Engineering the Future

The action forum for engineering

Response to the government's Productivity Plan

Business, Innovation and Skills (BIS) Select Committee

September 2015

This evidence is submitted by Engineering the Future (EtF). EtF is an alliance of professional engineering institutions and national organisations that between them represent 450,000 professional engineers. Through EtF, the engineering profession speaks with one voice on engineering issues of national and international importance. We provide independent – and expert – engineering advice to government. We promote understanding of the critical contribution that engineering makes to national policy and to addressing the grand challenges.

Much of the evidence and content for this submission was provided by the Royal Academy of Engineering. As the UK's national academy for engineering, the Academy brings together the most successful and talented engineers from across the engineering sectors for a shared purpose: to advance and promote excellence in engineering.

Some of the views described in this response were assembled through consultation with the Academy's Fellowship as well as positions previously stated in reports either by the Academy or published in partnership with other professional engineering institutions.

Question 1: Do you agree with the Government's assessment of the reasons for the UK's productivity slowdown (as outlined in the Annex to the Plan)? Has the Government acknowledged all of the main causes of the UK's poor productivity growth?

1. As the government assessment states, there are likely to be a number of reasons behind the UK's lower level of productivity. This response highlights a number of areas that we believe are critical to raising productivity:

   - continued public support for science and innovation
   - urgent action to address the shortage of engineering skills within the UK economy
   - investment and support for collaborative research and development (R&D).

   These points are substantiated in detail in our responses to the subsequent questions in this review.

2. The engineering sector and profession are tremendous drivers of productivity. Engineering has "improving productivity" as one of its permanent and intrinsic motivators. It employs the latest and most effective process thinking to improve productivity, and the profession fosters those 'habits of mind' that increase productivity – these include adapting, creative problem-solving and systems thinking.[1]

[1] Thinking like an engineer, A report for the Royal Academy of Engineering Standing Committee on Education and Training, May 2014

Question 2: One pillar of the Government's Plan is to increase "long-term investment". It outlines eight areas with specific measures to increase productivity.
a. Why has the UK's long-term investment been so low up to now?
b. How can we ensure that the measures relating to long-term investment in the new Plan will contribute to productivity growth?

A more competitive tax system

3. We would like to see more attention within the Productivity Plan to the potential for improvements in the way in which the tax system incentivises R&D. From 1 April 2015, the R&D tax credit for SMEs provides tax relief on allowable R&D costs of 230%. So, for each £100 of qualifying costs, an SME could have the income on which Corporation Tax is paid reduced by an additional £130 on top of the £100 spent. For large companies, tax relief on allowable R&D costs is 130%.[2] The government's Patent Box also provides Corporation Tax relief on profits earned from patented inventions or other innovations.[3]

4. Government analysis of the impact of R&D tax credits indicates that up to £3 of spending on R&D is stimulated for each £1 of tax foregone, with companies indicating their belief that these tax credits have contributed to an increase in R&D overall.[4] Over 15,000 companies claim around £1.4 billion via these measures each year.[5] In 2012-13, the SME scheme accounted for over 80% of these claims by number.[6] Evidently, many businesses consider these tax measures valuable in creating an environment that supports R&D and this view is echoed among the Academy's Fellowship, with some seeing it as a more targeted means by which to encourage investment in the UK than wholesale decreases in corporation tax. These measures may create less of an administrative burden than large grant mechanisms such as the Regional Growth Fund.

5. While R&D tax credits stimulate R&D expenditure, there is also confusion over the interaction between the R&D tax credit and State Aid rules. SMEs are still eligible to apply for the 'large company scheme' while in receipt of other funding without getting into State Aid difficulty. But guidance on this is not well understood, and use of the term 'the large company scheme' adds to the confusion. As the *Dowling Review of Business-University Research Collaborations* points out, there is also nothing within this system to encourage R&D to be carried out in collaboration with universities.[7] Much clearer guidance from HMRC and BIS is needed for businesses on how they can make best use of R&D tax credits and how these interplay with State Aid restrictions.

6. The small company R&D tax credit should have a key role in overcoming the shortfall in early stage financing for SMEs but take-up is low. There is no reference in the plan as to how this small company R&D tax credit take up might be improved. A further intervention might be to preferentially weight R&D tax credits in favour of non-incremental development activity.

Long-term investment

7. EtF welcomes any measures that improve public and private investment in R&D, a key mechanism for improving productivity. Investment in collaborative R&D also delivers real benefits to the UK, driving growth and productivity improvements for

[2] R&D tax relief, information at www.gov.uk/corporation-tax-research-and-development-rd-relief
[3] Corporation tax relief, information www.gov.uk/corporation-tax-the-patent-box
[4] Evaluation of Research and Development Tax Credits, HMRC, 2010
[5] Improving access to R&D tax credits for small business: consultation summary, HMRC, 2015
[6] Evaluation of R&D tax credits, HMRC, 2015
[7] The Dowling Review of Business-University Research Collaborations, Jul 2015

business and high quality research outputs.[8] R&D should be a core component of policies aimed at promoting productivity and competitiveness. Firms with persistently higher levels of R&D investment have, on average, 13% higher productivity than those with no R&D spending. Innovative firms are also more likely to be active exporters and achieve better value added per employee.[9] Firms which are more 'innovation intensive' exhibit faster growth, and it has been estimated that 51% of labour productivity growth between 2000 and 2008 could be attributed to innovation.[10]

8. A recent BIS-commissioned study suggested that the level of additionality achieved from public funding of research may have been underestimated: suggesting £1 of public funding will give rise to between £1.13 and £1.60 in private funding, whereas BIS currently use an estimate of £0.85.[11] As the government considers the future shape of public investment in science, R&D, skills, and knowledge exchange, it must recognise the value of stability in funding schemes. Stability allows businesses to familiarise themselves with the support available and builds the confidence needed for private investment.

A highly skilled workforce

The engineering skills deficit

9. The engineering community sees improvements in its skills pipeline not only as a key route to productivity improvements but as an area requiring urgent action to avoid damaging the UK's productive sectors, research base and wider economy. Engineering makes a £278 billion contribution to the UK economy (20% of UK GVA)[12] and has the potential to grow much further. Evidence suggests that engineering graduates and postgraduates – just one section of the engineers and technicians operating within the economy - provide the social networks, skills and absorptive capacity to not only undertake engineering tasks but also to drive business development more generally. Consistent with this, sectors with a higher concentration of graduate engineers all report higher than average levels of innovation activity and innovation-related income, as well as levels of labour productivity above the national average.[13]

10. Engineers and technicians of all levels can be found at the heart of almost any new product development initiative across most sectors of the economy. Despite this, the growth potential of engineering is threatened by a skills crisis that affects businesses right across the UK who are finding it hard to recruit the skilled people they need. By 2022 the shortfall in the UK of advanced technicians and professional engineers will be at least 550,000.[14] Almost half of engineering companies say that, right now, a shortage of skilled people is causing significant impact on their productivity and growth.[15] While some larger businesses can ameliorate this in the short term through recruitment of skills from abroad or by offshoring work, there is an endemic problem that will increasingly constrain the UK's capability in engineering if action is not taken now. Government, industry and the profession

[8] BIS Analysis Paper 04: Estimating the effect of UK direct public support for innovation, Department for Business Innovation and Skills, Nov 2014
[9] Our plan for growth: science and innovation evidence paper, Department for Business, Innovation and Skills, 2014, p17
[10] Innovation report 2014, Department for Business, Innovation and Skills, 2014
[11] What is the relationship between public and private investment in science, research and innovation? A report commissioned by the Department for Business, Innovation and Skills, Economic Insight, April 2015
[12] Engineering for a successful nation, Royal Academy of Engineering and the EPSRC, March 2015
[13] Assessing the economic returns of engineering research and postgraduate training in the UK, Technopolis Group, Mar 2015
[14] The State of Engineering, Engineering UK, 2015
[15] The contribution of engineering to the UK economy, CEBR, Oct 2014

have created fruitful collaboration on projects designed to help create the graduate workforce that industry needs. An example of this is the Aerospace MSc bursary scheme jointly funded by BIS and the private aerospace companies. This is run by the Academy and the Royal Aeronautical Society and is aimed at addressing the skills gap in the sector. Even so, the scale of the problem is significant and present at all levels of the profession, for example, the Engineering Council estimates that across all industries and occupations, more than 1.2 million people are eligible to join the national register as an Engineering Technician (EngTech), concluding that employers generally have low awareness of where technicians are located in their business and of the value that professional registration can bring for their technical staff.[16]

11. The Academy has undertaken detailed analysis of the skills gap and the reasons for it, modelling the engineering skills pipeline, mapping the major routes into and out of industry, considering how other sectors have sought to improve recruitment and identifying the levers that could have a real impact at the scale and pace needed.

12. The traditional routes into graduate-level engineering (from engineering and other STEM degrees) will not provide new engineers in the numbers we need and also provide greater career choice across competing sectors. Therefore there needs to be alternative pathways, including from inside and beyond engineering. The initiative on engineering conversion courses being developed by HEFCE, the Engineering Council and the Engineering Professors' Council with support from BIS is very welcome in this regard.

13. The lack of diversity in engineering is also a significant issue. Industry needs to improve its workplace culture and practices to attract, embrace and retain a more diverse workforce – a major undertaking that requires strong leadership. Improving diversity would yield significant wins: if all girls made the same decisions as boys at every stage of their education, the UK would gain another 9,000 professional engineers each year and would have a workforce that better reflects society as a whole. Black and minority ethnic (BME) students are underrepresented in engineering employment. The Academy is playing a leading role in promoting greater diversity and inclusion through its Diversity Leadership Group of employers, and Diversity Concordat Group of the professional engineering bodies which make up EtF.

14. A further issue is the lack of coordination of careers guidance and information and a complex array of schemes, scholarships, bursaries and work experience opportunities, combined with a plethora of often uncoordinated efforts to encourage greater uptake of science, technology, engineering and maths (STEM) subjects in schools and colleges and increase progression to engineering and technical qualifications. Although most have value, they are confusing to schools, coordination and targeting are limited and the overall impact is far below that required.

15. The Tomorrow's Engineers programme, coordinated by EngineeringUK, and part funded by the Academy, has been created to provide consistency and to develop scale in engagement between industry and third sector players and schools in order to maximise their value. All the professional engineering institutions that comprise EtF support Tomorrow's Engineers in their engagement with young people pre-16, ensuring these students receive a coherent message.

16. The lack of qualified teachers in STEM subjects, particularly maths, physics, computing and Design & Technology is a serious issue and one that affects the supply of future talent. More than 20% of mathematics and chemistry teachers, a third of physics teachers and more than half of computing teachers in state-funded schools in England have no relevant post-A-level qualification in the subject they are

[16] The State of Engineering, Engineering UK, 2015

teaching.[17] Government has a role in ensuring appropriate numbers of specialist teachers in STEM subjects and has committed to creating 17,500 additional maths and physics teachers by the end of its term. However, it should be noted that this figure actually only means an additional 2,500 new maths and physics teachers and the training of 15,000 current teachers (in other subjects) to enable them to teach maths and physics. The Academy is working with the Department for Education to see how engineering graduates and professional engineers may be able to support teaching in the subjects. This is a major issue to ensure the future supply of engineering skills to help the UK increase productivity.

17. In addition to addressing the shortage of STEM teachers, there is a need for both current and future teachers to have better understanding of engineering and to be able to inspire their students to take up the opportunities that arise from the study of STEM subjects. The EngineeringUK Brand Monitor even identified that 20% of STEM teachers would actively discourage their pupils from becoming an engineer. In particular, teachers lack an understanding of non-academic routes into engineering and technician roles as well as the career opportunities available through these routes.

18. The provision of further education (FE) is currently not adequate for the needs of the engineering industry and this is a fundamental, critical barrier which must be addressed to meet the technician skills needs of industry. We believe the government has rightly identified the need for apprenticeships and welcome its target for three million new apprentices over the course of this parliament. However, the focus must be on advanced level, high quality, long duration apprenticeships to meet the needs of the productive sectors. While major original equipment manufacturers (OEMs) find it easier to offer and fill apprenticeships, small and medium supply chain companies have greater difficulty in offering apprenticeships and the Academy heard that demand, partly driven by the government's recent emphasis on apprenticeships, is outstripping supply. Where small and medium supply chain companies are able to offer apprenticeships, they are not necessarily attracting high quality applicants.

19. Continued under-investment in the FE sector and impending additional cuts are having a significant impact on the quality and quantity of technician development. Fellows of the Academy have commented that the new compulsory levy for new apprenticeships, although not applicable to small businesses, should not become a tax on skills. We are very interested to see how the levy proposal develops, and how the professional engineering institutions might be able to support employers wishing to use it for 'professional formation' of engineers and technicians. While we welcome the introduction of employer-designed degree apprenticeships in Leadership and Management[18] and proposals for new income contingent loans for postgraduate taught masters students to contribute to the costs of an MBA, employment-based learning overall needs more focus and should include CPD by distance learning through to Professional Doctorates. Government could reimburse the employer for the time the employee takes out for training, or support those wishing to maintain their technical skills through professional bodies by other means. It also needs to improve the messaging and incentives that FE colleges receive regarding the skills that industry needs. There is currently a tendency to be attracted to high throughput, cheaper models of training, often incentivised by the funding that is available. A greater focus on training higher-level technicians needs to be properly incentivised. Funding and a better mapping of incentives with the needs of industry must create the right behaviour from FE colleges in the output skills provisions they provide.

[17] Vision for science and mathematics education, The Royal Society, June 2014

[18] Detailed in the section of the government's Productivity Plan on open and competitive markets.

20. Higher education capacity will need to expand to accommodate increasing demand from prospective students. Currently, some universities find it difficult to make a business case for expanding undergraduate engineering degree provision because the high cost of delivery is not covered by tuition fees and attracts a lower subject premium provided by HEFCE than medicine and dentistry.[19]

21. While the UK works to strengthen our system in support of a future UK workforce with engineering and technical capability, it must attract engineering potential and talent from outside the UK. There is a crucial need for clear messages and policies to counter perceptions that recent changes to immigration policy mean the UK is closed for business.[20] Overseas students bring cultural and financial benefits to our HE sector, but we are not realising this talent in our wider economy. Visa restrictions on non-UK/EU graduates mean that we are denied this pool of talent and lose out as employers, and risk compromising our competitiveness with other countries which offer the chance of immediate employment post-graduation. A quarter of current engineering graduates - around 5,000 every year - are non-EU domiciled, and restrictive immigration rules make it difficult for them to work in the UK.

Education reform

22. *Education for Engineering* (E4E), which is comprised of all 35 Professional Engineering Institutions, the Engineering Council and Engineering UK, is a part of EtF. It is focused on looking at the policy environment which leads young people to a career in engineering. This body has already given responses on a number of issues, including:

    - GCSE, AS and A level reform[21]
    - English Baccalaureates[22]
    - loans in Further Education[23]
    - reform of the National Curriculum in England[24]
    - the Richard Review of Apprenticeships[25]

23. A key concern with the promotion of the English Baccalaureate is that its current composition risks sidelining design and creative subjects that may prove a barrier to attracting students into careers such as engineering. The engineering profession has consistently argued for 'breadth and balance' to at least age 16 – seeking to encourage study that can produce creative and practical engineers and technicians able to meet the requirements for professional registration in a wide range of disciplines.

24. Another key concern is the risk of teacher shortages. Emerging evidence is of lower numbers of recruits, particularly in science and maths. There was a shortfall of 33% for physics trainees in 2014-2015, 56% for design & technology and 12% for

[19] Higher Education Funding Council for England – engineering is provided a 'Group B' laboratory based funding top up of £1,500 per student. By comparison, Medicine and Dentistry are provided 'Group A' funding top up of £9,900 per student (2013/14).

[20] International science, technology, engineering and mathematics (STEM) students, House of Lords Science and Technology Select Committee, 2014; Building a Stronger Future, The Royal Society, the British Academy, the Royal Academy of Engineering, and The Academy of Medical Sciences, Feb 2015

[21] These can be accessed here and here.

[22] This can be accessed here.

[23] This can be accessed here.

[24] This can be accessed here.

[25] This can be accessed here.

maths[26]. We have raised our concerns about the intention to recruit 17,500 teachers in STEM subjects in paragraph 16. It is doubtful that this figure can be met and so continued teachers shortages can be expected. Without excellent teachers in these subjects, students will not understand the importance of, or be enthusiastic about pursuing careers in technical areas. It cheats the students of opportunity, and the country of its potential technical workforce.

World-leading universities

25. The higher education sector generated £73 billion of output in 2011/12, through direct and indirect effects.[27] However, as seen in regards to the skills shortage in engineering, there is a pressing need to ensure better uptake of strategically important subjects, such as engineering. There are concerns that removal of the cap on student numbers will not achieve this increase in student numbers taking strategically important subjects and it may also lead to a reduction in the number of students opting for Level 4 and 5 qualifications. This is because there are practical issues with expanding engineering provision, and because UK student funding does not adequately cover the true costs of quality technical provision, leading to courses relying on overseas students to fill their current capacity.

26. We recognise the financial pressures around funding for Higher Education; however we are concerned that the replacement of maintenance grants with loans for new students from 2016-17 could arguably have a negative impact on productivity with many suitably talented students opting not to go to university.

Economic infrastructure

27. The engineering profession, through *Engineering the Future* and the Academy, has worked to highlight the role of high-quality infrastructure in a strong economy and for productivity. The UK has particular shortcomings in transport, supply of quality housing close to where people want to work, and high speed digital networks which enable people to work quicker, collaborate better and reach a wider client base. This section makes some broad points about infrastructure delivery in general while further sections then deal with particular types of infrastructure.

28. The increased visibility of future opportunities in the National Infrastructure Plan provides welcome confidence for investors funding the infrastructure and the companies that need to invest in the resources to deliver it. However, lack of stable, long-term strategies in areas such as transport and energy contributes to uncertainty, which then deters investment. Without such strategies, planning (including town and city planning and development of housing supply) suffers.

29. The ability to plan and deliver projects is constrained by skills shortages. Peaks and troughs in infrastructure programmes have made it difficult for long-term planning of recruitment and the development of expertise to drive project delivery. There is also a cost associated with the skills shortages; for example, HM Treasury and Infrastructure UK have previously identified a cost in infrastructure delivery from delivery teams man-marking across client and supply chain boundaries due to a shortage of qualified individuals.[28]

30. The role of the built environment in promoting or hindering productivity is not explicitly recognised in the government's Productivity Plan and deserves significant consideration. There is a growing body of evidence to suggest that the workplace environment plays an important role in staff productivity with well-designed built environment being a key factor. This was recognised by *Built for living*, a recent

[26] Based on analysis conducted on data sets available here.

[27] The impact of universities on the UK economy, Universities UK, 2014; Building a Stronger Future, The Royal Society, the British Academy, the Royal Academy of Engineering, and The Academy of Medical Sciences, Feb 2015

[28] Infrastructure Cost Review, HM Treasury and Infrastructure UK, Dec 2010

Academy report, which has a chapter addressing workspace design and productivity.[29] This finds that workspace design can enhance performance and productivity by influencing the retention, motivation and satisfaction of staff, creating better customer relations and improving the efficiency and effectiveness of work processes. This is true of offices, but also hospitals, schools, factories and other types of workspace.

31. Academy Fellows have suggested that the role of regulators could valuably be reoriented toward the promotion of productivity, reliability and sustainability, although this should only be where there is a clear market failure and strong evidence the regulator can contribute toward a solution.

Transport infrastructure

32. The engineering community has called for a systems approach to the management of the nation's transport infrastructure and this must also apply to the government's proposed Roads Investment Fund.[30] It may therefore be that an investment in or freeing up of freight by rail will have a positive impact on the road network. This includes improving access of ports for rail freight. Some large companies rely heavily on imports from the continent as part of their supply chain and so the freedom with which materials can be transported is a significant issue the importance of which was witnessed during the recent strikes by ferry workers in Calais that resulted in many near-critical supply issues for UK companies. Previous governments' commitments on airports and capacity have not been implemented to their full extent, which similarly needs to be addressed.

Energy infrastructure

33. Achieving a low-carbon, affordable and reliable energy system for the UK is an urgent priority of the government and will require some key decisions in the near term, in particular with regard to nuclear energy. So far, despite the obvious challenges, the system is on course to meet the targets set by UK and EU, but only just, and all the easiest actions have already been taken. Progress in the electricity sector will only get more difficult and there is a serious risk of non-delivery. Moreover, the heat and transport sectors, which account for most of demand and emissions, have yet to be addressed. Time is of the essence, with decisions taken now affecting what the system will look like in 2030 and beyond.

34. In developing energy policy, government must also always consider the whole system. Electricity, heat and transport are equally important, with complex interactions between them: targets will only be met by addressing all aspects of the system. The Energy Barometer, produced by the Energy Institute through consultation with its members, provides a useful reference point on what technology options are favoured by energy professionals.[31]

Digital infrastructure

35. We see digital infrastructure and skills as a key enabler of improved productivity and note that greater consideration of how digital technology can be harnessed to improve productivity is a key area in which the Productivity Plan might be strengthened. Working towards this goal, the Academy and the Institution of Engineering and Technology (IET) have a forthcoming report exploring the economic potential arising from digital infrastructure and data in key sectors of the economy. Focusing on the potential of data analytics (more colloquially 'big data') in different sectors, the report, *Connecting Data*, concludes that the UK is strongly placed to develop a leading data-enabled economy if the right policies are adopted.

[29] Built for living, Royal Academy of Engineering, Arup and the Economic and Social Research Council, Jul 2015
[30] An Engineering the Future response to Motoring for the Future, Engineering the Future, Sept 2014
[31] Energy Barometer 2015: Views from UK energy professionals, Energy Institute, 2015

36. Specifically, recommendations made by this study include:

- extend best engineering practices into less mature areas such as software development
- ensure that the infrastructure is in place to collect and distribute data and commands[32], both on the macro scale to support the inexorable transition from selling products to selling the services and capabilities enabled by those products, and on the micro scale to enable the ubiquitous networks of sensors and actuators across the 'Internet of Things'
- broadband access, at least compliant with the EU Digital Agenda for Europe targets of universal fixed access at a minimum of 30Mbits/sec download by 2020, is an essential prerequisite for a data-enabled economy
- similarly ubiquitous access to high-speed mobile broadband services is required
- creation of markets through which access to specified data sets can be traded for mutual benefit under rigorously specified conditions.
- establish methodologies for the formal valuation of data so that data assets can be more fully and accurately included on corporate balance sheets, rather than simply regarded as difficult to quantify intangibles
- ensure that the UK has the right skills and literacy in the area.

While the government's Productivity Plan concentrates on the physical infrastructure of the digital economy, a unanimous concern across all the sectors researched by the *Connecting Data* study concerned is a lack of the multi-skilled recruits required to convert data analytics theory into genuine business practice and performance.

37. There is also a need to develop the knowledge, technologies and skills needed to adequately address the risks involved in increased access and exploitation of data; for example, increases in cybercrime such as data breaches, intrusion and phishing. There are many important links between government, the private sector and academia in the prevention of cybercrime with academic institutions being an important partner in knowledge development and sharing. Currently, the private sector reports a range of cybersecurity awareness and actions but there is concern that small and medium-sized companies either do not take sufficient steps to protect systems or incorrectly perceive that they will not be a target. 33 As the prevalence of data increases further, such companies need to be adequately supported to address the risks posed when pursuing productivity gains through data exploitation. The suggested combination of skills is challenging, drawing on engineering, computer science, mathematics and statistics as well as specific sector knowledge.

High quality science and innovation

38. In modern economies, outstanding research and innovation advance economic, social, and cultural well-being, contribute to health, are a key source of competitive advantage, and can help increase productivity. Through R&D and innovation, companies can improve business performance by developing new techniques, technologies, and business models and processes and extend the capabilities and expertise available to the firm. Public investment in collaborative R&D de-risks private investment and involvement and delivers real benefits to the UK, driving growth and productivity improvements for companies and delivering high quality research outputs and skills for the economy. Innovation should be a core component

[32] A 'command' is an instruction given to a computer or a device in order to perform a particular task.
[33] Comprehensive Study on Cybercrime, United Nations Office on Drugs and Crime, Feb 2013

of policies aimed at promoting productivity and competitiveness, with full consideration given to its role in different sectors.[34] We welcome the government's recognition that the creation and application of new ideas is critical for long-term growth in productivity. The high level of enthusiastic participation in the Dowling Review from both universities and industry demonstrates that there is a clear appetite for collaborative R&D in the UK.[35]

Funding and international competitiveness

39. While the UK is already considered to be the most productive nation in the world in terms of its scientific output and the research community has made large savings through efficiencies such as equipment sharing and team science over the past Comprehensive Spending Review period[36], its leadership in science and research cannot be taken for granted.

40. In view of the dynamic and pervasive contribution to the UK's economy, there is a strong case for continued support for research and innovation.

41. Despite the maintenance of the science 'ring-fence', the science budget has been falling in real terms since the last CSR, with inevitable consequences for the health of the research base. Moreover, the UK suffers from a history of underinvestment in innovation, which persists today. International competition is stronger than ever and set to increase in years to come with key competitors such as Japan, Korea, the United States, Germany and France having increased investment and introducing ambitious strategies to reinforce their positions as leading knowledge economies at the same time as the UK has endured a real terms cut in funding for research. The UK was the only one of these countries with an R&D budget that was lower in 2010 than 2007[37] and is failing to keep pace with other leading nations. This risks eroding the UK's capacity to attract and retain the very best researchers from the UK and overseas.

42. While we recognise current policies are to reduce public spending and bring down the country's deficit, investing in research and innovation can help to create high value jobs and growth, strengthen productivity and improve the efficiency, effectiveness and resilience of public services. In today's highly interconnected world, companies – including those headquartered in the UK – have to make global choices about where to site their high value activities.

43. The Academy has called for an R&D investment level of at least 2.8% to bring it into line with other leading knowledge economies, accompanied by strong and well-targeted support for innovation. EtF, in its submission on the Science Budget to the Science and Technology Commons Committee, suggested that we should be increasing our spending by the rate of inflation, or the rate of our closest international competitor, whichever is the higher. Set against the backdrop of the severe pressures on public spending over recent years, the maintenance of the science ring-fence and the flat cash settlements secured for science and engineering in the CSR 2010 and Spending Review 2013 were widely considered to be positive outcomes for the research community. Indeed, the ring-fence is considered by many in the research community to be a powerful symbol of government commitment to continued investment in R&D. Nevertheless, these settlements represent a real-terms decrease of over £1.1bn in the ring-fenced science budget over a period when

[34] The Dowling Review of Business-University Research Collaborations, Jul 2015
[35] The Dowling Review of Business-University Research Collaborations, Jul 2015
[36] Fuelling prosperity, Royal Society, British Academy, Royal Academy of Engineering, Academy of Medical Sciences, Apr 2013; International Comparative of the UK Research Base – 2011, Elsevier, 2011
[37] Plan I - The Case for Innovation-led Growth, NESTA, 2012

key competitor countries have been increasing their expenditure on R&D, demonstrating that the ring-fence offers only limited protection from cuts.[38]

44. Much of the funding that is important to the research base, such as money for further education and higher education teaching, lies outside of the science ring fence that was maintained by the previous government. The Academy has recommended that government adopt a systems view of its investments in research and innovation, simplifies the public support mechanisms on offer and makes better use of procurement as a lever to stimulate innovation, in order to maximise the value delivered from these investments.

45. Looking specifically at engineering, there is much evidence of the world-class status of UK engineering research. 70% of research outputs submitted to the five engineering-related Units of Assessment in the Research Excellence Framework 2014 (REF2014) were classified as 'world-leading' or 'internationally excellent'. In addition, at over one and a half times the world average, the citation impact of UK engineering research has been particularly strong over the last decade relative to comparator countries such as the US, Germany, Japan and Canada, despite the activity level of engineering research in this country being only half the world average, and well behind emerging economies like China and India.[39]

46. The high quality of UK engineering research has also helped the UK to attract substantial high value inward investment from Europe, the US and the Far East which is contributing to new economic activity and employment throughout the UK, often in conjunction with regional growth initiatives. Recent examples include an investment of £7.5 million by Borg Warner to put in place the Turbocharger Research Institute in Bradford which serves as an engineering centre for Jaguar Land Rover, and Siemens' £160 million investment in wind turbine production and installation facilities in Yorkshire.[40]

47. A recent review jointly commissioned by the Academy and EPSRC estimated that UK businesses invest at least £9.5 billion per year in engineering R&D while the UK government spends an estimated £1.5 –3.1 billion per year. These data would seem to indicate that the UK achieves significant leverage on its public investment in engineering research, which in turns generates substantial wealth for the nation.[41] Government's collaboration with sectors in Growth Partnerships is one example of initiatives that build business confidence and de-risk private investments in order to achieve this leverage on public investment. In reference to the skills crisis in engineering, the UK's ability to develop, attract and retain people with the right skills and capabilities will be one of the most critical factors in determining our future competitiveness. Decreasing our investment in science and engineering could significantly undermine our ability to tackle this skills deficit.

University-industry collaboration

48. In its Productivity Plan, the government states its ambition that UK universities will continue to increase their collaboration with industry to drive research commercialisation as well as the recognition that there is still further to go in commercialising discoveries made in the research base and in ensuring the diffusion and adoption of these discoveries. We welcome the government's commitment within the Productivity Plan to support universities in collaborating with industry and commercialising research, especially the emphasis on working to ensure that the

[38] Building a Stronger Future, The Royal Society, the British Academy, the Royal Academy of Engineering, and The Academy of Medical Sciences, Feb 2015
[39] Engineering for a successful nation, Royal Academy of Engineering and the EPSRC, March 2015
[40] Assessing the economic returns of engineering research and postgraduate training in the UK, Technopolis Group, Mar 2015
[41] Engineering for a successful nation, Royal Academy of Engineering and the EPSRC, March 2015

means through which businesses access support for research and development are simplified, a key recommendation to result from the Dowling Review. We would, however, encourage the government to take a broad view of the types of innovation that can increase productivity within the economy to include not just the commercialisation of products and services but also innovation in business models and management practices, innovation in design practices and in consumer engagement.

49. As the government considers its response in full to the Dowling Review by the Spending Review, the Academy again highlights here the evidence showing that business-financed R&D intensity is greater where government financed R&D is greater.[42] Collaborative R&D also has a positive effect on productivity at the company level, and there is evidence that when trying to stimulate innovation in the private sector, collaboration delivers enhanced benefits compared to other, more 'closed', forms of innovation.[43]

50. Ensuring that the UK innovation system is able to support productive collaborations between universities and businesses is key to enabling the world class research produced by UK universities to be harnessed to support business innovation, resulting in broader economic returns for both individual firms and the UK as a whole. By connecting businesses to the excellence in the research base, collaboration can play a role in supporting long-term productivity improvements in the UK. It can help to ensure that the research activity in UK universities informs and supports the development of innovative services and products that create wealth and social benefit, as well as improving the competitiveness and productivity of the UK businesses that participate in the collaboration.[44]

51. Two of the key players in the UK's research and innovation landscape are the Research Councils and Innovate UK.

    - The Research Councils are an important source of support for strategic research partnerships between businesses and universities and there is some evidence that public funding for R&D which is channelled through the Research Councils leads to higher social returns, in terms of impact on private sector productivity, than that carried out by government departments.[45]

    - Innovate UK is the main vehicle through which the government provides incentives for business-led technology innovation. Encouraging business-university collaboration is a key part of helping to meet its ambition of accelerating economic growth through innovation. The Dowling Review identified widespread support during its consultation for the role played by Innovate UK in enabling this.[46]

[42] Insights from international benchmarking of the UK science and innovation system: Annex D, Department for Business, Innovation and Skills, 2014; The economic significance of the UK science base, Haskel, J., Hughes, A. and Bascavusoglu-Moreau, E., 2014

[43] BIS Analysis Paper 04: Estimating the effect of UK direct public support for innovation, Department for Business Innovation and Skills, Nov 2014; The Impact of Direct Support to R&D and Innovation in Firms (NESTA Working Paper No. 13/03), Cunningham, P. Gök, A. and Laredo, P., 2013; Evaluation of the Collaborative Research and Development Programmes, Innovate UK, 2013

[44] The Dowling Review of Business-University Research Collaborations, Jul 2015

[45] Rates of return to investment in science and innovation: a report prepared for the Department for Business, Innovation and Skills, Frontier Economics, Jul 2014

[46] Written evidence submitted by the Technology Strategy Board, Innovate UK, 2014; Business-university collaboration, House of Commons Business, Innovation and Skills Committee, 2014; Innovate UK response to BIS select committee report, Innovate UK, 2014

Industrial Strategy

52. Industrial strategy and the framework of support for key sectors and technologies provides powerful levers for stimulating business investment in R&D. The sector leadership councils have acted as platforms to convene private sector stakeholders, with major corporates bringing with them potentially valuable links to a wide range of SMEs through their supply chains. The perceived success of the early priority sectors has also led to demand from sectors not currently represented to be included in future iterations of the strategy.[47]

53. In March 2015, the Academy was invited by BIS to convene a workshop to bring to bear the expertise of Fellows to consider the impact and effectiveness of the UK's Industrial Strategy so far. Key messages included the following:

- The Industrial Strategy has been a very positive policy initiative that has demonstrated positive convening power, bringing industrial communities together where previously there was no mechanism or forum.
- Real change may take 10 years or more to realise and long-term continuity and consistency of support from government is of critical importance.
- The long-term nature of benefits needs to be recognised. Hard measures of success might not be identifiable in the short term and it might be sensible to adopt softer measures or models of continuous positive improvement.
- In the longer term, KPIs could include attracting investment, better access to finance, the availability of skills, a strong supply chain and changes in the structure of UK industry.
- The skills pipeline is a fundamental issue both within and across sectors. More unified engagement and career support is needed in schools and higher education to attract young people into STEM subjects and guide them through into the workplace.
- There is longstanding and continued concern regarding a hollowing out of UK supply chains which in turn reduces the capacity to leverage the UK's strong research base.
- Alignment of the Eight Great Technologies, leadership council priorities, and research council priorities is key. Part of achieving better alignment should be an effort to consolidate; there are currently too many bodies active in some sectors with overlapping objectives.

Catapult Centres

54. We welcome the government's intention to develop the UK's network of Catapult Centres for commercialising technology. The Catapult Centres are a good example of the long-term timeframes required for strategic activities and structures to mature. Mature Catapults today, such as High Value Manufacturing (HVM), have a wealth of outputs, networks and value[48] that it will take the newer Catapults time to achieve.

55. The new model initially presented a challenge to industry, in particular the challenge of bridging the gap between initial research activities and industrial application. However, since de-risking for industry emerged as a focus, experiences within the Academy's Fellowship suggest that industry has found involvement easier and beneficial. A key aim of enabling industrial R&D and innovation to co-locate and co-

[47] The Dowling Review of Business-University Research Collaborations, Jul 2015
[48] High Value Manufacturing Catapult: Pathways to Impact, Warwick Economics and Development, June 2015

create has meant a key strength of the Catapult model has been to draw in activities that would have previously happened in isolation. A key step has been to tackle firms' initial caution about sharing Intellectual Property (IP). As confidence in collaborative models has increased and benefits have been proven, willingness to share IP has increased, making it easier to engage supply chains. Now that benefits have been proved, some large companies now push for their supply chain to become involved.

56. The potential of Catapult Centres for impacting on economic growth and productivity is evidenced by the more mature Catapults. The Academy has received evidence from Rolls-Royce, which is a very active player in the HVM Catapult Centres. As well as progressing its own objectives, Rolls-Royce has also helped create solutions that support the needs of the wider HVM community in the UK, with the creation of world class research infrastructure by way of Manufacturing Research Centres and University Technology Centres (UTCs), established as 'national assets'. They have also developed the cooperative working models that promote collaborative behaviours and efficient business processes that can be adopted as 'best practice' standards across the community. While the government needs to continue to support existing Catapult Centres and create new ones where there is a compelling case and the resources to do so, there is also a concern that it is becomes politically attractive to announce increasing numbers of Centres and that this will stretch funding too far and dilute the current momentum. EtF agrees with the recommendation made by the Hauser Review of the Catapult Network, repeated in the Dowling Review, that gradual growth in the number of catapult centres would be beneficial but should only occur if additional funding is available and should not be at the expense of support assigned to existing centres.[49]

[49] Hauser Review of the Catapult Network, Hauser, H., 2014

Question 3: The second pillar of the Government's Plan is to encourage a "dynamic economy". It outlines seven areas with specific measures to increase productivity.
a. What are the main weaknesses of our economy, in terms of dynamism, which are suppressing our productivity?
b. Do the measures introduced under in the plan address those weaknesses and are they appropriate?

Open competitive markets

57. The Productivity Plan requires government departments to work with regulators to publish Innovation Plans by spring 2016. Departments and regulators must recognise and emphasise in their plans innovation in its widest conception, including business process innovation.

58. The Productivity Plan pledges a cut of a further £10 billion of red tape for business. It is important that standards are not swept away in this exercise: standards provide a certain kind of security to industry. Therefore careful impact analyses need to be done on what is being cut and careful attention needs to be given to wide stakeholder consultation in order to build the evidence base around what is holding back productivity and what, for some, is essential to their business security.

Resurgent cities

59. There is a strong need for economic growth in the regions outside of London and the South East, although their contributions within the supply chain to large infrastructure projects, such as Crossrail, should not be underestimated, infrastructure is one area that needs to be addressed. Better roads, railways and digital networks are needed to provide the connectivity that underpins productivity and job creation. This diversification will enable the UK economy to be more robust.

60. The present imbalance within the economy leads to a disproportionate number of people moving to the South East to pursue their career ambitions, leading to a lack of skills in other regions. Without a sufficient skills base, companies will not have the confidence to invest and create jobs yet, without jobs, people and skills will not be attracted these areas. A combined effort from government and industry is required to attract and retain talented people to the regions and to incentivise companies to create jobs outside of London and the South East. The Northern Powerhouse is a good example of such an initiative where the infrastructure is being provided to unlock and incentivise productivity growth.

61. While the work by the government to devolve powers to UK cities is welcomed, care needs to be taken not to compromise the UK's many centres of excellence and to maintain their international competitiveness. Within the agenda to devolve power to cities and regions, and as highlighted in the Dowling Review, there is also concern around the level of coordination that will remain. These stem from the granularity of LEPs. Specialisation in a field does not end at a LEP boundary and integration is required to ensure that work within a particular sector is coordinated effectively. It is vital that LEPs do not inadvertently duplicate capability elsewhere or compete with each other to the detriment of the overall benefit to the UK. Ensuring this does not happen will require intelligent national coordination, which should be led by Innovate UK.[50] The Dowling Review highlighted recent work commissioned by HEFCE that highlights the variability of SMEs within each LEP by number, sectoral composition, productivity and technological intensity.[51] Mapping activities such as these should help LEPs coordinate research and innovation activities in a way that is most beneficial to their region. If properly supported, close oversight by LEPs of the

[50] The Dowling Review of Business-University Research Collaborations, Jul 2015
[51] Collaboration between SMEs and universities - local population, growth and innovation metrics, HEFCE, 2015

local innovation geography may also provide the opportunity to take action to close any local skills gaps.

62. Also highlighted by the Dowling Review is the diversity and uncoordinated nature of advice provision to businesses, especially SMEs, at a local level ranging from the KTN to LEPs to EENs to Growth Hubs. The complexity of this landscape acts as a barrier and inhibitor for smaller businesses wishing to access support.[52] As the government continues with its strategy of devolution to cities and city regions, an urgent priority must be to simplify the mechanisms for provision of support to SMEs and to ensure that the new approach is communicated clearly and consistently. Innovate UK seems best placed to provide the leadership for this but will need to work closely with the LEPs and with support from DCLG and BIS if change is to be effected.

63. Given the Academy's support for investment in transport infrastructure as part of an integrated transport strategy, it particularly welcomes the government's renewed focus on plans to transform East-West rail and road connections via TransNorth and on options for a new TransPennine Tunnel.

64. Much UK R&D is funded by non-UK based companies. This potentially makes it easier for companies to migrate economic activity away from the UK so government policy should focus on how to increase the 'stickiness' of business activities in the UK. This could include steps to build close regional links between universities, lead businesses, supply chains and related services. The resurgent cities section of the Productivity Plan fails to give guidance on what a successful portfolio of British cities would look like in the future and how this could be underpinned, including how much funding would be needed for the cities/LEPs to achieve impact. We recommend the embedding of engineering 'habits of mind' applied to the development of local infrastructure, as this will embed practices such as systems-thinking and creative problem-solving, to maximise the potential effectiveness and efficiency of city systems.

[52] The Dowling Review of Business-University Research Collaborations, Jul 2015

Question 4: Overall, does the Plan adequately address the main causes of low productivity in the UK (as discussed in question 1) and will it have the desired results?

65. We believe that the measures in the plan will make a positive difference towards addressing the issues. The key challenge is to ensure that these measures are delivered: these challenges are complex and ingrained: this will require concerted, coherent, long-term effort from both government and industry.

66. The plan addresses a number of the known productivity challenges the UK faces and the steps which have been outlined should make a positive difference. Some further points for consideration:

    - The plan needs to be clear on its objectives, and targets need to be set for each of the individual elements in a measurable and tangible way.

    - The productivity challenge requires behaviour change / effort at an individual level. Although this is likely to be driven by senior business leaders, the productivity argument also needs to be understood by the wider population so they know what it means to them / what their role is. The points in the plan are essentially the tools to help them achieve this.

    - The UK needs to learn specific lessons from countries like the USA, France and Germany which have been highlighted as being more productive than the UK. Understanding the reasons fully and then applying them to how we operate in the UK should make a positive difference – in the same way that a multinational company applies best practice from around the world.

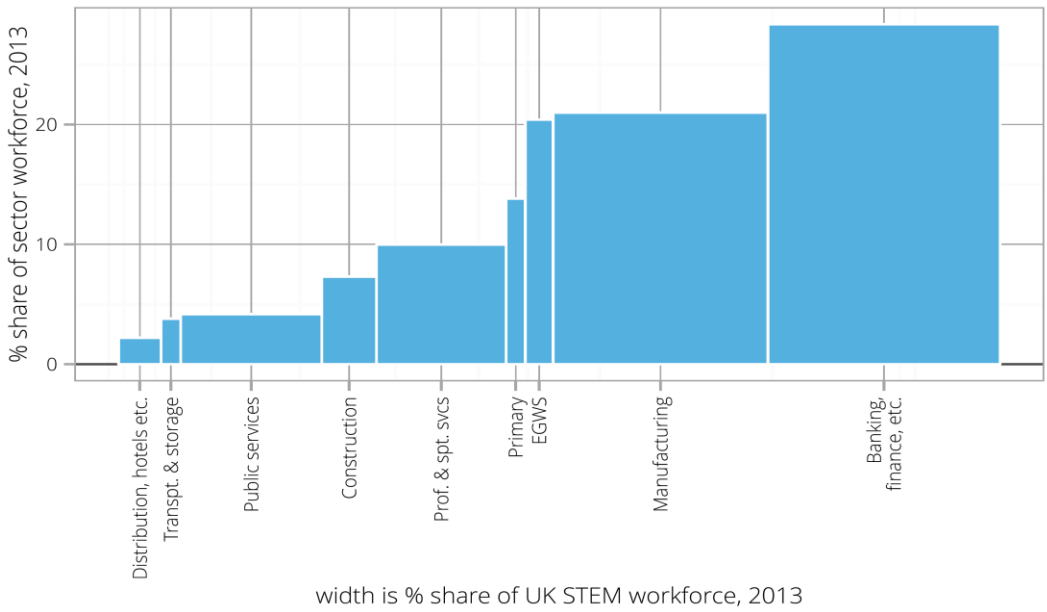
Public sector productivity

62. Given the fact that, with over 1.6 million employees[53], the NHS is the biggest single employer in the UK and has a significant influence on a large supply chain within the economy, it should receive significant attention in any Productivity Plan for the economy. The NHS and the health sector are notably absent from the current plan. EtF will shortly be publishing an analysis of *Engineering in Healthcare*, which demonstrates how engineering and engineering thinking contribute to effective health systems, not just through the development of technologies, but also through making systems like community healthcare more efficient. Engineering underpins public sector effectiveness in a multitude of ways. In EtF's recent Spending Review submission, we were able to draw out how engineering will help the government achieve its spending priorities. These include:

    - Engineering thinking in public services: It is those with an engineering 'mindset' who are able to move outside the traditional way of doing things, and come up with new and better processes. Engineering is also a highly collaborative profession, and increasingly multi-disciplinary in its approach. As a result, engineering provides the model, as well as the means to achieve greater innovation and collaboration in public services.

    - Engineers are also employed directly by public sector organisations. The following table, taken from *Reviewing the requirement for high level STEM skills*, UKCES 2015, shows the distribution of the STEM workforce by Labour Force Survey (LFS) industry sector, 2013. Although manufacturing accounts for the largest share, public services take a significant share of the overall STEM workforce.

[53] The NHS in England, NHS, 2015



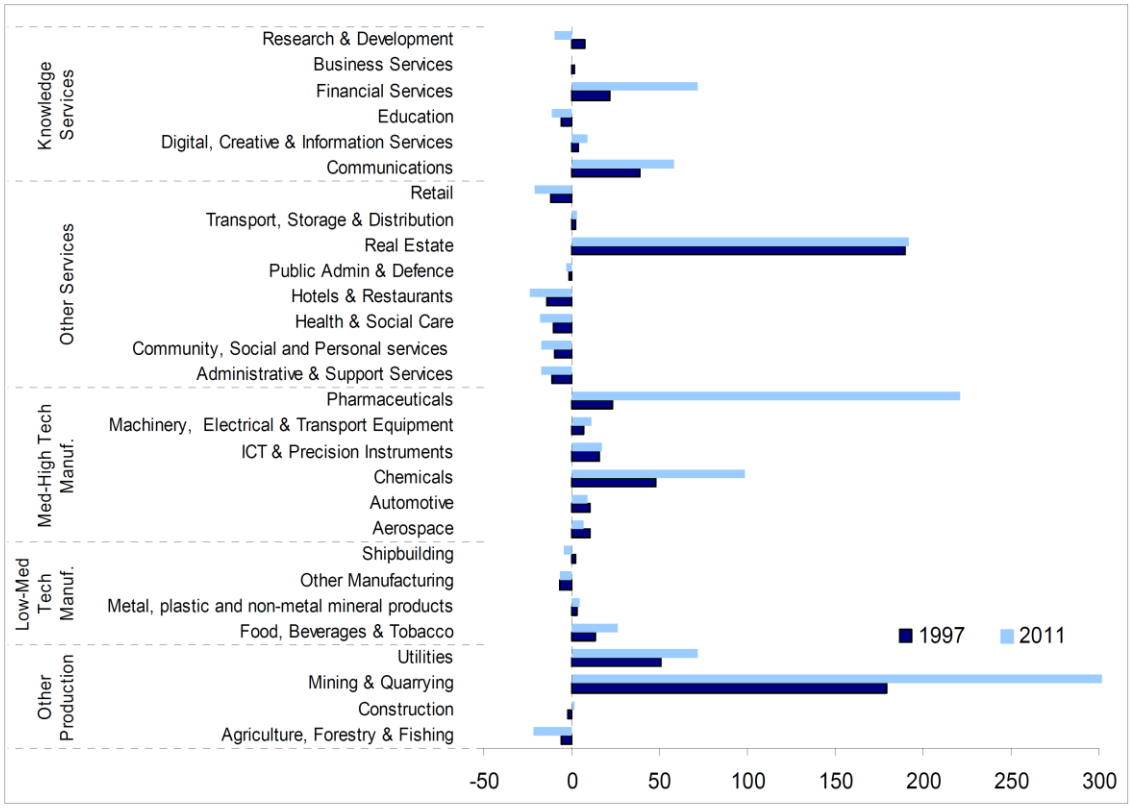
Source: UKCES analysis of Labour Force Survey. In Figure 7, sectors are from INDE07M.
Width is share of UK workforce, height is share of sector workforce.

Engineering's contribution to productivity

63. EngineeringUK's most recent analysis of the engineering sector and profession makes the simple headline calculation that "Engineering enterprises have the potential to generate an additional £27 billion per year from 2022". This is caveated with the presumption that engineering companies will be able to recruit the right people and skills.

64. BIS's own analysis of ONS data, published in BIS Economics Paper No. 18, *Industrial Strategy: UK Sector Analysis,* September 2012, shows that mid-high tech manufacturing is the only high level sector with a consistent positive contribution to UK GVA.

Figure 2.3: UK GVA per worker relative to whole economy (1997, 2011)



Source: BIS Analysis of ONS Data.

65. A more recent analysis as part of *Working Futures: 2012-2022*, suggests that in 2017, Primary Sector & Utilities and Manufacturing will be the two sectors contributing the highest levels of GVA per employee.

	GVA Levels 2017 (£000)	**Employment levels (000s) 2017**	**GVA per employee**
Primary sector & utilities	64012	789	£81,130.54
Manufacturing	146584	2542	£57,664.83
Construction	95848	2151	£44,559.74
Trade, accom, & transport	259276	8651	£29,970.64
Business and other services	509526	10327	£49,339.21
Public admin, health, education	263291	8350	£31,531.86
Total	1404076	32788	£42,822.86

Source: Table 3.1 and Table 3.2, Working Futures 2012-2022

66. Engineering also plays its part in the UK's relative global position, boosting our competitiveness and attracting overseas investment to the UK. We must be ambitious, not just to secure our place in international rankings, but to improve and outstrip our competitors. This is recognised by organisations such as the CBI, which details the contribution of Science, Technology, Engineering, and Mathematics.[54] The recent *Ingenious Resilience* briefing from the Engineering Professors' Council

[54] Engineering our future: Stepping up the urgency on STEM, CBI, 2014

and Cambridge University Science and Policy Exchange quotes a number of key statistics, not least that: "engineering contributed 27% of GDP in 2014 and employed 20% of all working people".[55]

67. In addition to all of these ways in which engineering supports growth and productivity, the sector also has a positive multiplier effect on the rest of the UK; for every new engineering vacancy that is filled, 2 new jobs can be expected to be created throughout the UK economy.[56]

Productivity as a policy driver

68. A fundamental issue which is particularly important to engineering is the question of whether productivity measures are the right ones or, more significantly, whether they measure what most people think they measure. The topic of the appropriateness of national statistics in an increasingly digital age is one of the areas being investigated by Professor Sir Charles Bean in his review.

69. An example of the potential shift in the modern definition of productivity is ICT, computing or data storage, where industry has delivered a hugely increased level of service for a small fraction of the price compared with 20 years ago, productivity is measured using GDP as an output measure, then the immense gains in terms of social and quality of life are not measured. This has other counter-intuitive effects: consider a country with similar technology but much higher prices for mobile and internet service (such as the US compared with the UK). The communications industry in such a country may show higher, not as one might expect lower, productivity because their higher prices contribute more to GDP. The productivity measure is not wrong - it just does not measure the whole spectrum of gains in terms of service, well-being, quality of life and social benefit.

[55] Ingenious Resilience: messages for a new government, Cambridge University Science and Policy Exchange and Engineering Professors' Council, 2015

[56] According to The contribution of engineering to the UK economy – the multiplier impacts, CEBR, Jan 2015