IOP Institute of Physics

The Spending Review 2015

Institute of Physics submission to the Spending Review 2015

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Submission to the Spending Review 2015

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Institute of Physics submission to the Spending Review 2015

- **The UK science base is world leading but under pressure**
- **Public investment in science has been shown to drive economic growth and national productivity**
- **Further reductions in investment in the UK science base risk long-term damage to the UK's world-leading science output and ability to drive growth**
- **There is a significant opportunity to grow the science base and leverage existing funding to the benefit of the UK**
- **There is strong evidence that programmes such as the Stimulating Physics Network are effective in getting more people to study science**
- **There is an urgent need to provide further support for the training of specialist physics teachers**

The UK science base

UK science is world-leading; from 0.9% of the world's population the UK contributes 15.9% of the world's most highly-cited papers,[1] and has maintained this position in the face of growing challenges from emerging economies such as China and Brazil.[2] This overall strength is reflected in UK physics research[3]: for example, a recent study noted that 35% of the top cited papers in astrophysics had a UK author[4] and in the recent Research Excellence Framework 88% of the assessed physics research was ranked as either "internationally excellent" or "world-leading".[5] This strength has allowed the UK science base to attract and engage the world's best researchers and to leverage external funding: the US National Science Foundation reported that 55% of UK authored science and engineering papers in 2012 had international co- authors[6]; the UK receives a higher proportion of funding for science projects compared to the level of funding it provides to the EU, winning over 16% of

[1] Elsevier - *Performance of the UK research base: International comparison* (2013): https://www.gov.uk/government/publications/performance-of-the-uk-research-base-international-comparison-2013
[2] King's College London and Digital Science - *The nature, scale and beneficiaries of research impact* (2015): http://www.hefce.ac.uk/media/HEFCE,2014/Content/Pubs/Independentresearch/2015/Analysis,of,REF,impact/Analysis_of_REF_impact.pdf
[3] IOP – *The UK's performance in physics research: national and international perspectives* (2014): http://www.iop.org/publications/iop/2014/file_63082.pdf
[4] Thomson Reuters – *The Research and Innovation Performance of the G20* (2014): http://sciencewatch.com/sites/sw/files/images/basic/research-innovation-g20.pdf
[5] HEFCE - *REF 2014: Unit of assessment summary data – Physics* (2014): http://www.ref.ac.uk/media/ref/results/AverageProfile_9_Physics.pdf
[6] National Science Board – *Science and Engineering Indicators* (2014): http://www.nsf.gov/statistics/seind14/content/chapter-5/chapter-5.pdf

funding from the most recent EU Framework Programme compared with its overall contribution of 11.5% of the EU budget. [7]

The role of science in supporting economic growth and productivity

There is an increasing evidence base that demonstrates that investment in science drives economic growth and national productivity. This impact can be seen in the transformative technologies that have their roots in publically-funded research[8] that are taken on by industry. But it has also been shown that public investment in R&D has a broad, direct impact through ‘crowding in’ private sector investment in R&D by raising the level of ‘background’ knowledge and expertise and absorptive capacity within the nation. Recent analysis for the Department for Business, Innovation and Skills (BIS) suggests that current estimations of the effect of public R&D investment in crowding-in private investment have been underestimated. Previous projections from BIS had suggested that for every £1 of public investment in R&D there was increased private investment of £0.85; however, new research suggests this could be as high as £1.36 for every £1 of public investment and an additional £0.29 from investment by Higher Education Institutions (HEIs) alone.[9]

Public spending on R&D has also been shown to enhance the outputs of this private sector investment. Research conducted by the UK Innovation Research Centre suggests that for every £1 invested in R&D by the government, private sector R&D outputs rise by 20 pence per year in perpetuity.[10] The same report notes that public investment in research and development increases total factor productivity (TFP) growth at industry level. The lack of growth in productivity is one of the great policy challenges facing the nation.[11] A recent report noted the problem of increasing national labour productivity is a problem of increasing national TFP[12]: public investment in R&D is a core element of creating growth in UK productivity.

Science and broader policy objectives

Effective investment in science and research is essential for the Government to achieve its policy priorities, whether these are strategic such promoting high-value manufacturing or improving healthcare provision, or reactive such as responding to public health emergencies. In manufacturing, for example, investment in and application of fibre laser technologies for cutting and machine tooling could enable the UK to retain a high-value manufacturing supply chain.[13] Investment in science is also vital for any future government to address the longer-term policy challenges that we face, such as climate change, ensuring energy security and

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[7] Russell Group response to the Government Review of the Balance of Competences between the UK and EU: Research and Development http://www.russellgroup.ac.uk/uploads/Russell-Group-response-to-Balance-of-competences-Research-and-Development-consultation.pdf

[8] IOP – *Physics: Transforming Lives* (2013): http://www.iop.org/publications/iop/2013/file_60314.pdf

[9] Economic Insight – *What is the relationship between public and private investment in science, research and innovation?* (2015): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/438763/bis-15-340-relationship-between-public-and-private-investment-in-R-D.pdf

[10] UK Innovation Research Centre – *The Economic Significance of the UK Science Base* (2014): http://www.uk-irc.org/resources/reports/the-economic-significance-of-the-uk-science-base/

[11] Richard AL Jones - Innovation, research, and the UK’s productivity crisis (2015) - http://www.softmachines.org/wordpress/wp-content/uploads/2015/09/Innovation_Research_Productivity_RALJones.pdf

[12] Imperial College London Business School - *Accounting for the UK productivity puzzle: a decomposition and predictions* (2015) - https://spiral.imperial.ac.uk:8443/bitstream/10044/1/21167/2/Haskel%202015-02.pdf

[13] UK Photonics Leadership Group – *Photonics: revolutionising our world* (2014): https://photonicsuk.files.wordpress.com/2014/02/photonics-revolutionising-our-world-1.pdf

health issues such as improving cancer survival rates. HEFCE's Research Excellence Framework exercise provides further examples of where the outputs of publically-funded UK research have had impacts in key policy areas, including driving efficiencies in health, energy and defence, and generating innovations leading to increased exports and significant financial returns.[14,15]

Future challenges

The continued strength of UK science is not guaranteed. It is a product of decades of sustained and secure investment in science through the Research Councils from which the UK is now reaping benefits. The protection in cash terms of the science budget in 2010 was welcome, but has had the consequence of a real term reduction of investment which the Research Councils report has already had an impact on the strength of the science base.[16] For example, over the five year spending round the number of PhDs trained through EPSRC and STFC has decreased,[17] reducing the supply of highly-skilled STEM-qualified workers. While the ring-fence has allowed these real terms reductions to be planned for, as much as has been possible, it has also presented an opportunity for moving additional expenditures into the science budget which has had the effect of exacerbating the impact of the reductions. The UK science base has the best chance of building on its current strength if the ring-fence is retained; but alongside this there must be clear community-informed decisions regarding what it is intended to be invested in and what it is not.

The real terms decrease in the science budget has had a corresponding impact on the value of HEFCE's QR funding allocated to the research departments within universities. This funding provides for a broad base of research and is particularly important for sciences such as physics which contain a significant proportion of 'basic' research. A recent study by the Institute of Physics and the Royal Society of Chemistry shows that UK university physics and chemistry departments are operating with significant deficits in both teaching and research.[18] In the departments surveyed, there was an overall deficit of 18.8% of income in physics departments and 20.6% in chemistry departments. These deficits were higher for research activities than for teaching activities, but most departments reported deficits in both. These deficits represent a threat to continued high-quality provision of teaching at both undergraduate and post-graduate levels. Any further reduction in support for the teaching of more expensive, lab-based subjects through the science budget and funding councils will likely have an impact on the capability of some departments to provide a highly-skilled, technically able workforce.

Opportunities for growth and efficiency

The real terms decrease in investment through the science budget has put pressures on the UK research base, but has also highlighted opportunities for further investment and the potential value of such investment. The Research Councils report finding themselves in the position of turning away research judged to be internationally excellent due to restricted budgets, and limiting access for researchers to leading large facilities; research identified as

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[14] IOP – *Inspirational physics for a modern economy* (2015): http://www.iop.org/publications/iop/2015/page_65902.html

[15] RSC – *Inspirational chemistry for a modern economy* (2015): http://www.rsc.org/globalassets/04-campaigning-outreach/campaigning/campaign-for-government-science-support/inspirational-chemistry-for-a-modern-economy.pdf?id=10935

[16] STFC Programmatic Review 2013

[17] Hansard (18 July 2011): http://www.publications.parliament.uk/pa/cm201011/cmhansrd/cm110718/text/110718w0009.htm#11071951002755

[18] IOP and RSC - *Under-funded and under pressure: the finances of UK university chemistry and physics departments* (2015)

offering a significant contribution to economic growth is not being funded. Further reductions to the science budget over the next spending period will exacerbate this, causing significant damage to the UK science base. However, an increase in investment would enable them to fund more research, with no drop in quality, leading to an increase in world-class science; driving economic growth and allowing the nation to gain the full benefit of past investment in research, skills and facilities.

- Departmental research and development

Over recent decades investment within the science budget has increased, however alongside this there has been a coinciding decline in investment, in real terms, through civil and defence departmental R&D.[19] This has created a system where the R&D requirements of government departments are increasingly met by research conducted through the Research Councils. This has the benefit of bringing excellent science into policymaking, but has also had the effect of putting government R&D in direct competition for funding with the science base. There is a case for revisiting this arrangement to ensure effective coordination of departmental funding of R&D and Research Council funded projects, while preserving the essential strengths and characteristics of both. Longer-term partnerships and greater investment in follow-on programmes between government departments and Research Council programmes will allow the UK to reap greater rewards from any initial investment.

- Science capital investment

The implementation of the long-term framework for capital investment announced in 2013 will be vital for the future of UK science. The UK is already home to leading large research facilities such as the Diamond Synchrotron in Harwell and the Astronomy Technology Centre in Edinburgh (ATC), but for the UK to keep pace with international competitors in the near future it must seek to invest in more such centres. However, the recent removal from the science ring-fence of capital investment, and its consequent separation from project and recurrent funding systems, has created some additional tensions within the science budget which must be addressed. The processes by which capital grants are prioritised and awarded differ from those of other projects and for recurrent expenditure. Often there is less involvement by the broader research community, creating a risk of misalignment between the priorities leading to the capital award and the priorities leading to recurrent funding. In many cases this can lead to capital facilities that are not used effectively because running costs are unavailable. Capital investments involve significant quantities of money and other resources. For them to pay dividends there must be proper consultation with the research community, including tensioning against other projects and priorities, before final decisions are made.

- International comparisons

Currently, the UK invests less in science than its immediate competitors. Total UK R&D investment is around 1.7% of GDP, a level which has remained relatively constant for a decade. In contrast, the OECD average is 2.4% and the G7 average is 2.3%.[20] The EU has set an overall target of 3% investment by 2020, and Germany, France and the Netherlands are all far ahead of the UK in their efforts towards this, with German R&D investment at around 2.92%.[21] BIS has reported that UK R&D intensity needs to rise to 2.9% of GDP if the

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[19] Department for Business, Innovation and Skills – *Science, Engineering and Technology Statistics* (2013): https://www.gov.uk/government/statistics/science-engineering-and-technology-statistics-2013
[20] OECD figures (2013)
[21] UNESCO figures

country is to ensure future economic success.[22] Public R&D investment fell below 0.5% of GDP in 2015, whilst the average in the G8 is 0.77%.[23] From the UK's current position, there is great potential to leverage economic and societal gains from increased investment in science. Increasing public investment in R&D towards the G8 average of 0.77% would 'crowd in' private investment and act to increase overall R&D towards the EU target of 3%. Such investment would likely make use of untapped economic potential within both the UK science base and UK industry, and also increase the nation's absorptive capacity allowing it to take greater benefits from the investments in science made in other countries.

Investment in skills

It can be argued that the most important output of the UK research base is skilled people and STEM-skilled workers are in demand across the economy. The CBI reports that business demand for STEM skilled workers is increasing[24]. The Social Mobility Foundation calculates that 40,000 more STEM graduates will be required annually to meet demand.[25] Physics qualifications are central to meeting this demand. Physics graduates are found in all sectors of the economy;[26] physics A-level is the gateway to engineering degrees and many other STEM disciplines.

- Teacher recruitment

The most important aspect of engaging students with physics at school is a teacher with good subject knowledge and an ability to communicate this knowledge effectively. Such 'specialist teachers' enhance the student experience and promote progression through the education system, ensuring that all students have the opportunity to reach their potential in physics. Currently the schools system in England lacks around 3,500 specialist physics teachers – there are not enough new teachers being trained in physics to replace those retiring or leaving the profession. To address this, the government introduced a specific target for entrants to physics teacher training programmes in 2011. While this annual target has not yet been met, it helped to increase the number of recruits into the profession.[27]

However, the numbers of recruits have recently started to decline. This decline has coincided with a recovering economy, putting pressure on the graduate recruitment market, but also with recent changes to the methods of bringing new teachers into the profession. In particular, the move towards schools managing their own teacher recruitment at a local level has meant the loss of the ability to track applicants in the system. To ensure that the UK has

[22] Department for Business, Innovation and Skills - *Insights from international benchmarking of the UK science and innovation system* (2014): 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

[23] The Guardian – *UK research funding slumps below 0.5% GDP – putting us last in the G8* (2015): http://www.theguardian.com/science/occams-corner/2015/mar/13/science-vital-uk-spending-research-gdp

[24] CBI and Pearson – *Inspiring Growth: Education and Skills Survey* (2015): http://news.cbi.org.uk/business-issues/education-and-skills/gateway-to-growth-cbi-pearson-education-and-skills-survey-2015/

[25] Social Market Foundation – *In the Balance: The STEM human capital crunch* (2013): http://www.smf.co.uk/wp-content/uploads/2013/03/Publication-In-The-Balance-The-STEM-human-capital-crunch.pdf

[26] IOP – *The career paths of physics graduates* (2012): http://www.iop.org/publications/iop/2012/file_55924.pdf

[27] Gatsby – *The shortage of physics teachers*: http://www.gatsby.org.uk/uploads/education/reports/pdf/the-shortage-of-physic-teachers-an-infographic1.pdf

a strong supply of well-qualified STEM-skilled workers, subjects like physics must ensure that they make the most of all their applicants; a central clearing house for trainee physics teachers should be created to ensure that national demand is managed effectively. We would welcome the opportunity for a creative dialogue with government on how recruitment of subject-specialist teachers can be boosted; for example by encouraging teachers to return to the profession.

- Teacher development

High quality continuous professional development (CPD) is essential for developing and retaining world-class science teachers. The Institute of Physics (IOP) has worked with the Department for Education (DfE) to provide cost-effective, high-impact CPD for teachers of physics in schools in England. The Stimulating Physics Network (SPN)[28] is an England-wide project to increase the uptake of A-level physics by improving the competence and confidence of those who teach it. The project is funded by the DfE and managed by the IOP in partnership with MyScience. The SPN works in schools with all teachers of physics. The project develops the subject knowledge and confidence of those teaching outside their specialism, improves the retention of early career teachers, and supports physicists returning to the classroom. The main objective of the SPN is to increase participation in A-level physics, particularly amongst girls. We have measured the impact of the SPN using the National Pupil Database (NPD). Our analysis shows that each phase of the project has been successful in achieving an increase in A-level progression from partner schools, above national trends. IOP analysis of the National Pupil Database shows that schools that joined the SPN between April 2012 and March 2013 have seen an increase in the number of pupils progressing to AS-level physics while in other state-funded schools numbers have declined slightly. This increase is particularly marked amongst girls.

- Improving gender balance

Girls continue to be under-represented in physics at A-level.[29] Consequently, they are under-represented on physics and engineering degrees. The implications and effects of this under-representation are well documented[30] and it could be argued that if the number of girls studying physics at A-level were raised to parity with the number of boys, the STEM skills gap would almost disappear. Over the years there have been many interventions that have had very little success. IOP analysis suggests that a 'whole school' approach is needed.[31] The DfE is funding a major pilot project – Improving Gender Balance (IGB)[32] – as part of the SPN. Its aim is to determine new ways (based on evidence) of addressing the imbalance in uptake and so reducing the shortage of people going onto physics and engineering courses. This project began only last year and is already showing promising results in the schools in which it operates. As a successful pilot programme, with continued support IGB has the potential to grow into a fully-fledged programme building on existing improvements to the nation's understanding of the problem of the underrepresentation of girls in physics and engineering and take significant steps towards solving it.

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[28] Stimulating Physics Network: http://www.stimulatingphysics.org/
[29] IOP – *It's Different for Girls* (2012): http://www.iop.org/education/teacher/support/girls_physics/file_58196.pdf
[30] Department for Business, Innovation and Skills - *Professor John Perkins' Review of Engineering Skills* (2013): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/254885/bis-13-1269-professor-john-perkins-review-of-engineering-skills.pdf
[31] IOP – *Closing Doors: Exploring gender and subject choice in schools* (2013): http://www.iop.org/publications/iop/2013/file_62083.pdf
[32] IOP – *Improving Gender Balance*: http://www.iop.org/education/teacher/support/girls_physics/improving-gender-balance/page_63795.html