has led to the development of new surface functionalisation techniques. Badyal developed methods that allowed plasmas to selectively protect the surfaces of a range of different materials. This work resulted in the development of a quicker, single-step process that was selective, cheaper, and lower energy. Badyal's research led to the formation of three start-up companies: Surface Innovations Ltd (2001); Dow Corning Plasma Solution Ltd (2001); and P2i Ltd (2004). Through P2i's Ion Mask™ brand, the surfaces of 100 million pipette tips and three million pairs of footwear have been protected, as well as 50 million mobile phones and 60% of the world's hearing aids under the Aridion™ brand. P2i Ltd is a growing company with an estimated turnover of £19 million in 2014, and 93% of revenues generated in geographic markets outside of the UK. It has led to the establishment of subsidiaries in China, Hong Kong, Singapore and the USA.[3]

Often the journey to an eventual application cannot be foreseen at the outset of the fundamental research. The 2016 Nobel Prize for Chemistry was awarded for the development of molecular machines. The roots of this research considered the interactions between molecules and how to exploit them in order to build molecular machines. This research paves the way for new materials, drug delivery systems, sensors and energy storage systems. Examples highlighted in recent literature include organ, body and disease-on-a-chip systems that have the potential to transform drug development and exploiting microfluidics for single cell sequencing, which could improve diagnosis of diseases like cancer. The knowledge gains made in understanding these molecular interactions and their later impacts could not have been predicted at the outset of this work.

The knowledge gains from fundamental research in core subjects like chemistry can have much wider impacts. For example new insights provided by fundamental research can change the way in which regulation is developed to protect the environment and/or the health of the population.

Fundamental research into gas phase chemistry at the Universities of Leeds and York has led to better policies and regulations around air pollution in the UK and around the world.[4] Air pollution can be very damaging to human health: studies estimate that each year it may shorten the lives of 40,000 people in the UK and cost the UK economy more than £20bn.[5] In 1993, researchers started working with DEFRA and the Met Office to develop a detailed chemical mechanism to understand the formation of key air pollutants. This 'master chemical mechanism' is now widely considered the gold standard, and has been used to improve air quality policies, legislation and abatement strategies in the UK, Europe, US and Hong Kong.

The Link Between Fundamental and Applied Research

Support for fundamental research also delivers longer-term benefits by providing transformative leaps in knowledge and by directly enabling developments in challenge-based or applied research.

Recommendation: In order to ensure effectiveness through mechanisms such as the Industrial Strategy Challenge Fund (ISCF), there needs to be robust support for fundamental research to develop the knowledge and the research base to provide the ideas, theories and understanding that lead to the transformational breakthroughs to support challenge-led research.

A case study from our report *Inspirational Chemistry For a Modern Economy*[2] demonstrates that fundamental research undertaken many years previously can provide the basis for advances in applied research that leads to the development of technologies to address specific problems:[6] For example, *Professor AP de Silva, Queen's University Belfast, was inspired to develop a blood analyser whilst caring for his grandmother who was suffering from hypertension. De Silva's doctor taught him that if salt levels could be monitored easily and accurately, a diuretic could be administered to remove the water and excess sodium from the system, decreasing the load on the heart. de Silva began pioneering research into fluorescent PET (photo induced electron transfer) sensors in 1985 and based on his seminal research, a blood analyser was developed which has been the market leader in point-of-care analysers ever since. Researchers at global healthcare company Roche read about de Silva's research and quickly recognised its commercial potential; the result was a collaboration with Optimedical Inc. to develop the sensor. Diagnostic cassettes worth over $50 million were sold from 2008–2013. The device can be used in a range of settings including GP surgeries, hospital critical care units, ambulances and veterinary practises. Blood test results can be available in less than 30 seconds, enabling rapid medical responses such as administering a particular blood type with the correct salt levels. As well as being rapid, the device is also easy to use. In Japan, doctors are able to immediately provide patients with test results in their surgeries, and paramedics in Sri Lanka and Libya were able to use the device in conflict situations. Furthermore, the technology has been adapted for veterinary surgeries.*

Our own research[7] into university-business collaborations in chemistry departments found that fundamental research is a key focus of collaborative projects between business and universities, helping to support the diffusion of fundamental research. We found that out of more than 1000 collaborations reported by 25 chemistry departments from 2012–15, 63% of collaborations with large companies (>250 employees) and 42% of collaborations with SMEs (<250 employees) focused on fundamental research.

We also found evidence of the mechanisms that universities use to share the gains from fundamental research with local businesses to support application of this knowledge in other settings:[8]

The Organic Materials Innovation Centre (OMIC) is a university innovation centre to support the speciality organic materials and polymer industries. It allows businesses access to knowledge within universities that they can use to innovate and grow. OMIC has an extensive track record of working with chemical using industries and has carried out over 150 projects for over 75 companies with a total project value of more than £5m. Projects may be directly funded or supported by a wide variety of funding mechanisms. These include; EPSRC funding for longer-term projects addressing fundamental scientific issues; industrial CASE postgraduate studentships and research projects; Innovate UK competitions for feasibility studies and collaborative R&D projects, innovation grants and vouchers; Knowledge Transfer Partnerships (KTP) and EU Horizon 2020 competitions.

The Role of Fundamental Research in Inter- and Multi-disciplinary Research

Evidence shows that advances in core disciplines, such as chemistry, underpin and enable interdisciplinary and challenge-driven research, as well as leading to the step changes in knowledge that can have broader impacts in the future.

Recommendation: As part of UKRI's review of long-term funding allocations, there must continue to be appropriate funding for core disciplines, alongside interdisciplinary and challenge-driven research.

Chemistry in UK university departments is funded across a number of different research councils reflecting the role of chemistry in enabling both interdisciplinary research and its role in partnering with research in other core disciplines. Data from the Higher Education Statistics Agency show that in 2015/16 over 30% of Research Council funding for UK university chemistry departments came from outside the physical sciences through, for example, Research Councils covering biological, medical and environmental sciences. See Table 1.

Table 1 Research Council funding received by chemistry departments in UK universities in 2015/16. Source: HESA Finance Record http://hesa.ac.uk

Funding source	Funding amount (£1000)	Percentage
Arts & Humanities Research Council	23	0
Biotechnology and Biological Sciences Research Council	15381	15
Economic and Social Research Council	6587	0
Engineering and Physical Sciences Research Council	73189	69
Medical Research Council	3024	3
Natural Environment Research Council	6455	6
Science & Technology Facilities Council	803	1
Research Council - other	86	6

Evidence shows that fundamental physical sciences discoveries are critical to enabling applied solutions in the life sciences:[9]

A review carried out by the Engineering and Physical Sciences Research Council (EPSRC)[10] highlighted many examples where developments in engineering and the physical sciences led to innovation in the life sciences. Since 2000 most of the Nobel Prizes for Chemistry and half of the Nobel Prizes for Physics have been awarded for discoveries with life sciences applications. Furthermore, developments in the physical sciences will continue to have an impact for life sciences in the future, in areas such as:

- *Spectroscopic, imaging and new analytical techniques offer improvements in diagnostics, sensors, 'omics' and single molecule studies. Super-resolved fluorescence microscopy, recognised by the 2014 Nobel Prize in Chemistry, allows the visualisation of biological processes at the molecular level, which will lead to developments in both biology and medicine. A major theme for the Rosalind Franklin research institute will be next generation imaging methods, including biological mass spectrometry and advanced microscopy.*
- *Materials chemistry for medical devices, self-healing and other smart materials especially prosthetics, implantable and delivery devices. For example, the interfaces between prostheses or biomedical implants and body tissues require the optimisation of many material properties, key amongst which are biocompatibility and softness. Satisfying such conflicting demands requires innovative molecular design to make materials that are biocompatible, hard-wearing and possess appropriate viscoelastic properties, and calls on an intimate knowledge of synthetic chemistry, polymer chemistry, the physics of macromolecules, tribology and lubrication among others.*

The Dual Support System

The dual support system, which combines project based funding (through the research councils and other sources) with quality-related (QR) funding, is highly valued and contributes to the strength and long term health of the UK research system.

Recommendation: QR funding allocated in the REF should continue to serve as baseline funding for institutions to invest in infrastructure and fund fundamental or early-stage research.[11]

This funding is highly valued, across our community, for providing stable levels of funding over the period between research assessment exercises in a manner that can be deployed at the discretion of the university. QR funding provides a valuable baseline of support for facilities and research operations, enables long-term planning, and gives universities across the country the opportunity to support emerging research areas and new appointees.

Funding to support the long term health of science delivers results – the panel assessing chemistry submissions to the REF in 2014 stated that the percentage of research outputs receiving the highest possible rating (4*) had increased as a result of *"the general strengthening and investment in the discipline over recent years"*.[12]

Levers for Encouraging Private Spending & Innovation

The interaction between public and private investment

Public investment in research can enable wider growth in the UK economy. This is particularly valuable in settings like small and medium enterprises (SMEs), where sharing the risks of innovations can yield wider gains in terms of growth and jobs around the UK.

Recommendation: In developing funding for translation, UKRI should carefully consider the needs of start-ups and small businesses..

As part of our *Open for Business* report[7], we found that chemistry departments and businesses draw on a range of funding sources to support research collaboration. Over 60% of chemistry departments use some form of public funding to support their collaborations with SMEs, for example from Research Councils, InnovateUK or Higher Education Innovation Funding. Collaborative research projects between business and universities range from fundamental research to applied programmes addressing a specific challenge.

We also uncovered examples that showed how funding from public streams was being used to support companies to grow within regional economies:[13]

Established in 2011, the Sheffield Science Gateway (SSG) is a project that allows industry to collaborate with the faculty of science at the University of Sheffield. The scheme is supported by Higher Education Innovation Funding (HEIF), and received a total of £1.2M between 2011/12 and 2014/15. The SSG has a team of trained scientists with business experience in a range of markets. They offer access to extensive industrial and academic networks to help solve science-based problems. They also provide access to funding, specialist facilities and assistance with intellectual property. The SSG collaborates with multinationals, SMEs, professional bodies, and the third sector and government agencies, regionally, nationally and globally. These collaborations can take many forms, including long and short-term projects, knowledge transfer partnerships, sponsored research and consultancy. People transfer is also available, through secondments, sabbaticals and student placements.

It is important that funding schemes to support innovation are designed with the needs of the target sector in mind, for example by making sure that the application process and time-to-grant is suitable. One company we spoke to reported that while public funding through instruments such as the Biomedical Catalyst, is very valuable, the length of the application process and time to decision is too long to support the needs of their business. The time taken from start of application to receipt of funding can be 9-10 months, which was too long for this small business to plan around. This issue could merit further investigation.

Consideration should also be given to wider mechanisms that support translation of research within certain sectors, for example, the role of the charity sector, to ensure coordination and avoid duplication. The role of charities is particularly prominent in the field of life sciences:[14]

Bridging the "valley of death" between basic research and patient impact is a key aim of LifeArc, a UK based medical charity, planning to invest over £500 million in the next 5 years in areas such as antimicrobials, neuroscience, personalised oncology and respiratory medicine. They have recently announced translational awards for academic scientists to progress drug discovery projects, and *importantly have prior experience of leading successful collaborations culminating in four marketed drugs and a test for antimicrobial resistance.*

Non-financial levers

Evidence from our community shows that support in the form of mentorship, advice and guidance can be just as critical to supporting a business to grow and thrive in a competitive environment as financial support.

Recommendation: When considering the levers available to encourage innovation, there are a number of non-financial elements that need to form part of an overall approach.

Access to agencies and people that can provide advice, guidance and mentorship from within the sector can be invaluable in helping a new business to survive and grow in a competitive environment. This is especially true of university spin-outs, where staff with an academic background may be developing a new company with little or no prior business experience.

Previous discussions with our community suggest that an ongoing challenge in research translation remains a lack of access to expert technical knowledge, e.g. for protocol development or scale-up.[15] This can be a barrier for researchers based in academia, smaller companies or those working in emerging areas of science, for example in biotechnology or synthetic biology. Facilitating the provision of tailored advice at different stages of a company's life, whether this is technical, financial or business advice, supports the growth of innovative businesses. Through our Emerging Technologies competition, the Royal Society of Chemistry is actively working to support innovation in this way:[16]

This annual competition aims to accelerate the commercialisation of innovative technologies across the areas of health; energy & environment; food & drink; and materials & enabling technologies. The competition is open to small companies (with fewer than 20 employees and an annual turnover of less than £2 million) and universities across the UK and Europe. Successful entrants are invited to pitch their work to industry leaders who evaluate entries on the basis of the scientific feasibility of the technology, its potential market opportunities and the approach to commercialisation.

Prizes are awarded to two winners in each subject field (eight in total). Alongside a cash prize, the winners are offered tailored business support from our partner multinational companies including advice on product strategy and market insights, and access to their laboratories. The winners are also provided with intensive business training, intellectual property advice and tailored financial mentoring, as well as broader exposure for their company through our networks and media.

The competition has been running since 2013 and in the case of earlier winners, we have seen evidence of how the non-financial support provided has led to the growth of the company and leverage of funding from other sources:[17]

The Medical Research Council (MRC) team working on IHAT (a nanoparticulate form of iron) technology were winners of the Emerging Technologies competition in 2014. The team had completed early clinical work but had been unsuccessful in securing the funding needed for a clinical trial. They entered the Emerging Technologies competition to achieve greater visibility for IHAT and to receive strategic advice from key players in industry on how to progress.

Winning the competition gave the IHAT team a chance to be mentored by pharmaceutical giant GSK who could advise them on target markets, product development, business strategy, regulatory aspects, and the implementation of medicines in developing countries. GSK also provided input in a number of funding bids to finance clinical trials with IHAT and, in 2015, the team successfully secured $1.7m from the Bill and Melinda Gates Foundation. The grant, awarded under the Gates Foundation's Grand Challenge New Interventions for Global Health Pilot Awards Scheme, is funding a field trial to test the efficacy and safety of IHAT in young children living in the most deprived areas of the Gambia. If IHAT is successful in the trial, there will be the opportunity to secure further funding from the Bill and Melinda Gates Foundation. This will be used to conduct the trials needed to support a market authorisation and to help place IHAT as an oral iron supplement in not-for-profit markets, where the need for a safe iron supplement is most pressing.

The publicity generated from winning the Emerging Technologies competition led to increased commercial interest in IHAT and the team were contacted by several companies interested in knowing more about the technology. As a result, the IHAT technology is currently being reviewed by a number of companies with a view to potentially licensing the technology and associated intellectual property (IP). The licensing of the technology by a medical food products company, Nemysis Ltd, was announced in July 2017[18]

So whilst schemes that provide tailored funding for innovation are valued by our community, a more holistic approach to improving productivity and growth needs to harness and share more widely the knowledge and experience across the business community.

Contact

The Royal Society of Chemistry would be happy to discuss any of the points raised in our response in more detail. Any questions should be directed to **Dr Clare Dyer-Smith,** Programme Manager, Science Divisions, dyersmithc@rsc.org 01223 432341

About us

With over 52,000 members and a knowledge business that spans the globe, the Royal Society of Chemistry is the UK's professional body for chemical scientists, supporting and representing our members and bringing together chemical scientists from all over the world.

Our members include those working in large multinational companies and small to medium enterprises, researchers and students in universities, teachers and regulators.

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[1] - *Response to the House of Commons Science & Technology Select Committee inquiry into Science Budget and Industrial Strategy*, Royal Society of Chemistry, October 2017
[2] - *Inspirational chemistry for a modern economy*, Royal Society of Chemistry, June 2015
[3] - *Chemistry protects soldiers, footwear & smartphones*, Royal Society of Chemistry, June 2015
[4] - Master Chemical Mechanism, University of Leeds, National Centre for Atmospheric Chemistry and University of York.
[5] - *Every breath we take: the lifelong impact of air pollution*, The Royal College of Physicians & The Royal College of Paediatrics and Child Health working party report, February 2016
[6] - *Chemistry analyses blood in 30 seconds*, Royal Society of Chemistry, June 2015
[7] - *Open for Business, A chemistry department perspective on university– business engagement*, Royal Society of Chemistry, November 2016
[8] - *University-based innovation support, The Organic Materials Innovation Centre*, Royal Society of Chemistry, November 2016
[9] - *Response to the House of Lords Science & Technology Select Committee inquiry into Life Sciences and the Industrial Strategy*, Royal Society of Chemistry, September 2017
[10] - https://epsrc.ukri.org/newsevents/pubs/the-importance-of-engineering-and-physical-sciences-research-to-health-and-life-sciences/
[11] - *Response to Lord Stern's review of the Research Excellence Framework*, Royal Society of Chemistry, April 2016
[12] - *Research Excellence Framework 2014: Overview report by Main Panel B and Sub-panels 7 to 15*, January 2015
[13] - *Using higher education innovation funding, The Sheffield Science Gateway*, Royal Society of Chemistry, November 2016
[14] - *Response to the House of Lords Science & Technology Select Committee inquiry into Life Sciences and the Industrial Strategy*, Royal Society of Chemistry, September 2017
[15] - *Response to the House of Lords Science & Technology Select Committee inquiry into Life Sciences and the Industrial Strategy*, Royal Society of Chemistry, September 2017
[16] - http://www.rsc.org/competitions/emerging-technologies/
[17] - *Response to the House of Lords Science & Technology Select Committee inquiry into Life Sciences and the Industrial Strategy*, Royal Society of Chemistry, September 2017
[18] - https://www.lifearc.org/lifearc-negotiates-exclusive-licence-deal-nemysis-limited-oral-iron-supplement-technology/