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Square Kilometre Array set to be world's largest radio telescope

The UK has signed an agreement in Rome as one of the first organisations involved in the world's largest radio telescope. The international headquarters for the telescope, which is 50 times more sensitive than the Hubble Space Telescope, will be in Jodrell Bank, Manchester.

British scientists will get the chance to improve the understanding of the evolution of the universe over billions of years and map hundreds of millions of galaxies thanks to this powerful telescope project.

Unlike optical telescopes that point

into the sky and can be affected by cloud cover, this radio telescope detects radio waves emitted by a wide range of celestial objects some millions of light years away.

With its headquarters at Jodrell Bank, the Square Kilometre Array (SKA) will have its telescopes in South Africa and Australia and will be the world's largest and most sensitive radio telescope in history.

The UK directly benefits from three significant aspects of the project:

- hosting the international HQ;
- involvement in design and construction;

- at the heart of world-leading science.

The telescope will be able to study the period in the early universe around 380,000 years after the Big Bang, when the universe was mostly dark until the first galaxies began to shine.

Scientists and engineers at UK universities and institutions are involved across the design of the SKA. UK industry has also been involved with the design of the SKA with around 55 UK companies awarded contracts in systems engineering, project management and software development.

New Antarctic Survey centre will use AI for environmental work



A new Centre for Doctoral Training, involving researchers from the British Antarctic Survey, will develop Artificial Intelligence (AI) techniques to address critical environmental challenges.

Climate change and environmental hazards pose some of the greatest risks for society in the 21st century. In addition, datasets are bigger and more complex than ever due to advances in monitoring technologies and improvements in data storage and analysis.

Data science and AI offer huge potential to transform our ability to understand, monitor and predict environmental risks. Funded by UK Research and Innovation (UKRI), the Centre for Doctoral Training in Application of Artificial Intelligence (AI) to the study of Environmental Risks (AI4ER) is one of 16 new Centres for Doctoral Training (CDTs).

A collaboration between the University of Cambridge and the British Antarctic Survey, the Centre builds on existing research activity involving the application of AI to environmental science problems. One such example is supporting marine conservation through the use of sophisticated image processing techniques to identify whales in high-resolution satellite imagery.

UK needs to pursue 'vision' of fusion energy

The UK Atomic Energy Authority's pursuit of commercial fusion is an "example of the vision the UK needs to pursue" to deliver the Government's commitment to spend 2.4% of GDP on science and research, according to new Minister of State for Universities, Science, Research and Innovation Chris Skidmore (right).

He was visiting the UK's new fusion experiment MAST Upgrade and the European research JET at Culham Science Centre.

"The work of UKAEA here at Culham will help make British fusion power a reality – this kind of national endeavour is a great example of the vision we need to pursue to deliver the 2.4% R&D target," he said. "World-class science, tackling a big global challenge, deeply embedded in the real world and in its community."

In addition to talking about charting a path to an economy investing in science, research and innovation, the minister



said one urgent priority was ensuring that as the UK leaves the European Union, it has the "right relationship with European research programmes and with the wider world of science and research."

Mr Skidmore added: "The Joint European Torus is one of the most impressive international scientific facilities not just in the UK, but perhaps in the world. It symbolises the application of world-leading research and engineering to tackle one of the world's greatest challenges: the challenge of clean energy."

Research project aims to 'smell' rotten food

Scientists in the UK are working to develop new technology which will be able to 'smell' when fruit or vegetables are going off – potentially saving tonnes of waste.

According to the UK waste advisory body WRAP, 1.2 million tonnes of fresh fruit and vegetables are needlessly wasted each year.

The UK-based research team is hoping to develop a quick and cost-effective quality assessment solution for the food and drink industry, using a technique

commonly used in space science. Not only would this help reduce waste, but crucially this will allow food suppliers to be able to pinpoint when the produce is at its peak condition, and therefore has the most nutritional value to consumers.

The research project has been funded by UKRI's STFC Food Network+, which brings together researchers from different disciplines in the agri-food sector with the aim of solving some of the world's greatest food sustainability challenges.

EDITORIAL

Dr Dougal Goodman was Chief Executive of The Foundation for Science and Technology from April 2000 to February 2019. Here he looks back at some of the themes and events that have shaped the organisation over that period.

Making better choices: analysis and evidence in political and business decisions

Dougal Goodman

Politicians, and for that matter, senior managers, are expected to be decisive individuals, able to see the essential amidst a multitude of details and equipped with the courage and insight to take effective action. Analysts, on the other hand, must carefully sift and weigh every detail and contingency for meaning and import. Their task is to ensure that all the avenues, all the risks, have been considered and properly weighed. That may be a rather simplistic description, but it characterises an essential difference in cultures. Working together, these two different approaches can help identify and action the best result in given circumstances.

However, that same difference, in approach or priorities, can often lead to misunderstanding and, in some cases, to a less than ideal outcome. The aim of The Foundation for Science and Technology has always been to provide a non-partisan space where ideas and issues can be clearly and openly debated, so mitigating that risk: different approaches can be aired, contrasting insights shared, all in an environment where 'open and frank' exchange is encouraged. The Foundation brings together Parliamentarians, officials from civil and public service, leaders from business and senior academics – specialists in their own fields with expertise that can provide useful insights to others. The Foundation's role is to 'hold the ring' and create an environment where the exploration of diverse views can help to shape new thinking.

We have welcomed Government ministers to our debates, including Greg Clark, David Willetts and Lord Sainsbury, as well as Nobel laureates such as Sir Paul Nurse, and Government Chief Scientific Advisers including Sir Patrick Vallance, Sir Mark Walport, Lord May, Sir David King and Sir John Beddington. Departmental Chief Scientific

Advisers have come not just to put forward their own (and their Departments') views, but also to hear from others in different parts of the scientific, business and political worlds.

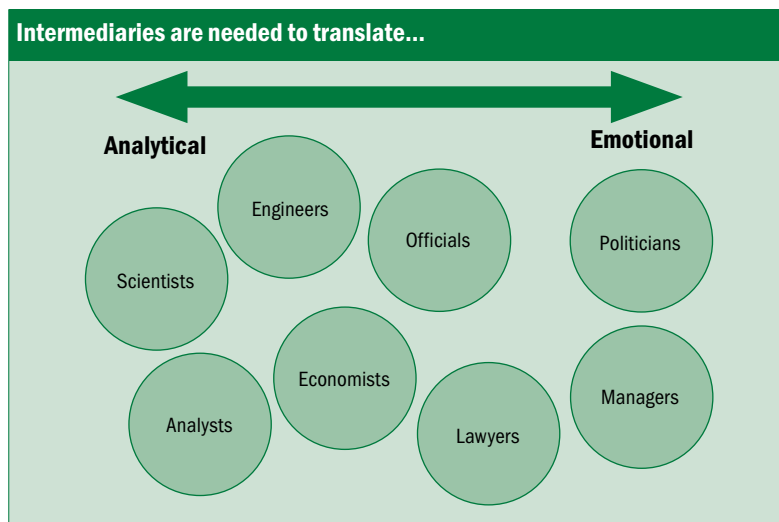
Foundation meetings have covered a wide range of topics, most where a political choice is to be made or implemented that is underpinned by an element of science, engineering or medical science. Among the most memorable must be an evening, jointly organised by the Foundation and the US Embassy, featuring a panel of American astronauts, including Neil Armstrong, the first man to set foot on another world, Jim Lovell, the Commander of Apollo 13, and Gene Cernan, till now the last person to stand on the lunar surface. The Apollo programme must surely be one of the most striking examples of just what can be achieved by the coming together of scientific expertise and political will.

Political support for science has been a feature of all industrialised societies. In late 2017, we were privileged to hear the views of three eminent Parliamentarians – the Lords Hennessy, Heseltine and Willetts – in a meeting on the history of industrial strategies since the Second World War and how successive governments have sought to close the productivity gap between the UK and the US through investment in science and innovation programmes.

Looking back over the years, there has been a huge diversity of subjects debated, with some featuring on a more regular basis because of their continuing importance to the UK economy. There are the perennial questions of how science and innovation should be funded, what proportion of the national income should be devoted to research and development and how much influence Government should have in determining priorities.



Dr Dougal Goodman OBE FEng is a Vice President of The Foundation for Science and Technology. From April 2000 to February 2019 he was Chief Executive of the Foundation. He is a former Acting and Deputy Director of the British Antarctic Survey and a general manager for BP where he worked as head of safety for the company, operations manager for the Magnus oil field and in strategy and planning. He has been on many expeditions to the Arctic and the Antarctic for research and with his family. He was awarded the Polar Medal for leading polar expeditions and has an OBE for services to science.



The differing mindsets of the Minister or manager and the scientist/analyst need to be recognised in effective decision making.

We have discussed how best to tackle the productivity gap between the UK and its major competitors and how to ensure the economic, physical and mental health of all our citizens.

Specific issues of concern to the public, where science and innovation can make a real difference, are also on our agenda. Changes to regulatory regimes and improvements in building technologies were examined in the wake of the Grenfell Tower disaster. Official responses to the BSE and Foot & Mouth crises were considered in the light of relevant science – and the controversial policy to cull badgers was also scrutinised.

Yet the Foundation for Science and Technology has a wider remit than just the geographical borders of the UK. After all, science knows no boundaries and national interests do not stop at the country's frontiers.

Climate change threatens major change to the global ecosystem. While the principle of anthropogenic change may be generally accepted there is still plenty of uncertainty about whether nations can deliver the Paris Agreement carbon reduction targets. Increasing carbon dioxide emissions throw a spotlight onto the role of energy supply in today's societies and how these can be secured in a low-carbon future. Climate also affects commerce and global geography: the UK has interests in both polar regions and there are exciting opportunities emerging here.

While predicting the future is full of pitfalls – as some science and industrial strategies have found to their cost in the past – some issues in the near term are clear. Whatever the final shape of our relationship with Europe, the Brexit process will have a profound effect on many aspects of our economy, not least in the area of academic research. The UK has traditionally 'punched above its weight' here and Government faces an urgent task in ensuring that we retain a leading

role in global science.

Over the years, the Government has acknowledged a central role for science and innovation in creating a prosperous society in the UK. Yet that commitment needs continual renewal and review if this country is to remain competitive. Other countries invest more in their science and technology areas and the UK must not be complacent when it comes to championing our key strengths.

While most of the Foundation's meetings are held at The Royal Society in London, we are keenly aware that the capital is not the only repository of expertise and insight. For many years, the Royal Society of Edinburgh has welcomed us to its home and while the debates have had a distinctly Scottish flavour, the issues have been chosen to have a wider resonance. The Foundation has also hosted a meeting in Cardiff with the Learned Society of Wales. There are centres of academic and industrial excellence across the UK and the Foundation wishes to encourage and celebrate these.

The Foundation

The Foundation has received financial support from Government Departments, from UKRI, as well as core supporters such as The Royal Society, The Peter Jost Memorial Fund, The Haskel Family Foundation and many others for which I am very grateful. But equally, it relies on the efforts of a small number of people who put in a great deal of effort, often unseen.

This includes our former Chairs, the Lord Jenkin of Roding and the Earl of Selborne – as well as the current Chair, Lord Willetts – the editors of the *FST Journal* Sir John Maddox and Sir John Enderby (and its production editor, Simon Napper) in addition to the office team that keeps the organisation running – Angela Pusey and Keith Lawrey. I would also like to recognise the invaluable contribution made by members of the Foundation's Trustee Board and Council and those providing the summaries of our meetings, especially Sir Geoffrey Chipperfield.

The Foundation for Science and Technology has undergone a significant evolution over the past 18 years in responding to changes in society and technology. The internet and social media, for example, are now established channels of debate, yet were in their infancy when I became Chief Executive. The pace of change shows no sign of slowing and the Foundation will need to adapt as it strives to remain relevant and vital in its chosen mission. There is a huge and important agenda for science and innovation in delivering a healthy and prosperous future for UK citizens. The new Chief Executive, Gavin Costigan, will not lack for opportunities to press that agenda: I wish Gavin well! □

While predicting the future is full of pitfalls – as some science and industrial strategies have found to their cost in the past – some issues in the near term are clear.

INDUSTRY AND THE REGIONS

Great science and innovation occur the length and breadth of the UK. The question is how to ensure that all the opportunities are grasped wherever they may be found. A meeting of the Foundation for Science and Technology on 19 December 2018 examined how the UK's Industrial Strategy can be embedded in all parts of the country.

The role of place in the Industrial Strategy

Greg Clark

SUMMARY

- For centuries, British innovation and ingenuity have been firmly rooted in our regions and our nations
- Government is working with regions, towns and cities to help them build on their unique strengths
- The power of the Industrial Strategy's Growth Deals is to bring people together
- The UK is creating technologies today which the rest of the world will use tomorrow
- From space to solar, from care to construction, we are building on the best of local strengths right across the UK.

To illustrate the crucial importance of place throughout our industrial history, I want to take the example of George Stephenson. In 1825, on the verge of a revolution in railway technology, he had to travel to London to answer questions from a parliamentary committee about his proposed Liverpool to Manchester line.

Faced with the 'father of the railway', the committee might have shown some enthusiasm for the project. In fact, quite the contrary as the committee's lawyers subjected Stephenson to three days of intense questioning. 'How fast will the railway go?' 'How will the pistons work?' 'Will it go around corners and if so, how?' 'Would it scare the horses?' 'What would happen if it hit a cow?' They even had the temerity to mock his strong Geordie accent. One committee member asked if he was a foreigner while another implied that he was mad. Indeed, at the end of the proceedings, the lawyer Edward Alderson declared Stephenson's plan to be "the most absurd scheme that ever entered into the head of a man to conceive".

The bill was put to a vote and Stephenson lost. Yet, as we all know, it was Stephenson who had the last laugh. His Stockton to Darlington line opened later that year. His Liverpool to Manchester line

followed five years later and the year after George Stephenson died, his son Robert was elected as a fellow of the Royal Society.

Many stories of the fellows of the Royal Society do not start in London. James Watt's 'eureka' moment for a steam engine with a separate condenser did not happen in St James's Park, London, but on Glasgow Green.

When 16 year old James Chadwick joined the queue for the physics entrance examination – which would lead him eventually to discover the neutron and to win the Nobel Prize for Physics – this was not at UCL or Imperial but at the University of Manchester.

Anglesey's William Jones first used the symbol for π 300 years ago, while Swansea's Edward Bowen was instrumental in developing the radar that defended our shores during the Battle of Britain. Aberdare's Dr Lyn Evans switched on the Large Hadron Collider for the very first time 10 years ago. For centuries, British innovation and ingenuity have been firmly rooted in our regions and our nations.

Growing up on Teesside I saw this first-hand. The founders of the great industrial town of Middlesbrough did not need to approach central London for permission to develop their industry and to lay out the town that Gladstone described as the 'infant Hercules'.

Yet that ability to initiate and shape the future of an area has increasingly moved from the banks of the Tees to the banks of the Thames. This has not been, in my view, in the interests of Teessiders over the years because the decision-makers no longer have the local knowledge to know exactly what is needed.

During my time in Government, whether as Minister for Cities, Communities Secretary, Minister for Universities and Science and now as the Secretary of State responsible for industrial strategy, I have striven to promote the devolution of decision-making from SW1 to our great cities, towns, regions and nations. One of my proudest moments as Communities Secretary was the signing of the



The Rt Hon Greg Clark MP is Secretary of State for Business, Energy and Industrial Strategy, and MP for Royal Tunbridge Wells. He has served as Minister for Cities, Financial Secretary to the Treasury, Minister of State at the Cabinet Office and Minister for Universities and Science. He was Secretary of State for Communities and Local Government from May 2015 until July 2016.

It is not the Government's job to tell places what they need or what they are good at. They already know this better than anyone.

There is not a society in the world that is not being transformed by AI and big data, clean growth, changing mobility technologies or the aging of the population.

Cardiff Capital Region City Deal, the largest deal agreed in any of the devolved nations.

The launch of the Industrial Strategy in November 2017 was a landmark moment for Wales and other nations because every place and every person could benefit. Beyond the money and the resources, the power of the Growth Deals is to bring people together.

It is not the Government's job to tell places what they need or what they are good at. They already know this better than anyone. However, through the Industrial Strategy, Government can work with them to help them build on their unique strengths.

Now, there is not a society in the world that is not being transformed by AI and big data, clean growth, changing mobility technologies or the aging of the population. These are, then, the four Grand Challenges of the Industrial Strategy.

Many aspects of these challenges are reflected in other strategies such as the Welsh Government's Economic Action Plan (EAP). Britain's regions and nations are perfectly placed to be a leading force in research and innovation. In the UK, we are creating technologies which the rest of the world will use tomorrow. The UK has a deserved reputation for R&D excellence.

Take the first Grand Challenge: AI and the data-driven economy. This was the subject of a multi-billion pound sector deal launched in April 2018. Some 40% of all small communications satellites launched into space are designed and built today in Britain. But the sector deal is not focussed just on London and the South East.

Glasgow, for example, designs and builds more small satellites than any other city in Europe. And while today the UK designs and builds satellites, from the 2020s we want to design, build and launch them – becoming the first place in Europe so to do.

We are working with the Highlands & Islands Enterprise Board on the proposed space port in Sutherland on the north coast of Scotland. Local people are promoting local strengths, creating hundreds of highly-skilled jobs in this part of the UK.

Clean growth is a field in which Wales is leading the way. The Welsh Government's EAP names decarbonisation as one of its calls to action. Across Wales, universities and firms have been answering that call for years. The work being done at Swansea University on so-called 'active buildings' is a good example. Through new coatings and materials, renewable technologies are turning buildings into power stations: that is to say they are producing more energy than they consume.

Swansea's initial research, as is so often the case with successful research and innovation, had a snowball effect. Companies like Tata Steel and institutions like Cardiff University joined them as

partners, receiving seed funding from the Welsh Government. Through the Industrial Strategy Challenge Fund, Swansea University has been awarded over £30 million to develop these technologies further.

Swansea is perhaps a decade ahead of anywhere else in the UK, with enormous potential to help us achieve the mission of our clean growth Grand Challenge, which is to halve the energy use of new buildings by 2030.

The third Grand Challenge is to make the UK a world-leader in the future of mobility. Wings for nearly all Airbus aircraft are assembled in North Wales at the largest single manufacturing site anywhere in the UK. Airbus are working with Siemens and Rolls Royce to help transform the future of flight through the Industrial Strategy – we are working with them to fund a demonstrator for hybrid electric propulsion for commercial aircraft which will not only be cleaner, but quieter too.

The aerospace sector deal was launched in December 2018 to develop our leadership in this area with funding of a quarter of a billion pounds, half from industry and half from the UK Government. It aims to develop a new supply chain for the 21st century, providing bespoke training and access for over 70 small and medium sized aerospace firms across the UK. It is a massive opportunity for suppliers, especially in places like Wales and the South West of England.

In the British population today, there are 15,000 citizens who have reached their 100th birthday. Yet out of all those currently alive in the UK, 10 million can expect to reach that age! This is a huge transformation.

Greater Manchester already benefits from a historic health and social care devolution deal – the first devolution deal that I negotiated in the last Parliament. Early in 2018, Greater Manchester was named the UK's first 'age-friendly city region' by the World Health Organisation (WHO). It is also one of the biggest tech hubs outside of London. The region's local industrial strategy will combine these unique strengths to help people live better for longer.

While the strategy itself is still being agreed, options under consideration include a programme for people to live well, at home, for longer. This will involve a new model of independent living, making the most of new assisted-living technologies. One of the aims of this Grand Challenge is to make sure people enjoy at least five extra, healthy, independent years of life by 2035.

The West Midlands Local Industrial Strategy aims to make the region a world leader in electric and connected vehicles while the Oxford/Milton Keynes/Cambridge corridor is looking at how a

Glasgow designs and builds more small satellites than any other city in Europe.

joint industrial strategy can harness its very evident scientific strengths. Government is working with all the mayoral combined authorities and the local enterprise partnerships (LEPs) to develop local industrial strategies.

Even today, 200 years after Stephenson was mocked by that imperious parliamentary committee, there are still those who think that great ideas

can only prosper if presented in London before Parliament, Select Committees and institutions based in the capital. They could not be more wrong.

From space to solar, from care to construction, we are building on the best of local strengths right across the UK. Everyone, everywhere can be proud of the contribution that each can make to economic success. □

Growing the industrial and science base in Wales

Ken Skates

SUMMARY

- Wales is home to world-leading research and innovation
- Growing the industrial and science base in Wales is the aim of both Welsh and UK Governments
- Wales has grown the volume, the quality, the impact and international reach of its research base since devolution in 1999
- Most EU funding for Welsh R&D comes from structural funds rather than the Horizon 2020 programme
- Both the Welsh Economic Action Plan and the UK Industrial Strategy recognise the crucial need to achieve a regional rebalancing of the economy.

Wales is already home to some of the most innovative, dynamic and exciting industrial activities anywhere in the world, from international centres of aerospace engineering expertise in the north of the country to cutting-edge innovation in metal such as steels, marine technology and automotive production in the south.

Our Economic Action Plan (EAP) was launched in December 2017. This set out the Welsh Government's vision of growth, based on the foundations of tomorrow's super-charged industries, located in productive and cohesive regions. Research, innovation and skills are at the very heart of that plan, critical components for driving growth and prosperity in our economy.

The commitment to grow Wales' industrial and science base is shared by both Welsh and UK governments. There are clear synergies between the Economic Action Plan and the

UK Industrial Strategy. We must exploit and commercialise inventions, encourage discoveries and innovations, and work to improve the performance of the Welsh economy which, of course, aids the prosperity of the UK as a whole.

The UK science base is recognised as a world leader. The Welsh Government's 2012 policy on science saw the launch of the Science for Wales Strategy which reflected our intention to grow the research and development base here. It set out the ambitious Seren Cymru programme, which means 'Star Wales'. It created a unique partnership between the Welsh Government, the Higher Education Funding Council for Wales, our HE institutions and the Welsh/European Funding Office – as well as the European Commission.

Investment of some £100 million has secured more than £131 million of competitively-won research funding, attracting 12 world-class research chairs and their teams from 28 countries, including Canada, China, New Zealand and Denmark.

While securing just 2% of the UK's total R&D expenditure, Wales has grown the volume, the quality, the impact and international reach of its research base since devolution in 1999. We are now the most efficient of the UK countries at converting relatively small levels of funding into highly-regarded research.

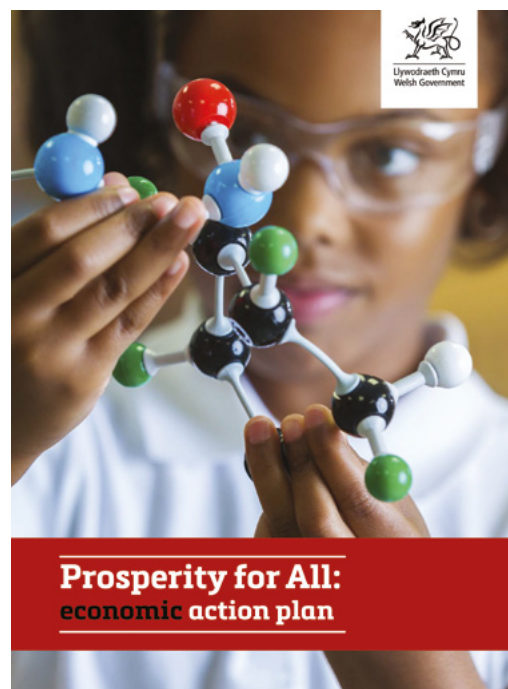
Research Excellence Framework

The Research Excellence Framework showed in 2014 that Welsh research was holding its own. Some 77% of all Welsh HE research was assessed as being world-leading or internationally excellent. 86% of research was judged to have an outstanding or very considerable impact on the



Ken Skates AM is Minister for Economy and Transport in the Welsh Government. He was Deputy Minister for Culture, Sport and Tourism in 2014 and promoted to Cabinet Secretary for Economy and Infrastructure in May 2016. He was appointed to the Welsh Government as Deputy Minister for Skills and Technology in 2011. His policy interests include manufacturing, mental health, sport and leisure, eliminating poverty and political economy.

The Wales Economic Action Plan (EAP) set out the Welsh Government's vision of growth, based on the foundations of tomorrow's super-charged industries, while the recent Reid review highlighted the strength of the Welsh research and innovation ecosystem.



economy, society and culture. In terms of field-weighted citation impact, Wales has out-performed the rest of the UK as well as many similar-sized countries who spend similar amounts (or indeed much more) on research. In 2016 Wales obtained the highest international collaboration share across all UK constituent countries with nearly 70% of its publications involving co-authors from beyond Wales.

Research and innovation are complementary activities. Our programmes of investment in innovation are making their mark, but we need to do more. The level of funding secured for Wales from InnovateUK has risen significantly from £3.8 million in 2011 to £18.4 million in 2016. The 2018 UK Tech Innovation Index shows that clusters in Wales have significant strengths across a range of sectors including AI, digital, clean growth and advanced manufacturing. Wales was ranked as the top region of the 2017 'strong innovator' grouping in the regional score board and on balance is performing more than 19% above the EU average.

But Wales' small research base is vulnerable. It secures some 75-85% of its total EU funding for research and innovation from structural funds, rather than from Horizon 2020.

Unbalanced

Brexit will bring an end to a significant stream of R&D investment for Wales, with consequences for our country's programme of research and innovation, capacity-building and support. The UK remains the most regionally unbalanced economy in Europe and in a post-Brexit context it is absolutely vital to see a rebalancing. This

need is recognised by both the UK Industrial Strategy and by the Welsh Economic Action Plan.

Britain has many areas that have never fully recovered from de-industrialisation. Many remain trapped by poor infrastructure, low investment and relatively poor skills levels. Productivity has lagged behind London and the South East, creating an imbalance that is increasingly unsustainable.

The Industrial Strategy Commission argues that the future performance of the UK economy will be held back by this high degree of regional imbalance. The regions have untapped potential for Britain, which could enable it to grow into a stronger economy and a fairer society.

'Place'

The Industrial Strategy has rightly made 'place' one of its five foundations for productivity improvement. The Welsh Government's Economic Action Plan, with its commitment to regional growth, complements this approach while respecting the different responsibilities of the two governments.

The Welsh Government has also made clear its aim that in leaving the EU, Wales should not lose a penny of the structural funds currently supporting economic growth in some of our most deprived and most challenged communities. I hope that the UK-wide Shared Prosperity Fund currently being developed will respect the devolution mandate and enable continuity of these funds for Wales over the coming years. The Welsh Government has also been clear that it should maintain control of replacement funding for structural funds so it can maintain and

The regions have untapped potential for Britain, which could enable it to grow into a stronger economy and a fairer society.



R&D funding for Wales through Innovate UK and the Industrial Strategy Challenge Fund includes awards for small firms such as Hexigone Inhibitors (top right) in Swansea.

hopefully surpass the research and innovation performance to date.

Professor Graeme Reid's recent review highlighted the strength of the Welsh research and innovation ecosystem – it includes strikingly successful examples of university/business collaboration and research impact. However, the research base does not currently have the scale necessary to deliver its full potential, so we want to secure more research funding in the future. The Industrial Strategy Challenge Fund offers a crucial opportunity here.

The level of competitive R&D InnovateUK funding secured for Wales has been rising. An award of £50 million over five years will see the creation of a National Compound Semi-Conductor Centre of Expertise and the first Catapult to be headquartered in Wales. The Catapult will focus on helping businesses turn the materials developed at the Centre into new products. With match-funding, this will result in a total investment of £150 million.

Since 2016, the Industrial Strategy Challenge Fund has seen 36 successful projects from Wales, including the Active Building Centre which has been awarded a total of £44 million. The Advanced Therapy Treatment Centre will play a key part in the translation of ground-breaking therapies benefitting many, many patients. The winning consortium includes Cardiff-based Business Tracker which is developing scheduling and tracking software for advanced therapies.

Smaller awards have been made to Hexigone Inhibitors in Swansea to develop an environmentally-responsive self-healing coating, to Picoflu-

idics in Cardiff for surface engineering and coating of polymer templates, and to Metaphor in Cardiff for virtual reality aids for ultrasound-guided needling.

The future

I want Wales to grow its share of UK research funding. In order to do that, we will promote greater awareness of Welsh research and innovation, developing stronger bilateral relationships between governments, academic institutions and organisations with an interest in science, innovation, education and skills.

We are recruiting staff for our Welsh Government Office for Science based only yards from the Department for Business, Energy and Industrial Strategy (BEIS) in London. They will be dedicated to forging stronger links with innovation businesses, with research bodies and with key UK Government contacts.

We are engaging with individual Research Councils, and with UKRI as a whole, on future funding programmes and streams of activity. We have also been working with the UK Government, industry and academia on sector deals. For example, our support for the Nuclear Sector Deal recognises the current importance and potential opportunities for the industry in Wales. The deal will build upon the considerable investment made over many years by the Welsh Government.

Wales is clearly contributing to UK economic performance but we are also very clear in saying that more needs to be done. Partnership working and collaboration is, therefore, even more critical to succeeding in what are very uncertain times. □

We will develop stronger bilateral relationships between governments, academic institutions and organisations with an interest in science, innovation, education and skills.

The power of place

Mark Walport



Sir Mark Walport FRS FMedSci HonFRSE is the Chief Executive of UK Research and Innovation (UKRI), which is responsible for the public funding of research and innovation. He was Government Chief Scientific Adviser (GCSA) and Head of the Government Office for Science from April 2013 to September 2017. He was previously Director of The Wellcome Trust, Professor of Medicine and Head of the Division of Medicine at Imperial College London and a non-executive member of the Office for Strategic Coordination of Health Research.

Place really matters for science and innovation: there are some activities that can only be done in particular locations. A good example is astronomy – optical and radio astronomy need places with a low background of human optical and radio activity.

While such conditions are no longer common in the UK, astronomy has a very important history here. Jodrell Bank in Cheshire, so seminal in the development of radio astronomy, remains the HQ of the Square Kilometre Array, even though the telescopes will be sited in South Africa and Australia. The SKA will generate enormous amounts of data and of course one of the underlying pillars of the Industrial Strategy is data science and artificial intelligence. Not far away from Jodrell Bank, Daresbury is the location of an important partnership between IBM and UKRI on big data.

Other science can only take place where the environment is right. UK strengths in marine and ocean research and innovation are in places like Lowestoft, where the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) is based, Bangor which is very powerful in marine biology, St Andrews, Southampton (NOC) and Plymouth.

For agriculture, animal and plant health, too, proximity to the right environment really matters. Norwich has great strength in plant science and health, while Siemens is working in the important agricultural area of the East Midlands in partnership with the University of Lincoln. The North East has an enormous amount of windpower, so the Offshore Renewable Energy Catapult is located there.

Critical mass matters as well. The Harwell cluster brings together some of the most powerful research and innovation infrastructure in the world. In the North West, Sellafield and the National Nuclear Laboratory have specialist expertise in the fields of nuclear energy and decommissioning. People with skills will tend to cluster where there is converging expertise.

The challenge of course is that there are also areas with low levels of innovation and low diffusion of technology. Look at any sector of the

SUMMARY

- Place really matters for science and innovation
- There are globally excellent clusters distributed the length and breadth of the UK
- Each region and nation has substantial strengths and potential
- Universities have extraordinary potential to enhance economic growth
- The challenge is to bring all the different elements together and maximise the synergies.

economy and the gap between the most productive and least productive companies is larger here than in almost any OECD competitor.

Yet the other side of the story is that there are globally excellent clusters distributed the length and breadth of the UK. Belfast, for example, has world-class strengths in computer science and cyber security, in the creative industries and in digital pathology.

In Dundee, it is the life sciences, in Southampton opto-electronics. Photonics is embedded across the whole of southern Scotland, from Strathclyde to St Andrews. Cardiff has fostered a link between the new BBC Wales HQ, the university and local businesses.

Ingredients for success

There are four key ingredients to these success stories. The first is the universities. Sir Andrew Witty, in his 2013 review of universities and growth, noted that “universities have extraordinary potential to enhance economic growth”. These institutions have a three-fold mission: education, research, as well as local civic and economic engagement. They are absolutely key to the local economy, not only in terms of the research they carry out, but also in the skilled people they turn out. The challenge is to retain those skills and make them places where people can live, work and play.

The second ingredient is business. The effect of Rolls Royce on Derby, that of the automotive, aerospace and defence industries in the south west, of GSK in Stevenage – is very clear. Clusters have formed around companies such as QinetiQ, BT, and also around public sector establishments such as the Met Office in Exeter,

Place really matters for science and innovation: there are some activities that can only be done in particular locations.

DSTL near Salisbury and GCHQ in Cheltenham.

The third is local government and public sector support. Finally, the fourth is the power of leadership – people like Martin Sweeting in satellites, David Payne in optoelectronics in Southampton, Drew Nelson who has been so important in compound semi-conductors in South Wales.

Strength in Places Fund

The Strength in Places Fund, administered by UKRI, recognises that every region and nation has substantial strengths and that ultimately they are best placed to decide how to capitalise on them. The BEIS Science and Innovation Audits, introduced in 2015, prompted different parts of the country to identify their strengths.

The Strength in Places Fund was first announced in the Industrial Strategy White Paper. It took its place alongside core Government programmes such as the Transforming Cities Fund and the local industrial strategies.

The total budget for the Fund in the period up to 2021-22 stands at £235 million. The programme is designed to encourage all parts of the UK to build on their R&D strengths. UKRI is in the final stages of agreeing the shortlist of projects for Wave 1.

The Strength in Places Fund is different from anything that has gone before as it links together regional R&D strength with local economic growth. It forces places to consider how their strengths can drive tangible economic effects in their areas. It is about new and better jobs, increased inward investment and an improved skills base. The Fund aims to make places 'sticky' so there are jobs that will keep skilled people there. It does so by bringing together key economic actors: universities, other research facilities, Public Sector Research Institutes (PSREs), businesses, local government and local leadership.

This all takes place in close alignment with wider local economic plans. Local spill-over benefits from investment in R&D are most acutely felt when they involve a range of local partners. By building on local strengths, evidenced through the science and innovation audits, for example, efforts can be focussed on developing clusters that have real potential to be nationally and globally competitive.

There is, too, the Catapults programme led by Innovate UK. This network is designed to transform our capability for innovation in specific areas and drive future economic growth. They are distributed around the country, from high-value manufacturing in Strathclyde, through satellite communications at Harwell, compound semi-conductors in South Wales, cell



Adrian Pingstone

and gene therapy in Stevenage to offshore renewable energy in the North East.

Direct R&D investment is absolutely critical but other factors – local planning, availability of skills, quality of local transport – have a significant impact on the growth of R&D activity across our country.

So this activity needs to work alongside the Government's £1.7 billion Transforming Cities Fund which is focussed on intercity connectivity. This will enable people to move more quickly and efficiently, within and between large urban centres. It will ensure that modern transport infrastructure is in place to oil the wheels of industrial development, complementing (and then attracting more) R&D investment.

Local industrial strategies

Then there are the local industrial strategies. The first of these are being developed in areas like Greater Manchester and the West Midlands as well as the Oxford/Milton Keynes/Cambridge corridor. They will be important in achieving maximum impact from the new Shared Prosperity Fund which will be a critical factor when the UK leaves the EU and will help to replace structural funding.

The Strength in Places Fund is thus part of a greater whole. The challenge is to bring all of these elements together and maximise the synergies. UKRI has an absolutely critical role in ensuring that place really does matter and that we can build on place throughout the UK. □

Clusters have formed around public sector establishments such as GCHQ in Cheltenham.

Direct R&D investment is absolutely critical but other factors – local planning, availability of skills, quality of local transport – have a significant impact.

Linking policy and place



Katherine Bennett OBE FRAeS, Senior Vice-President of Airbus and a member of the Made Smarter Commission, joined the panel after the formal presentations.

The Industrial Strategy is the right path to follow: previous administrations also focussed on this approach and it is important for industry that this continues. And linking the policy to specific places is also vital.

Many years ago, I heard a politician say: “It is not worth investing in anything outside of the M25.” Now they may have been referring to the importance of the City and the South East, but there clearly is plenty of life outside the M25!

Strategic links

So, it was good to see the Secretary of State and his ministerial team in Bristol on 6 December to launch the Aerospace Sector Deal. Aerospace and defence are important industries in the South West and bring significant local benefits. And strategic links are being made to other nearby regions. Wales is not so far from the South West and I have recently been invited by Professor Peter Halligan, the Chief Scientific Adviser to Wales, to serve on the Welsh Science and Innovation Council.

The fact that the Industrial Strategy Challenge Fund is over-subscribed must be a good thing. This programme attracts additional pri-

vate sector funding from businesses, and with so much interest an expansion of the scheme would further increase business investment.

I am a member of the Aerospace Growth Partnership. Business people meet with Government representatives to discuss what is important for the sector and see how to develop it further.

A role for business

In terms of place, there is a role for business to play. When I served on the Local Enterprise Partnership (LEP) in the South West, I used to say to colleagues in the region, “Use local businesses. Business follows business. When we have foreign business leaders visiting, we field our own local business people to say what a good place this area is to invest in.”

Skills are also an important element in success, especially digital skills. The Made Smarter Commission, in which Government, academia and industry come together to promote the digitalisation of manufacturing, will have a major part to play in this. Indeed, many businesses today find themselves recruiting people that are teaching these new skills to those currently in the company. □

Place is key



Dr Julia Sutcliffe FRAeS, Chief Technologist and Head of Engineering Strategy, Air Sector, at BAE Systems, joined the panel after the formal presentations.

We welcome the Government’s emphasis on place in the Industrial Strategy. BAE Systems is the country’s largest defence, aerospace and security business, employing 34,600 workers in the UK, some 70% of them highly-skilled. A further 95,800 full-time equivalent jobs are sustained through nearly 9,000 companies in the supply chain. With over 50 UK sites, generating economic value in 382 of the 391 local authorities, place is critically important.

Our ability to design, develop, assure and support some of the most complex systems in the world today is dependent on our skills and ability to innovate. As technologies of the fourth industrial revolution look set to bring profound change to all industries, we must seek partnerships across sectors, across businesses and institutions, to develop the skills and innovative products that will secure our future success. Indeed, the Industrial Strategy and the UK MoD’s Future Combat Air Strategy are calls to action.

Place is therefore key because companies exist as part of a local ecosystem consisting of public and private sector organisations, businesses large and small, local authorities, trade associations, charities and learning institutions. When this ecosystem is underpinned with great social services, health provision, schools and infrastructure, we create vibrant regions able to attract and retain skills, capable of delivering ambitious visions for growth and prosperity on an international stage.

Skills partnerships

Examples of skills partnerships across the ecosystem include brilliant initiatives such as the National Apprentice programme, the Engineering Development Trust, the National Science Learning Centres, the Movement to work scheme and the Productivity through People scheme.

Examples of innovation partnerships can be seen through initiatives like Supply Chain 21 aiming to ensure frictionless trade between big business

and SMEs. Our ambition for non-traditional, cross-sector innovation is also signalled by our partnership with Williams F1 Advanced Engineering. Local Enterprise Partnerships (LEPs) are also encouraging clusters of companies around larger scale businesses and academic institutions in enterprise zones, to incubate innovation under programmes such as Made Smarter.

Place is fundamental to this generational oppor-

Place is fundamental to this generational opportunity for social partnership.

tunity for social partnership across sectors, across public and private organisations, across businesses large and small to bring a mix of skills together to embrace new technology and innovate to secure our future prosperity. □

The debate

After the formal presentations, members of the audience raised a number of issues, including: technical skills levels; the role of the supply chain; local benefits; and regulation.

Public engagement is not necessarily a question of getting the public involved in the ‘how’ of research and caution has to be exercised in relation to the ‘wisdom of the crowd’.

Annual spending per head on R&D is £112 in the East of England but only £62 in the North East, so the agenda of place has to be addressed. The experiments a decade ago led to investments in nanotechnology centres in every region, and most of these have failed. Those responsible for public funding have to maximise success.

There must be sufficient provision of technicians. These are hard to source in some sectors. In aerospace and medical research there have been successful initiatives on technician training, bringing together larger and smaller employers. Deepening supply chain relationships can bring other benefits, helping to achieve sufficient specialisation and complexity to compete internationally.

Coherent contribution

Communicating the Industrial Strategy in the regions means focussing on the benefits it can bring, rather than just making people aware of the policy itself. Greater coherence among the many public bodies involved in contributing to implementing the Strategy would be highly desirable.

Defra has published a strategy on waste and food waste raises important challenges. Food and drink is a priority sector in the foundation economy in Wales. A food and drink sector deal is being negotiated for the whole of the UK.

Regulatory burdens, particularly for SMEs, need to be reduced. A regulatory innovation fund has encouraged regulators to become more innovative.

Businesses tend to locate in regions with the best growth prospects and highest productivity. Given the relatively better performance of London and the South East, it is hard to see the economic

case for businesses to move their spending away from this region. Nevertheless, there are areas of strong skills and capability which can attract business if other factors such as good education, health services and culture are also in place. □

FURTHER INFORMATION

The Industrial Strategy: forging our future

www.gov.uk/government/speeches/the-industrial-strategy-forging-our-future

Industrial Strategy: the 5 foundations

www.gov.uk/government/publications/industrial-strategy-the-foundations/industrial-strategy-the-5-foundations

Prosperity for All: economic action plan, Welsh Government

www.gov.wales/topics/businessandconomy/economic-action-plan/?lang=en

Reid Review: Government-funded research and innovation in Wales

<https://gov.wales/newsroom/science-and-technology/2018/180606-plans-to-grow-welsh-research-published-in-reid-review/?lang=en>

Encouraging a British Invention Revolution: Sir Andrew Witty's Review of Universities and Growth

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/249720/bis-13-1241-encouraging-a-british-invention-revolution-andrew-witty-review-R1.pdf

Future Combat Air Strategy

www.gov.uk/government/publications/combatair-strategy-an-ambitious-vision-for-the-future

Made Smarter Commission

www.gov.uk/government/news/leading-business-leaders-and-academics-join-forces-with-government-to-make-manufacturing-smarter

Supply Chains for the 21st Century (SC21) www.sc21.org.uk

MEASURING ECONOMIC GROWTH

Gross Domestic Product – or GDP – is the mostly commonly used measure of economic performance. Yet critics argue it is not fit for this purpose. A meeting of the Foundation was held at the Royal Society on 23 May 2018 to consider how good a measure it really is and what improvements – if any – could be made to it.

Improving measures of economic performance

Jonathan Haskel



Jonathan Haskel CBE is Professor of Economics at Imperial College Business School, London, and Director of the Doctoral Programme at the School. Since September 2015, he has been a member of the Financial Conduct Authority Competition Decisions Committee and the Payment System Regulator Enforcement and Competition Decisions Committee. Since February 2016, he has been a non-Executive Director of the UK Statistics Authority. In October 2017 he was the joint winner of the first Indigo Prize, for re-engineering GDP. In September 2018, he became an external member of the Bank of England's Monetary Policy Committee (MPC).

As an economist, my view is that we should not jettison GDP completely: we should keep the desirable features and improve it.

Although GDP would seem to be an arcane subject, there is currently a great deal of public interest in it. There is some doubt about its usefulness, though. David Pilling, a very senior journalist on the *Financial Times*, has recently published a book entitled *The Growth Delusion*. In the early pages, he states: “We live in a society in which a priesthood of technically-trained economists, wielding impenetrable mathematical formulas, sets the framework for public debate.” He goes on: “The invention of GDP has given rise to a class of technocrats and economists who implement policy for the good of the economy, but not always for the good of the rest of us.”

As an economist I feel I should reply to this. My view is that we should not jettison GDP completely: we should keep the desirable features and improve it. I want to set out two principles that I believe are essential.

Since GDP is about counting the economy, let us start with an example of a small economy – the Amazon warehouse in Dunfermline, Scotland. Now of course the economy as a whole consists of billions and billions of goods and the Amazon warehouse fewer, but it is a good start.

Suppose, for the sake of discussion, there were 100 iPads, 100 biros, 100 packs of photocopying paper in the Amazon warehouse. How would we count all of that together? How, somehow or other, could we add together iPads and biros and packs of photocopy paper? Adding together different types of goods is actually a common challenge. The Human Development Index solves this problem by taking three perfectly good indicators of economic development across different countries – life expectancy, education and GDP per capita – then simply multiplies them and takes the cube root. That is one method of combining disparate items together, essentially giving each the same weight. I am uncomfortable with such a simplistic approach.

It seems to me then that Principle No 1 should

SUMMARY

- There is currently a great deal of interest in GDP as a measure of economic activity.
- We should keep the desirable features of the current measure and improve it.
- When different indicators are aggregated there should be some meaningful weights included in the process.
- Any effective system must avoid the problem of double-counting.
- People could choose their own measures of wellbeing.

mandate the use of some meaningful weights – I cannot see that just arbitrarily adding things together is going to get very far.

The issue of double-counting

Let us go back to the mini-economy of the Amazon warehouse. According to Google Maps, three miles away is the Bay Printing Company – a local printer with local prices – who will do photocopying for you. Let us count up this economy. Why not add the biros, paper and the iPads from Amazon and add them with the photocopies from Bay Printing. How difficult can that be?

Well, there could be a significant problem if the printers were to buy their paper and biros from Amazon. We would not want to count the paper and the biros in one place and then count them again in another. In economics, this is the problem of ‘intermediate goods’. If we ‘double count’, we will not be creating a very good index.

However, there are some indices that do not worry about this problem; my favourite (or should I say my least favourite) is the EU Innovation Scoreboard which adds together a range of general indicators of innovation. One of these is R&D, another is high-tech equipment exports.

The scoreboard adds all 17 indicators together and just takes 1/17 of the total as the final result.

There is a significant difficulty here as, presumably, some of the R&D will go into high-tech equipment exports and so be counted twice. So my Principle No 2 is: 'Do not double count'.

Improving the measurement of GDP

This then is the strength of GDP. There are meaningful weights that can be used in a modern economy, that allows you to add iPads and pieces of paper. Those weights are called prices. And that is what GDP uses. So the reason why the Office of National Statistics (ONS) can add up all the different goods in the economy, is that they can be weighted by price.

Therein lies an important point: economists are interested in prices because they give an incredible amount of information about people's valuations in the economy and the relative importance of different items.

However, in order to ensure that GDP is an effective measure and to avoid double-counting, the intermediate goods need to be taken out. It is not good enough just to add together the Bay Printing and Amazon goods: it is necessary to subtract the paper that the printing shop is using.

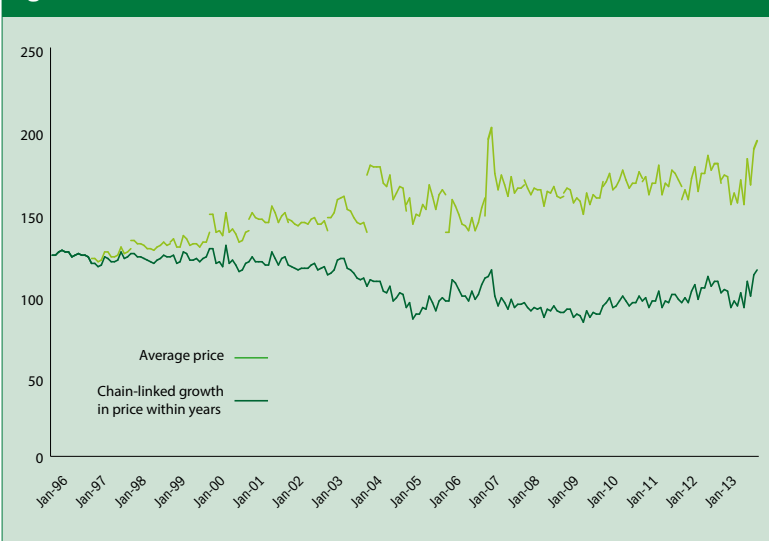
Yet that leads to at least a couple of issues. What is an 'intermediate good'? Here, it is necessary to know what it will be subtracted from. Dyson, for example, carried out a great deal of R&D in order to get further on than a Hoover. How that R&D is to be treated can be quite difficult. It could be treated like the photocopy paper at the photo shop, in other words it is all used up in a year. Alternatively, it might be decided that the R&D and other types of knowledge give an enduring benefit to Dyson. That is the first difficult choice.

The second – again a key question in economics – concerns whether prices give the right signals. There are lots of situations where there are no prices (this is known as the 'production/non-production boundary'). Think of it this way – if you do your own vacuum-cleaning that is 'non-production', you are just doing it at home. If you pay somebody to do the vacuum-cleaning, then suddenly that is 'production'. If the situation is fluid and things go back and forth across the production border, economists have to figure out what the right signals are.

Airbnb is an example where you are using your house to sleep in and suddenly a technology comes along that allows the house to be used to gain rent.

Now there are many free goods around – Google Maps, Skype phone calls, Facebook and so forth – these are examples where there are no

Figure 1. Prices of vacuum cleaners 1996-2013.



prices at all. How should they be accounted for? So that is the second question.

A third issue concerns quality-adjusted prices. Economists spend lots of time worrying about vacuum cleaners. Figure 1 shows a time-series of the price of vacuum cleaners between January 1996 and January 2013. It jumps around and, in particular, there is a big jump in January 2004.

ONS price collectors gather the prices of vacuum cleaners. That is fine if the vacuum cleaner basket consists of just Hoovers but when Dyson comes along it then has to start collecting the prices of the new goods. If the composition of the basket changes that can result in a very large increase in the price.

The question is whether that large increase in the price is really inflation, or just the fact that there are better quality (and more expensive) vacuum cleaners in the basket. There are various procedures called 'quality change' where this is not treated as a rise in inflation but as a change in quality. This is, of course, difficult to do, especially in an era with lots of goods changing their quality all the time.

The dashboard approach

The ONS publishes a wellbeing dashboard. People can log-on and view a range of different indicators such as life satisfaction, people's feeling about whether their lives are worthwhile, their happiness and so on. So, maybe one way of solving the issue of appropriate weightings is, essentially, to privatise it: each individual decides how much store they place on these different indicators. □

Dyson, for example, carried out a great deal of R&D in order to get further on than a Hoover. How that R&D is to be treated can be quite difficult.

The question is whether a large increase in the price is really inflation, or just the fact that there are better quality (and more expensive) vacuum cleaners in the basket.

Let's be clear about what we are measuring

John Pullinger



John Pullinger CB is the National Statistician, Head of the Government Statistical Service (GSS) and Chief Executive of the UK Statistics Authority. He has also been President of the Royal Statistical Society and Chair of the United Nations Statistical Commission (UNSC). He joined the Central Statistical Office in 1992 and was the project manager for the creation of the Office for National Statistics. He was appointed a Companion of the Order of the Bath for services to Parliament and the Community in 2014. He has also served as Librarian to Parliament.

When talking about measures of economic growth, what is it that we are trying to capture? 'Growth' seems a little one-dimensional; the idea of prosperity feels a little bit richer. To understand how well GDP performs as a measure, it is necessary to think about the collective set of questions it is designed to summarise. What, essentially, does it describe?

Is it Britain's place in the world, how competitive we are and how well we compare with other countries? Does it indicate risks and opportunities for Britain? Does it provide clues on how to improve innovation and enterprise and drive the country forward in a way that makes everyone prosperous?

Is prosperity achievable for everyone or just a few – are certain groups in the country being left behind while others are surging ahead (how prosperity is understood and perceived may vary across different parts of the country too)?

Finally, how sustainable is this prosperity? And is it sustainable over an individual lifespan or should the timeframe include inter-generational issues? The former might focus on how we fare as we move into old age and become less capable or on how disabled people might fare through their lives and whether they have access to employment, or not.

At the macro-level of the economy, sustainability will have to consider potential depletion of our resources: are we behaving in such a way that prosperity could be compromised in the future?

For me, the test of whether GDP is a good measure is how well it fares against those kinds of questions.

The advantages of GDP

For a long period of time GDP has fared very well: anything that can be captured through the medium of price is there. It is an expression of everything people earn, spend or produce. It links the domestic economy of the UK with international activity and allows a comparison with other countries. It provides a view over long periods of time about how well the UK is doing. It can furnish a breakdown by different industries, different income groups – indeed, a whole range of criteria. It serves those purposes very well.

SUMMARY

- We need to identify what exactly GDP is measuring
- GDP is an expression of everything people earn, spend or produce
- The indicator allows a comparison with our international competitors
- Some sectors, such as intellectual property and intangible assets are not fully captured
- A series of 'satellite accounts' could supplement and augment the information that GDP currently gives.

But GDP has always had its detractors. In the 1970s, it was the Club of Rome and the oil shock that brought the idea of environmental degradation into the picture – GDP does not capture that very well.

In the 1980s there was monetarism – the rise of the financial sector and the Big Bang. Did GDP really capture what was happening to the economy? Through the 90s, did it really help to understand who was getting left behind in the rise of inequality and social exclusion? Did it capture the rise of digital technology and phenomena like the 'dotcom' bubble? Then, since the Crash, what has really been going on?

These kinds of questions have always been there. Yet GDP will not be able to answer all of them because, frankly, many of them are not purely economic. They are concerned with the way we live our lives which should not be boiled down to something which is a quantity and has a price. We do still need to understand these factors, though.

Making GDP a better measure

How can GDP be made more fit-for-purpose? What could complement it and capture those broader social, environmental and other questions?

Some say that GDP is good at measuring things that were important 20 or 30 years ago. The last revision of the system of National Accounts dates from 2008 and itself took several years. At the most straightforward level, it is vital

to keep up with what is happening in the segments of the economy we think we understand – the retail sector, for example. Data from this sector has been collected since well before Amazon warehouses came into existence, but it is important to track what is happening in those warehouses: what is being produced and how the products are being consumed. There is also the question of how to measure the value of production. And that is just retail.

In almost every sector, innovation is challenging boundaries, changing the way value is created and adding to the prosperity of the country.

Statisticians have to keep ahead of that curve, thinking about what is on (or just over) the horizon and about the measurements and the sources of data necessary to understand this all.

Some sectors are not accurately recorded: intellectual property and intangible assets, for example, were not included in the last System of National Accounts of R&D. Look at the balance sheets of most of the significantly growing countries and it is clear they are dominated by items that were not significant when assets were purely physical.

It is vital to understand how knowledge creates value – how patents are created, how R&D really manifests itself – and how that can be captured in the GDP framework.

Allied to this is the emergence of the digital economy. It has changed all our lives but much of the activity is not really economic, more a ‘disintermediating’ of services. The value of all this is quite hard to capture in a mechanism designed just to look at quantities and prices.

And while this all applies to activities within the market sector, a significant part of our economy lies in the public sector. Here we have goods, but they are not priced goods – although the NHS, for example, clearly costs money. How can the productivity of the NHS, the justice system, education (indeed, any aspect of the public sector) be incorporated into GDP?

Improving GDP

To make GDP useful as an indicator of economic growth it must be improved. Let us be clear, though, it cannot do everything. Among the areas that lie outside the traditional production boundaries is the environment. For 20 or 30 years now, there have been sustained efforts to understand the idea of ‘natural capital’: the stocks, but also the flows into and out of the environmental system and how these interact with the economy.

This could be published as a ‘satellite account’. So, alongside the national accounts which describe what is happening to the economy as measured by GDP, this would show what is happening to the

environment. Indeed, a series of satellites like that could highlight different activities and relate them to the national accounts and GDP.

A household account would be another example, helping to understand questions such as how human capital is interacting both with the market and non-market economies. For nearly a century, the household sector grew larger as people bought more from the market rather than making it themselves, whether childcare, transport or cooking. However, this trend has now gone into reverse, partly because of the digital revolution, and the latest estimate puts the household sector at 56% added on to GDP, up from 52% some 15 years ago.

Another concept which is in need of review is welfare. Economists refer to this as ‘consumer surplus’, the extra value we gain over the price we pay. Free goods are a case in point, but there are many others like Facebook and Skype, even the feeling of being safe on the streets. These are things that we value although we cannot necessarily put any price on them. Equally, the consumer surplus or welfare that different people gain from those types of goods will vary according to the person or the community and their individual or communal perceptions.

The idea of wellbeing is linked to this. ONS has six years of data on this topic. These show generally a rising trend over most of the population but issues like anxiety are highlighted.

Increasing investment is being focussed on the question of inequality. How are health and disability experienced by different parts of a community? We need to think about the way our very diverse nation – different racial groups, different regions – experience these issues. We need to find something that is meaningful for them because it is undoubtedly the case that some people do not see their own lives reflected in the macro-GDP measures that we publish.

Most ambitiously of all, ONS is developing complementary measures that mirror the Sustainable Development Goals agreed by the United Nations three years ago. This international vision set out 17 goals, 169 targets and 232 indicators. The aim is to ensure that by 2030, across the world, no-one is left behind and we are seeking to track these indicators in the UK too.

So let us keep GDP, but also invest in complementary measures. As we do so, I believe we should keep three criteria in mind:

- we should work collaboratively with colleagues around the world. The UK cannot do this on its own;
- we should look ahead. Let’s measure today’s economy and society (and

How can the productivity of the NHS, the justice system, education (indeed, any aspect of the public sector) be incorporated into GDP?

To make GDP useful as an indicator of economic growth it must be improved. Let us be clear, though, it cannot do everything.

- tomorrow's), not yesterday's;
- we must think about the way our measures resonate with different people and communities across the country. The Brexit vote raised the question of whether our current measurements really reflect how people across the country perceive prosperity.

When thinking about future investments to be made in intangible assets, consideration should be given to our statistical system which is an intangible asset of national importance and will provide a rich return through valuable data upon which to base better decisions for the country in the years ahead. □

A useful indicator of overall prosperity

Tera Allas



Tera Allas CBE is a Senior Fellow and Director of Research at the McKinsey Center for Government, McKinsey's global hub for research, collaboration and innovation in government performance. She works closely with McKinsey Global Institute, McKinsey's economics and business research arm. She has expertise in economics, productivity, innovation and public policy, and is a member of the UK Productivity Leadership Group, the Council of the National Institute of Social and Economic Research, and the Scale-Up Institute Evidence Committee.

GDP, despite all of its problems, is a useful – and fairly accurate – indicator of overall economic prosperity and growth. However, it will not do everything: we need to consider carefully how we use it, how to complement it and how to modernise it for today's economy.

There are many things that GDP does not capture that are good and, due to the measuring process, it also includes some things that are undesirable such as wars or accidents (see Table 1). When examining GDP metrics, it is important to understand what is going on underneath and see to what degree it is the good things that are pushing it up rather than the bad ones.

More fundamentally, though, is economic growth really the only thing people care about? Obviously not: health and employment are actually at the top of the league table when it comes to what really matters to people's wellbeing. However, GDP does correlate with employment; and across a number of different countries and over time, GDP also correlates very well with health outcomes. So it is a reasonable proxy for wellbeing – not perfect, but not that bad, either.

When it comes to economic value, the problem is that GDP does not capture consumer surplus. This is the amount of money someone is willing to pay for something, less the amount actually paid for it. So, for example, I might be willing to pay something like £500 a year for Google Maps. That is the value that I get at the moment, but it is not being recorded in GDP because it is free of charge. This frequently arises with free online services. In the USA, free internet services are estimated to add about \$100 billion of value in consumer surplus each year, but this is not captured in GDP in any way.

Consumer surplus is equally important in some basic products such as UK natural gas – far removed

SUMMARY

- GDP is a useful indicator of economic prosperity
- It does not take adequate account of some important factors such as consumer surplus
- GDP is an aggregate figure, so hides a lot of important detail
- Increasing data flows and new technologies such as AI need to be factored in going forward
- GDP is one of a range of useful metrics. It should be retained, improved and complemented with other metrics.

from digital but nevertheless an important market. On a typical winter's day, there are a number of owners and producers willing to sell gas at different prices depending on their costs or opportunity costs. Then there is another group of people demanding gas and willing to pay a lot for it. One group – the operators of gas-fired power stations – may be prepared to pay more than 7,000 pence per therm to keep the lights on. Another is willing to pay to avoid a supply interruption because businesses really do not want to be without hot water and heat. But then there are others who are price-sensitive and can switch to coal or oil, so if the price of gas goes above a certain level they are going to say 'no thank you'. Putting all those together, economists can figure out what the market clearing price for gas on a given day is. On the day in question, it turned out to be about 65 pence per therm.

Yet some people were willing to pay in the order of 7,000 pence per therm and that consumer surplus has not been captured in GDP. In fact, the figure for the total economic welfare, adding together consumer and producer surplus, was around £6 billion, more than 100 times the GDP number. The

Table 1. Improvements in measured GDP are not always 'good'

Good things missing from GDP • consumer surplus • free goods (e.g. internet, recycling) • unpaid and volunteer work • leisure time • value of family, friends and community • health, wellbeing and happiness	Bad things that can increase GDP • unsustainable use of resources • unsustainable debt-fuelled consumption • war, disasters, crime, accidents, illness
Bad things not included in GDP • pollution, noise, congestion • visual and landscape impairment • inequality	Good things that can reduce GDP • lower prices (if not adjusted accurately by deflators) • value of self-service (convenience, control)

When examining GDP metrics, it is important to understand what is going on underneath and see to what degree it is the good things that are pushing it up rather than the bad ones.

real problem, though, comes if we forget about the known issues with GDP and use it for the wrong reasons and come to the wrong conclusions.

This can happen when media, and sometimes policy-makers, take the numbers out of context. In 2014, there were reports that growth in 2013 had been very high and that this was a turning point for the UK economy. In fact, a look at the longer term trends in GDP shows that, in the scheme of things, 2013 was not that special. There is danger in looking at the latest numbers and assuming that they always have trend-defining information embedded in them.

More generally, GDP is an aggregate figure: it represents the total of everything produced in the economy, summed up in monetary terms. This total, or any measures (such as GDP per capita) derived from it, hides important detail. For example, while the UK's GDP per capita is a respectable £30,000 (ahead of, for example, France), there are wide disparities between different regions: the GDP per head of Camden & the City of London is 22 times that of the Isle of Anglesey. In fact, as with any metric, it is necessary to know the purpose it is being put to and the way it is constructed in order to really understand what is going on.

Modernising GDP

How can GDP be modernised for today's world and what complementary metrics can be brought to bear?

To take one area ripe for review, in the current accounting regime, 44% of the Standard Industrial Classification (SIC) codes are dedicated to manufacturing; yet only 14% of the non-financial market economy in the UK is in this sector.

Rather than just fixing today's problems, though, we need to be mindful of future developments, too. There is a widespread notion that 'data is the new oil'. Data are inputs into production in the same way as labour and capital. Somehow, this will need to be captured. This is not an

insignificant issue. Studies by the McKinsey Global Institute have concluded that the flows of data across borders actually have a bigger impact on GDP than the flows of goods. The question then is how to capture this reality, how to accurately measure output and how ultimately to measure economic prosperity.

Another common quote, from the artificial intelligence guru Andrew Ng, is that 'AI is the new electricity'. In other words, this could be a new general purpose technology, or it could at least provide a suite of advanced analytic techniques that pervades all sectors and aspects of modern life.

It will certainly make the consumer surplus problem much bigger because the quality of services and products will become better and more tailored. That in turn will make these harder to quantify in GDP terms. Costs, and hence prices, for comparable products and services are likely to go down (perhaps dramatically) which could mean a drop in GDP unless appropriate adjustments for quality and value are made.

So there are plenty of reasons why the way GDP is measured may over- or under-estimate economic value, output and growth. These issues are understood, though, so there is every reason to continue to use it. Yet it must be complemented with other metrics with take account of welfare, wellbeing, happiness, equality and so on. The aim should be to measure broader economic value and not just what is exchanged in the market place.

A car driver does not solely focus on the speedometer. There are other metrics in play as well: the amount of fuel left in the tank, the temperature of the engine (at least that it is not overheating), and so on. GDP is just one metric. It will not be 'fixed' by trying to cram into it every other metric. In the same way that no-one wants a car to have a single summary indicator, a single mega-index for economic growth would not actually be very helpful. So let's not throw out GDP, but improve and complement it instead. □

Studies show that the flows of data across borders actually have a bigger impact on GDP than the flows of goods. The question is how to capture this reality.

A reliable economic measure



Clare Lombardelli, the Chief Economic Adviser to the Treasury and joint head of the Government Economic Service, joined the panel after the formal presentations.

The debate on how to measure economic growth is not new and inevitably turns to GDP – the broadest measure of our economic health. It is used by almost every country. It faces two broad criticisms: does it measure the right thing and are we measuring that thing correctly?

From a policy perspective, the priority is to have a reliable measure of the economy. No single statistic can do that but, given the scale of the challenge, GDP does a pretty impressive job in aggregating the economy, cross-referencing output, expenditure and income.

Of course, it is not perfect. I recall that early estimates for the period at the end of 2011 and the beginning of 2012 indicated the UK was in recession. That raised some challenges for Ministers from those who doubted their economic strategy. The revised data three years later tells us that the UK was not in recession at the time. Time gives us a more accurate guide but I suspect provides little consolation to those who have been criticised in the moment for talking about ‘green shoots’.

So it is crucial to take the long view. Many economists, commentators and journalists rush

to interpret the quarterly GDP estimates as they are published. Yet these are not conclusive judgments on the current state of the economy and the data can be skewed by one-off events – the weather, bank holidays, royal weddings.

In interpreting GDP it is vital to understand what it tells us – and more importantly what it does not. Some argue for the inclusion of wider considerations. In trying to understand the economy, GDP is one useful bit of data but a whole range of other data also tell us useful things – such as tax receipts, production, manufacturing and consumption. In addition, it is right to be concerned about inequality, about social impact, about environmental impact. Keeping the measure up to date is a continuing process and the ONS are implementing important reforms to do this.

In terms of changing what it measures, we should tread carefully to avoid introducing value judgements. For example, there is no way to include distributional data without imposing judgements which would be implicit in the way the data is constructed. Ultimately, the priority for GDP is to ensure a relatively straightforward measure which is easy to understand and interpret. □

The strange history of GDP



Professor John Kay CBE FRSE FBA, one of Britain's leading economists, also joined the panel.

The first national accounts in Britain – indeed the first detailed national accounts prepared anywhere in the world – were constructed in the Second World War by a Treasury team led by James Meade and Richard Stone. James Meade once told me about the compilation of these accounts. He said they had got a long way through aggregating various sectors of the economy when they noticed they had forgotten hairdressing. “I said to Dick Stone, ‘How often do you get your hair cut and how much do you pay for it?’ He rang his wife and asked her the same question. These amounts were aggregated up to produce the first estimates of the national output of hairdressing!”

So, GDP is not the result of a conspiracy to mislead us into giving economic weight to factors that do not deserve it, while at the same time subverting democracy and social justice! It is a construct, created by able men trying their best to defeat Hitler.

Mead and Stone were under the tutelage of J M Keynes, trying to understand the circular flow

of income in the UK economy: that is why there was income, expenditure and output. This enabled them to understand the disposition of resources so their use could be directed towards winning the war. That also explains some of its odder features such as why the measure is Gross Domestic Product rather than Net. In 1941, there was not much concern about depreciation: the focus was to have the largest output to direct at the enemy!

Physicists use concepts like mass and velocity which are well-understood and uncontested. Economic and social science concepts are generally not like that: there is an element of subjectivity and arbitrariness in measurements that has given rise to many problems. Nobel laureate Paul Romer has recently discussed these under the heading of ‘mathiness’, where people use symbols and models without being clear to which empirical phenomena these refer.

GDP has been a measure of aggregate output since Meade and Stone. We need to stick with it

Ministry of Information Photo Division Photographer [Public domain]



In 1941, there was not much concern about depreciation: the focus was to have the largest output to direct at the enemy!

for that reason alone. That it is not a measure for a lot of other things is not an effective criticism. In fact, most criticism of GDP comes not from people who are willing to engage in a technical analysis, but from people with a political or ideological agenda (hidden or apparent).

GDP is a good measure of what it was intended to measure. There is every reason to produce other policy indicators, but GDP should remain part of the system of national accounts, explaining the flow of resources, output, income and expenditure in the British economy. □

Is the rate of change of GDP the best way to measure economic growth?

Looking back, GDP developed separately from the concept of 'national income accounting'; they then were brought together. Now, if the price of the imports that a country buys goes up, real GDP is completely unchanged while real income has certainly fallen. So the concept of 'income' diverges from the concept of GDP.

Many of the things that people want GDP to be – an indicator of welfare, an economic indicator of wellbeing (which is quite distinct from a general indicator of wellbeing) – are better done through measures of national income which the ONS produces already.

A particularly important issue is the 'gross' in Gross Domestic Product. This means 'gross of depreciation'. However, it would be better to think of welfare-related items on a net basis: that would provide a ready-made framework for incorporating the use of factors such as natural resources. The extent to which these are depreciated, exploited or used up would be taken into

account in the same way as economic depreciation of capital.

Even then there is the rather important matter of distribution. Who gets the national income? Personally, I would like to take the rate of growth of each household's real income and average these growth rates. This would treat each household equally. It matters for welfare purposes whether increases in income accrue mainly at the top of the distribution or whether they are spread evenly. GDP does not discriminate.

There are questions about how exactly best to implement this averaging idea. But in terms of creating an indicator of changes in welfare, making this the first focus is easier, simpler, and more explicable than devoting attention to measuring consumer surplus.

So, in parallel with the updating of GDP, I would like to see attention focussed on welfare-related indicators that treat each household on an equal basis. □



Professor Martin Weale CBE, Professor of Economics at King's Business School, King's College London, also joined the panel.

The debate

After the formal presentations, members of the audience raised a number of issues, including: productivity, Industrial Strategy, Brexit, price and quality.

Is the assumption that GDP should always go up flawed? It can lead to the rejection of policies which result in short term reductions, but which offer longer-term gains. This could be an argument for not using GDP as a policy driver.

GDP does not reflect the impact of increased productivity (in the digital communications sector this has led to sharp drops in prices) but this is more related to employment rather than purely the measurement of economic growth.

Additional measures

Do GDP figures throw any light on the success of Government Industrial Strategy or the effects of Brexit? The expenditure elements in GDP are useful in indicating future consumption, while income measures do give an idea of distribution. However, separate additional measures need to be developed. The national statistical offices in many countries (notably the UK, USA and New Zealand) are active in this area, but there needs to be a continuing political drive.

Brexit may make GDP more important as the UK will need an internationally recognised measure to at least indicate direction of economic movement. GDP does not take into account where companies and assets are owned, but another indicator (GNP or Gross National Product) does.

Looking at the broader international context, could (or should) GDP take into account externalities such as changes in national or international politics? This might dilute the focus – and



A price-based metric of the national economy has both strengths and weaknesses

usefulness of GDP though. It may be better to aim to achieve international agreement on additional dashboard metrics to cover a range of other factors. But what additional metrics would be useful? Or is it more important to improve the accuracy of existing units (particularly measures of price and quality)?

The strength of a price-based metric is that it avoids difficult concepts like poetry and beauty while its weakness is that it does avoid precisely those difficult things! □

FURTHER INFORMATION

Solving the Productivity Puzzle: The Role of Demand and the Promise of Digitisation. McKinsey Global Institute report

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R&D SPENDING TARGETS

The Government has set a target of spending 2.4% of GDP on R&D by 2027. But is the target achievable and, if so, how should this be done? The questions were debated at a meeting of the Foundation on 17 October 2018.

Delivering the Government's R&D spending target

Patrick Vallance

SUMMARY

- A 2.4% target for R&D spend is reasonable and achievable
- Several other countries including Germany and the USA are already close to 3% or above
- Most competitor countries have a higher percentage of business investment in R&D than the UK
- Companies thinking of investing in R&D in a country value access to science talent more than anything else
- Service sector R&D is not sufficiently accounted for in the UK.

The Government has set a target of spending 2.4% of GDP on R&D by 2027, with an ambition to get to 3%. The fundamental question must be whether that is the appropriate level of funding? Sir Paul Nurse, in his review of research funding, outlines the dilemma. If the boundary is set too high, he argues, there is a danger that resources will be wasted and the quality will be too low. On the other hand, if the boundary is set too low, then the research endeavour becomes inefficient or dysfunctional.

From a national perspective, there are few data to provide a guide as to the right number. There are some indications that the higher the spend, the higher the economic growth. There are also some weak indications that there may be a plateau somewhere between 2.3% and 2.6%. So the data are not clear.

UK funding is currently 1.7%, which is lower than a number of other countries: it is considerably lower than Korea, Israel, Switzerland, Sweden and Japan, for example. In fact, the UK is not even in the middle of the pack and so an ambition to reach 2.4% – which is actually the OECD average – seems a very reasonable start.

What the UK achieves for current spend is impressive. Using publications as a surrogate for

research output in terms of impact, the country has 1% of the world's population, 3% of the funding but gains 12% of citations (and 16% of the world's most highly-cited articles). So, the UK is pretty good at research and the science base is world-class. There is no doubt about that.

Innovation efficiency

Ask a slightly different question – 'how do we do in terms of our ability to turn this into products' – and a slightly different picture emerges. The Global Innovation Index suggests that the UK falls into the 'high innovator' category. Yet it has slipped from being second overall in 2014 to fifth in 2017. There is a mismatch between how we perform in research and how we do in innovation.

In terms of innovation efficiency (the ratio of innovation outputs to inputs) we come down to 21st out of 126. We are not as good at turning research into innovation outputs and economic benefit as we probably should be.

About 50% of what we spend as a country on R&D comes from business, with the rest from Government and the Research Councils, the EU (which is Government-funded spend), Universities, as well as charity and not-for-profit spend (Figure 1). 50% from business is low – in other countries such as Korea and Israel, it can be up to about 80% of the total spend.

In reflecting upon ways to build up to 2.4% there is, first of all, a question about our national labs and public sector research establishments. In other countries these are more prominent and can be important vehicles for translating blue skies research into something more attractive and tractable for industry.

Just as important is the question of whether it is possible to achieve the higher level of 2.4%? Starting from 1.7%, an increase of 0.7% is needed over 10 years. At least 10 countries have achieved this sort of increase, but a very substantial part of the funding in those cases came from business.

It is worth noting that spending in Germany is now above 3% and the USA is close to 3%, so an



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R&D SPENDING TARGETS

About 50% of what we spend as a country on R&D comes from business. In other countries such as Korea and Israel, it can be up to about 80% of the total spend.

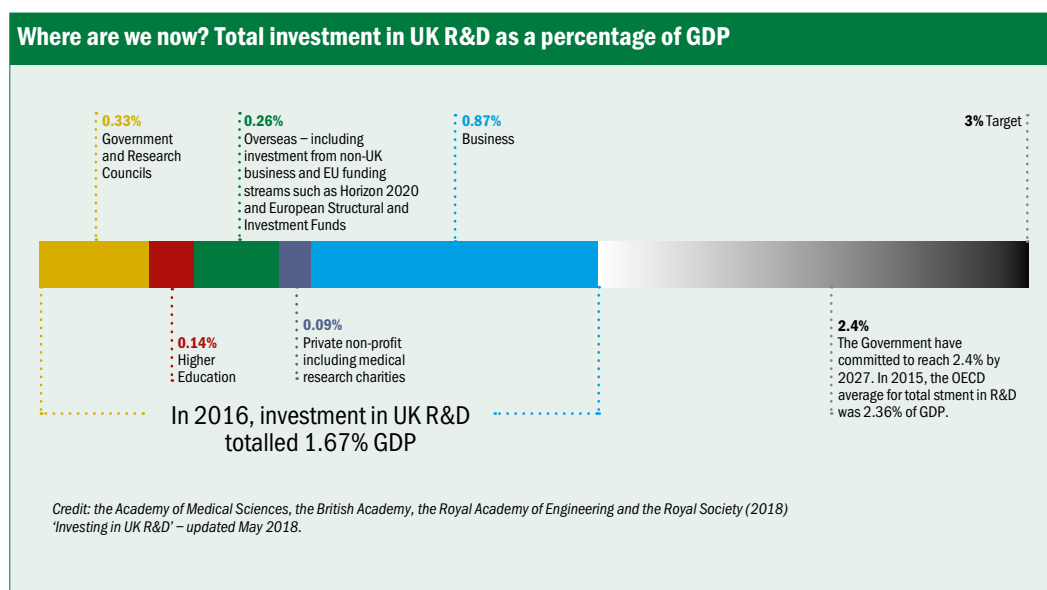


Figure 1. Current R&D spending

ambition to get to 3% is reasonable and possible, but the evidence suggests this will rely on attracting greater R&D investment from business. That, in turn, raises the question of the UK's relative underperformance in innovation compared with fundamental research.

Business investment priorities

What drives business decisions to locate R&D activities in any particular country? EU figures indicate that top of the list is 'access to specialised R&D knowledge and results' and second is 'high availability of researchers' (Figure 2). The most important thing that companies care about is talent and a high supply of well-trained people who understand how to work in a research environment and have the ability to access research information from universities.

If the UK is to reach 2.4%, we must have the right talent. When you look at the make-up of the talent in UK universities, it is a highly international mix. So international talent in our universities and in our research base is a clear requirement from businesses.

What other things matter? There is good data that certain aspects of tax and financial incentives make a difference, too, including direct grants, loans and subsidies to companies – particularly to smaller and growth companies. There is no doubt that certain types of R&D tax credits can make a difference. There is not much data in support of most other fiscal interventions.

There is evidence that an ecosystem with small companies in a cluster produces a magnifying effect, although the exact mechanisms are not completely clear. Several different components need to be right and there is good evidence that the regulatory environment is important in terms of attracting companies.

And then there is procurement. You have got to be able to get into the market in the first place and there have to be agreed methods of trading. This is highly relevant to areas like defence and security, but also to health.

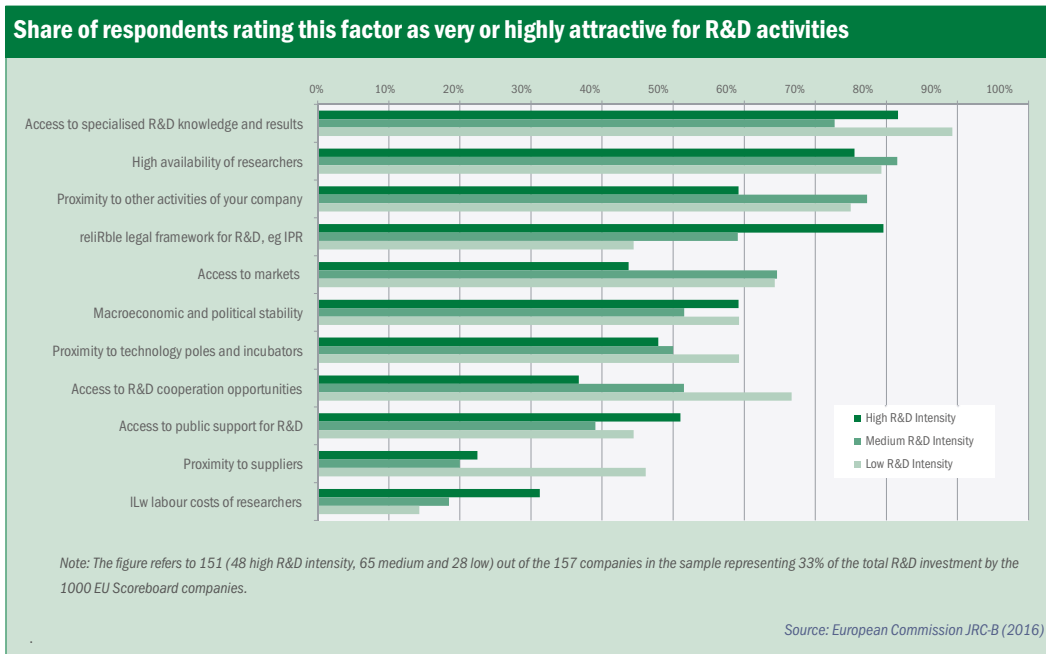
The UK has a relatively high percentage of foreign-owned businesses doing R&D in the UK at 51%, compared to some other countries like Japan (just 6%), the USA (16%) as well as France and Germany (20-22%). We also have a high proportion of business R&D funded from abroad. It is therefore very clear that there needs to be a concerted effort internationally to continue to attract R&D business investment into the UK.

The service sector

The R&D base is normally thought of in terms of its relevance to manufacturing, engineering, pharmaceuticals, high tech, etc. That is correct, yet in reality the UK economy is highly focussed on the service sector (Figure 3).

Two points spring to mind. The first is that we do not capture the R&D activities of the service sector well enough in the statistics – perhaps there is a flaw in the way we assemble some of the figures? The second point is that to achieve a target of 2.4%, we need to identify the R&D needs in this area and determine how they can be met through the encouragement of inward investment.

There needs to be a concerted effort internationally to continue to attract R&D business investment into the UK.



The UK economy is somewhat more reliant on the services sector than any other G7 country. While our reliance is similar to that of France and the USA, we differ from Germany where a lower proportion (69%) of GDP came from the service sector in 2014.

Figure 2. Reasons to locate R&D activities in a country

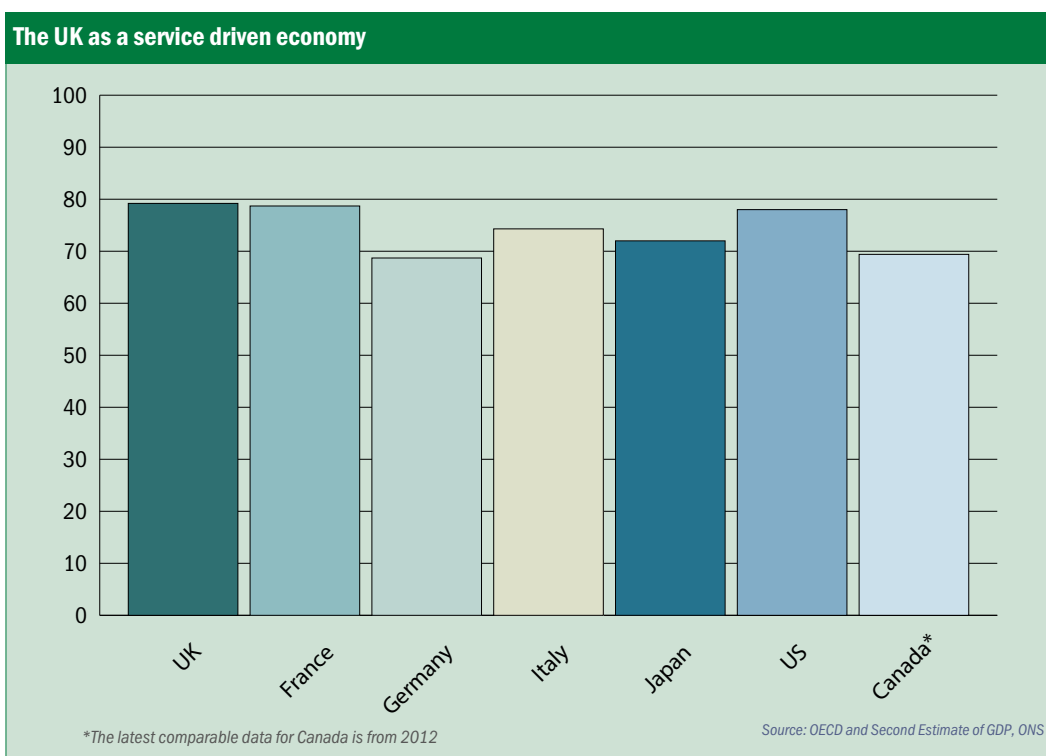


Figure 3. Percentage of national GDP that comes from services sectors, G7 countries, 2014

Conclusions

A target of 2.4% seems perfectly reasonable, while 3% would bring us in line with Germany and the USA and should drive growth. The countries that perform best have a 2:1 or 3:1 ratio of business-compared-to-government investment.

To reach the goal will require a series of initiatives, including action on tax, direct loans, subsidies and grants, as well as regulation. One thing is certain, though – and I say this from my experience

as Head of R&D at GSK – there is nothing that trumps the ability to attract key talent from top universities and the research sector. The ability to interact with world-class research is still the biggest lever we have for attracting increased investment from business. □

Nothing trumps the ability to attract key talent from top universities and the research sector.

R&D should be the engine of progress for the UK economy

Chi Onwurah



Chi Onwurah MP is Labour's Shadow Minister for Industrial Strategy, Science and Innovation and is MP for Newcastle Central. She graduated from Imperial in 1987 with a degree in Electrical Engineering. She has worked internationally as an engineer and was appointed Head of Telecoms Technology at Ofcom in 2004. She is Chair of the All-Party Parliamentary Group on Diversity and Inclusion in STEM, and she is a trustee of The Foundation for Science and Technology.

Lower reinvestment of profits combined with rising debt makes industry ever more prone to short-term thinking. This is not conducive to spending on R&D, which, by definition, takes time to produce a return.

Some 29% of the UK workforce are employed in science roles and these employees typically earn 40% more than the average wage. That is part of the reason for the gender pay gap, given science's poor diversity record. Science jobs are projected to be created at twice the rate of other posts over the next five years. So science is absolutely critical to creating the high-skill, high-wage and high-productivity economy that both the Labour Party and the current Government want.

Yet, our country lags far behind other developed nations when it comes to R&D, spending just 1.7% of GDP. That compares to the OECD average of 2.4% and the 4.2% of high-fliers such as Israel and Korea. If everyone agrees that science is so important, why is it not financed properly?

Part of the answer can be found in the financial sector. It is 10 years since the financial crisis. As the economists Mariana Mazzucato and Laurie McFarlane wrote in a recent report: "the banking sector has largely retreated from funding the real economy". That in itself is nothing new. In the 1980s, Margaret Thatcher declared that our future was in services – financial services in particular. We could let the world be our workshop and we could keep our hands clean.

Decline

Today, just under 3 million people work in the manufacturing sector – a third of the number 50 years ago. As a percentage of GDP, on the other hand, our financial sector is now (pre-Brexit!) larger than that of any other G7 economy. This has coincided with a decline in our national R&D spend.

There are two main reasons for this. The first is that the financial sector has stopped resourcing the real economy: instead of investing in companies that produce goods, finance is financing finance. Why invest in a long-term R&D project when a bet on some options hedged with other options guarantees a return in a few weeks?

While low investment in the real economy directly impacts manufacturing and some services, it also has consequences for science. With fewer manufacturers and businesses investing in improving their productivity, there is less demand for innovation and therefore less demand for R&D.

Secondly, this emphasis on financial services

SUMMARY

- Science is critical to creating a high-skill, high-wage and high-productivity economy
- The current focus on financial services is leading to a short-term approach which is impacting on R&D spend
- The proposed National Investment Bank will consist of a network of regional banks, taking local decisions
- We must welcome talent in all areas and at all levels of science
- Labour's target for R&D is 3% of the UK's GDP.

changes the motives behind economic activity, giving investors with short-term interest greater importance. This results in lower reinvestment of profits combined with rising debt, making industry ever more prone to short-term thinking. This, of course, is not conducive to spending on R&D, which, by definition, takes time to produce a return.

We believe we need to turn the tide of financialisation and this is what Labour's Industrial Strategy is engineered to do. Our mission is to build an innovation nation, investing in science and technology and – critically – democratising the benefits so that it works for everyone. We want innovation to be part of our cultural DNA across the board.

Significant funding

One of the areas where Labour strategy differs from the Government's is that we will put significant funding behind it. So there will be a National Transformation Fund for Infrastructure. There will also be a National Investment Bank made up of a network of regional investment banks. Investment decisions will be taken locally, building up scientific excellence and R&D across the country.

Our commitment is to raise public and private R&D spend to 3% by 2030. We do not believe in merely being 'average' because innovation needs to be the driving factor behind the kind of economy we want to deliver.

To achieve that, we will make an additional £1.3 billion of public investment available in our

first two years in office. That will immediately raise R&D spending to 1.85% of GDP. Much of this additional spend will support a number of Industrial Strategy Missions: one is to create more innovation, another is to reduce carbon emissions from energy generation by 60% by 2030. Funding research into carbon capture and storage (CCS), for example, is part of our commitment to decarbonising the economy as well as stimulating new jobs in green technologies.

Private investment

While this would be unprecedented public investment, to reach the 3% target it needs to be matched by unprecedented private investment.

R&D is, in some ways, its own reward: companies that invest in R&D benefit in the long-run through higher productivity and growth. Analysis from the Campaign for Science and Engineering (CaSE), among others, shows that publicly-funded R&D has a strong multiplier effect, bringing in private sector investment. CaSE argues that Government expenditure on R&D raises private sector productivity by 20% per year in perpetuity. Other multiplier effects used by the Government itself estimate that every pound spent on the environment brings in around 30p of private sector investment. On that basis, our initial public sector investment would boost investment generally to 2% of GDP. But there are a further range of measures that will deliver on the 3% pledge.

Access to skilled personnel is the number one reason for companies to invest in the UK, yet the lack of skilled people is currently one of the barriers to businesses expanding their R&D programmes. We will introduce a National Education Service providing free, high-quality education from cradle to grave, as well as an NHS for the innovation age. We will also provide opportunities for retraining.

Unlike the present Government, Labour will not impose arbitrary immigration targets, such as the ban on what is termed 'low-skilled migration' that would hit the science sector – with its reliance on technicians, post-docs, etc – really hard. Our aim is for a post-Brexit immigration system based on fairness and economic need. In the parliamentary debate on Brexit and Science, almost everyone agreed that, to enable innovation, we must welcome talent in all areas and levels of science.

Labour's Treasury Team has been looking at ways to simplify fiscal policy, ensuring that it better supports business innovation among other goals. R&D tax credits and other schemes such as Seed Enterprise Investment Funding (SEIS) and Entrepreneur's Relief play a crucial role for many businesses.

I recently visited Oxford Science Park with

Shadow Treasury Minister Anneliese Dodds. It was clear how taxation, collaboration and access to skilled labour together could create an environment where business innovation could flourish. But growth is also being limited by poor transport links and the high price of housing – both of which Labour would address.

The benefits of innovation must be enjoyed by everyone though – not just science insiders. We are closely monitoring the development of the Knowledge Exchange Framework and exploring how it could be used to support prosperity in communities across the country. We are also considering how UKRI can best be used to direct research funding to the places that most need it and can most benefit from it.

We have the most regionally unequal economy in Europe and are second only to Mexico in the OECD. That is not a recipe for social cohesion or indeed the best use of talent. So our Industrial Strategy will also focus on place and on devolving powers to address local needs and drive local prosperity. Our National Investment Bank will be made up of a network of regional banks so investment decisions can be taken locally.

While Labour's Industrial Strategy is mission-rather than sector-based, we do recognise their importance and will engage with sectors, setting up Councils modelled on successful examples such as the Automotive Council. These will not, as at present, be limited to a favourite set of industries, though. We will, for example, establish a Catapult for the retail sector to encourage innovation in what is our largest employment area. The creative industries too are a significant part of our economy which we need to support and promote.

Universities are keen to play a bigger role in supporting knowledge exchange with local businesses and we can help establish local infrastructure funding to address this – local authority capacity to provide support to small businesses has almost vanished.

Research & Development

I believe, as an engineer and as a politician, that Research & Development should be the engine of progress for our country. To achieve Labour's 3% target, we will need to increase existing business R&D, create entirely new R&D-intensive businesses and attract overseas companies to do R&D here.

Our Industrial Strategy aims to address all three by supporting our infrastructure, our skills and our industrial base. The strategy will be backed by real investment, aligned with a serious approach to Brexit and will be implemented through a series of measures to spread the benefits and sources of science excellence more widely. □

R&D is, in some ways, its own reward: companies that invest in R&D benefit in the long-run through higher productivity and growth.

We will establish a Catapult for the retail sector to encourage innovation in what is our largest employment area. The creative industries too are a significant part of our economy which we need to support and promote.

Finding the best means of incentivising R&D

Chris Haley



Dr Christopher Haley is Head of New Technology and Startup Research at Nesta, the innovation foundation. He leads the organisation's research and policy activities related to how startups and new technologies can drive innovation and economic growth. Prior to joining Nesta, he worked for several years in technology commercialisation and early-stage investment, as well as in university enterprise strategy.

On overall innovation performance, the UK now ranks significantly above most EU countries. Our wider spend on intangible assets is also now high by international standards.

In every country that has achieved a similar increase in R&D to the one the UK is attempting, it has been led primarily by business. Yet, our business R&D (as with Government R&D) is currently below the OECD average, even when adjusted for our economic structure.

One interesting question is whether businesses are substituting R&D with other activities, such as collaboration with startups, or other forms of innovation. Innovation is a key driver of growth but is clearly much more than R&D: it encompasses all the means by which new ideas create value, such as design-based products, business model developments like Uber and Airbnb, service innovations like Revolut and Crowdcube, as well as improved internal processes.

So perhaps British firms are under-investing in R&D because they are investing instead in other innovative activities such as design and business model transformation, which do not show up in the R&D statistics? If so, then concerns about the R&D gap would be misplaced.

Nesta's 2006 report, *The Innovation Gap*, examined this possibility. Despite the fact that traditional indicators of innovation performance were heavily-biased toward investments in scientific and technological invention (and so did not capture innovation in other sectors) it was still the case that British businesses did not innovate enough, so this could not serve as a substitute for R&D.

Fast forward 12 years and the picture has changed somewhat. On overall innovation performance, the UK now ranks significantly above most EU countries. Our wider spend on intangible assets is also now high by international standards, and our measurable non-R&D innovation activity (such as design) has increased substantially over the past decade or so. However, despite that, compelling evidence that UK firms are investing in wider innovation activities as a substitute for R&D is still lacking. We need more innovation and we also need more R&D.

Now, there is a separate argument for changing the definition of R&D to include some of these other innovation-related activities that currently do not qualify. The creative sectors, in particular, are active in areas such as computer gaming, virtual reality and augmented reality.

SUMMARY

- Higher R&D activity is correlated with higher net profits
- Incorporating innovation incentives in pay has a positive impact on firm performance
- Only a minority of the UK's largest firms use innovation metrics in their annual bonus or short-term incentives
- We need to enable freer movement of researchers between academia and industry.

Such activity does not meet the current definition of R&D but looks quite similar in intent and would undoubtedly benefit from the stimulus afforded by R&D tax credits. This could encourage more innovation investment in areas where the UK excels – even if it risks accusations of ‘moving the goalposts’ – but even so this does not solve our core problem.

One puzzle is that the long-term average internal rate of return of business R&D has been variously estimated at around 10-15% (and as high as 30% in some studies), so it might therefore be expected that enlightened firms (and markets in general) would encourage more investment in R&D – even if it meant raising funds to do so. Why is this not happening?

It is often claimed that equity markets are too short-term in nature: investors are too impatient to invest in innovation that may take decades to come to fruition. Certainly, there has been a declining percentage of shares in UK companies held by individuals, insurance funds and pension funds which explicitly care about long-term growth. Institutional ownership of companies has been shown to exert not only a positive impact on R&D spend but – perhaps more importantly – has an even larger effect on the productivity of that R&D (at least, in terms of patent outputs). However, over the past two decades, these institutional investors have largely been replaced by overseas investors and others with a lower quality of interaction with firms. The resulting fragmentation of shareholders reduces the incentives for engagement and the

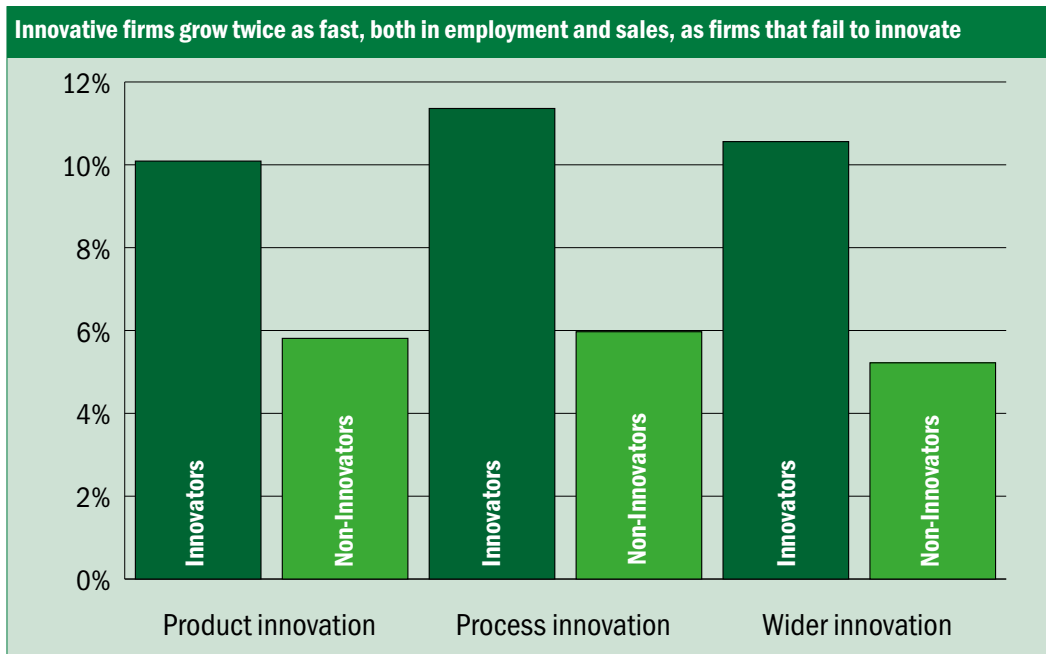


Figure 1. Innovation drives growth

level of control enjoyed by each shareholder.

Why does this matter? Well, shareholders can exercise control by influencing remuneration policy and incentives. There is a substantial body of research demonstrating that incentives for individual executives can sometimes run counter to the long-term interests of their firm.

For example, one survey from 2005 found that an astonishing 78% of corporate executives would be willing to sacrifice long-term value in order to meet quarterly earnings targets. There is evidence that CEOs often reduce long-term investment to increase short-term earnings, when approaching vesting periods for equity and options – and this seems causal: the more equity that CEOs have vesting in a given quarter, the more they cut investment.

The converse also seems to be true: longer-term individual incentives have a positive effect on firm innovation. There is evidence, for instance, that more long-term incentives (such as restricted stock options) are associated with more heavily-cited patents, far more so than short-term incentives.

Some companies have moved away from quarterly reporting, precisely in order to reduce the short-termist attitudes which this creates. But do the UK's largest companies have adequate incentives to innovate, on average?

Nesta recently commissioned an analysis of incentive packages across the FTSE350 (companies which are particularly important for business enterprise R&D: our largest 15 R&D spenders, who are mostly large companies, account for a full third of all business R&D, and the top 50 account for half; by contrast, independent SMEs only

account for about 4% of BERD). From this, several conclusions emerged:

1. The work confirmed that higher R&D activity correlated with higher net profits.
2. Among R&D-active firms, the use of innovation-related performance metrics was correlated with higher net profits.
3. Across the FTSE350, there was a clear lack of board-level responsibility for innovation-related functions (compared with sustainability or safety, say, where there is very often a clear, nominated committee or individual).
4. Only a minority (37%) of these firms used innovation metrics in their annual bonus or short-term incentives. Further, a much smaller minority (5%) used them in long-term incentivisation plans.
5. Within incentive schemes, metrics that explicitly promote investment in innovation were, on aggregate, substantially outweighed by metrics which (inadvertently) discourage investment in innovation, such as measures which favoured cost-cutting.
6. Of the metrics which could feasibly be considered innovation-related, nearly all (95%) were qualitative in nature, making it hard for shareholders to compare between companies. Specific targets for R&D spend were found in just 2.1% of incentive schemes.

Such disincentives are undoubtedly unintended: most firms genuinely appreciate the importance of R&D and broader innovation, and many invest substantial resources in this. However, businesses have been led to adopt innovation-dis-

Innovative firms grow twice as fast, both in employment and sales, as firms that fail to innovate.

couraging metrics because they are relatively easy to measure, reasonably objective and well-understood by analysts. The benefits of correcting this could be substantial for all, though these will require not only a rethink by remuneration committees but also a change in focus from analysts, shareholders and fund-managers.

There is no silver bullet for R&D spend. How-

ever, a good place to start is by looking at our large firms and trying to understand whether their executives are incentivised in the right way.

Evidence shows that incorporating innovation incentives in pay does have a positive impact on firm performance. Somehow, we need to ensure that shareholders, analysts, investment managers and the companies themselves take this to heart. □

A framework for innovation



Dr David Halpern, Chief Executive of the Behavioural Insights Team, joined the panel after the formal presentations.

What can be done to encourage more firms to do more R&D? Well, R&D tax credits have a pretty respectable evidence base. Many small firms hesitate to claim them because they are not sure they will get the money afterwards. So more forward guidance by HMRC to give 'advance assurance' is crucial.

Closer to home, Government does not currently spend anywhere near 2.4% on R&D. Is it not possible to improve and innovate around educational practice, let alone health or criminal justice – even design and welfare? Why are these sectors not subject to the same kind of innovation, funding and activity as manufacturing?

We have huge numbers of legacy activities and programmes where there is no attempt to try out variations which would deliver a significant step forward. In Canada, by contrast, every government Department has to allocate a certain proportion of its activity to R&D. The UK could be much bolder.

There are major market failures around adop-

tion of technology and its procurement. Within Government, the prevailing attitude towards new technologies is to wait until they have been around for a few years and have 'settled down'. But if there are no 'early adopters', who is going to actively catalyse innovation?

We talk a lot about the Valley of Death in relation to the obvious areas of R&D, the universities. But there is a bigger Valley of Death in 'user generated innovation'. It is estimated that about 6% of the population are serial inventors and adaptors – they just keep fiddling with stuff, in the workplace or at home. The mountain bike, the baby jogger, disposable nappies – these were not developed by companies, but by individuals who had a cool idea.

However, it is much more difficult to translate ideas generated in this way to the marketplace. There are untapped sources of innovation and activity here, but how can we measure it? Even more importantly, what kind of translation activity is needed to enable them to permeate across the economy? □

What might the future look like?



Rebecca Endean OBE, Strategy Director of UKRI, joined the panel after the formal presentations.

More important than the target are the outcomes it generates: a knowledge-based economy with more jobs, a better society, better culture, greater wellbeing and more resilience. Of course, all these things will affect economic growth in the long run, but let's not get stuck on the target *per se*.

The research base generates insights which lead to innovation and then, in general, to the growth of a better society – yet much of this is not captured by the current measure of R&D because it is not 'development' in the traditional sense. Conventional metrics give rise to the conclusion that all R&D is concentrated in particular industries, is concentrated in particular areas and is

concentrated in particular firms. This does not correspond to what is actually happening around the country. We need to capture what comes from design, from creative industries, from data and AI, from software: all of it driving economic growth, especially in the service sector.

How would the country look different if the target is achieved? Well, we think we need at least 60% more researchers with all the related technicians and people with skills to make it all work. We will need to encourage an ageing workforce to stay in work and retrain. We also need to consider how to ensure a continuing flow of international talent.

It is also worth thinking about the way we pres-

ent ourselves as a nation because we have a habit of doing ourselves down – we are, after all, one of the best research nations in the world. While there are many things that can be done to improve the links between academia, Government and industry, we are already one of the most innova-

tive nations in the world. The reason we attract so much overseas funding to carry out R&D is because of the huge quality of our research base. We have great strengths and we need, particularly at this point in time, to make sure we let the world know about them. □

The debate

Are the right incentive structures to invest in R&D in place within Government? More thought should be given to R&D in the context of Departmental objectives. Public sector research establishments and Research Councils attract business investment, but there is also a case for more public laboratories, and more could be done to promote research and innovation in areas such as housing and transport.

More can be done to incentivise ‘patient capital’, particularly in support of start-ups, providing funding over a longer period. There are increasing numbers of corporates experimenting with start-ups but this needs further encouragement. There is a case for more innovative funding methods (e.g. crowd funding), as well as drawing on examples of strong innovative systems overseas (e.g. Boston).

The UK favours research rather than development but China initially focused more on the latter, although it has begun to invest substantially in pure research in universities.

Procurement can be better used to incentivise R&D. The current arrangements are strongly

biased in favour of minimising risk, and yet innovation inherently involves risk. The budget for the Small Business Research Initiative (SBRI) has not been spent. Perhaps more resources should be allocated outside Government to encourage risk-taking.

Home markets, for example, energy, housing and transport, should be used to drive investment in innovation within the UK. Innovation standards (e.g. zero-carbon homes) could be developed to drive demand.

Company reporting requirements should promote the long-term market. There is evidence that the right regulatory environment incentivises business, though care should be taken to avoid international regulatory divergence. Regulation in emerging sectors, where no harmonisation exists at present, can play a key role.

Diversity should be improved: we were not using all the potential skills at our disposal. The short-termism of employment contracts for early postdoctoral careers should be addressed, and there should be more transparency and accountability in reporting by university departments. □

The audience at the meeting were invited to offer their own insights and views. Topics covered included: support for start-ups; the role of procurement; incentivising home markets; regulation and company reporting requirements.

FURTHER INFORMATION

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Goodridge P, Haskel J and Wallis G (2014) UK Innovation Index 2014, Nesta Working Paper No. 14/07

https://media.nesta.org.uk/documents/1407_innovation_index_2014.pdf

Nesta (2012) Plan I: The Case for Innovation-led Growth

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ONS: Research and development expenditure.

www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure

UNIVERSITIES

What is the role of universities in today's Britain? They face an array of demands and expectations from different groups across our society. The question was explored in a meeting held at the Royal Society on 14 November 2018.

Building partnerships and trust

David Sweeney



David Sweeney is the Executive Chair of UKRI. He chairs the Research England Council and provides leadership and oversight of Research England's strategy and functions. Previously he was director of research and knowledge exchange at the Higher Education Funding Council for England. David was appointed as Executive Chair designate of Research England in early 2017 and took a lead role in shaping the new Council and leading the transition of responsibilities from HEFCE into Research England.

I visited 16 countries in 2018, pursuing the goal of UKRI – and the country – to build relationships around the world. I have been stunned by the respect and admiration there is for UK universities from governments and from other universities across the globe. They admire our system, they want to understand how it works and they are full of appreciating for what we are achieving.

When asked 'What are universities for?' my first response is to wonder who is asking. The report from the All Parliamentary Group on Entrepreneurship on Enterprise Education¹ had some very strong suggestions about how universities could support students better, but with an underlying tone that this demanded greater attention. Lord Kerslake's Civic Commission similarly is clear that universities should be more strongly driven by local civic objectives. There are many other examples. It is very frustrating for universities to be consistently asked to dance to many tunes.

My particular concern about many of those groups – and business often takes the same line – is that they see it is a power relationship where universities are in service to them. It is difficult to sustain engagement where you are always the lesser partner. This despite the fact that we have some of the best universities in the world.

The nature of the relationship has to change from a position of ownership by many disparate groups to one of partnership. There has to be mutual benefit and mutual interest.

The issue of trust

However, having a partnership is difficult if there is no trust and the press provides regular reports of a very considerable deficit in this area. I believe that the only way universities will develop balanced, respectful partnerships is to rebuild that trust: but it will not happen without effort.

Of course, universities are autonomous, legally private institutions who make choices about what they do. While that may be true, continual reiteration of the autonomy principle hinders the building of a trust-based relationship. Universi-

SUMMARY

- Relationships between universities and other parts of the community must be mutually beneficial and link common interests
- Partnerships are difficult in the absence of trust
- Universities need to understand their roles and responsibilities in their communities
- There are some immediate decisions that could be taken to start rebuilding trust
- Universities have a place at the heart of post-Brexit Britain.

ties are also very good at talking about academic freedom, but not so good on academic responsibility: a more balanced approach to the two would be a step towards building a partnership. Universities have demonstrated why there is a trust deficit very readily recently in relation to the Teaching Excellence Framework (TEF), where universities gave a message of 'why should we do it if there is no money in it?'. That reduces universities to 'guns for hire'.

Autonomous institutions being perceived to be chasing money and then complaining about an accountability overload will not generate confidence and trust.

Leadership

There are some wonderful people at the helm in our universities, but recently it has been very difficult for them to really demonstrate the leadership required. One reason is the Achilles' heel of remuneration. The University of Bath developed a very good framework to engage and explain. Other universities would do well to follow the same path. Some have addressed the issue, but none as publicly as Bath – a strategy which has helped rebuild trust.

Vice-Chancellors are also hindered by the pensions dispute. I have been appalled by the vitriolic, personal abuse directed towards some of them. That is unjustifiable, especially when they



Graduation Day for Bath University students: the University of Bath developed a good framework to engage and explain about the issue of remuneration

are attempting to be fair and reasonable on a very difficult issue. The minority in the workforce targeting Vice-Chancellors should realise there are consequences in undermining public trust in their leaders.

Attention needs to be paid to these two areas – remuneration and respect from their staff – if we are to successfully address the issue of public trust.

Universities need to have greater understanding of their role in (and responsibility to) civil society. They are typically the largest, or second largest, employer after the Health Service, certainly in communities outside London and the South East. In many areas, they sustain the whole business environment through their knowledge-based interactions and the provision of skills. They are in receipt of large amounts of public funding. It should be recognised that this is not an entitlement but a contract, something which should be reflected in the universities' engagement with its stakeholders.

Universities are having real difficulty with their relationship to the body that is now its regulator. It is early days and there will be teething problems, but universities have very strong positions to help them engage with the regulator. Universities can surely rise above these initial difficulties and build a strong, constructive relationship.

Respect

I want to see Vice Chancellors quoted in the press as respected figures, speaking publicly about the issues of the day – and particularly about how their institutions can contribute. Our universities

will be a major contributor to the post-Brexit world, building new relationships around the globe. They are, in fact, at the heart of what post-Brexit UK should be. Yet effective leadership is required if they want to take that role, together with a sustained effort to build trust by demonstrating their care and concern for different groups in society.

In the effort to rebuild trust, there are some clear decisions to be taken. For instance, why not stop making unconditional offers when it is very clear that the public thinks these are unacceptable? There are other simple things – like refusing to engage with grade inflation – where universities could take the lead by working collectively.

Universities ask why they should stick together when they are in competition in the UK. My answer is that if they continue to behave in an entirely individualistic manner, they will not rebuild trust in the sector – because that is clearly a collective quality.

It is necessary for the future of the country that our universities recover their position of thought-leadership and respect. Relationships with other groups in society need to be on the basis of partnership not service.

There may also be difficult decisions about funding to come. Virtually every other part of society has had to face that challenge: many have risen to it, but not all.

I want our universities to be winners. I want them to retain their global position. I want them to regain respect. □

¹<http://appgentrepreneurship.org/research>

It is early days and there will be teething problems, but universities have very strong positions to help them build a strong, constructive relationship with their regulator.

A force for public good

Nancy Rothwell



Professor Dame Nancy Rothwell DBE DL FRS FMedSci FBPhS is President and Vice-Chancellor of The University of Manchester. She joined the Victoria University of Manchester in 1987, became Professor of Physiology in 1994 and held an MRC Research Chair from 1998 to 2010. She has been Vice-President for Research (2004-2007) and Deputy President & Deputy Vice-Chancellor (2007-2010). She was the founding President of the Royal Society of Biology and has also served as a non-executive director of AstraZeneca. She is currently co-Chair of the Prime Minister's Council for Science and Technology and a member of the Industrial Strategy Council.

Students come to study at a particular university so that they can be taught by a leading scholar who is making discoveries. They want to do a research project as part of their learning.

What are universities for? I believe that they are for public good. They are places of learning, enquiry and scholarship, and the discovery of new knowledge. They also make a contribution to their local communities and, more widely, to UK society in general.

I will not focus on the value of the university degree but there is a clear drive to widen access to these courses to people from backgrounds which have not traditionally participated. There is evidence that a university education has an impact beyond just learning and qualifications. It affects behaviour and life choices.

However, universities in the UK, and indeed globally, are facing massive change – from globalisation, increased competition, student consumerism and so on.

There has also been a sustained period of negative media attention, whether berating universities for having students who do not leave with a good degree, or conversely complaining that universities give too many good degrees! This is, perhaps, symptomatic of a lack of trust or understanding about what universities do.

Yet there are so many different stakeholders, each feeling some level of ownership. That sense of public ownership may be a good thing, but on the other hand it makes us accountable to a wide range of communities who have differing expectations.

Education and research

Universities are, of course, places of learning first and foremost. Whenever a member of staff tells me they do not feel they should do much teaching I ask them how they can justify that view. We always need to remember that this is what we are here for and that this was the basis for the foundation of universities; it would be a mistake to forget that.

There are, however, changing expectations of universities, particularly from students. They are paying more and are consequently living with more debt. It should be remembered, though, that the number of students applying to study at university has gone up and up, even with increasing fees. The number of students from disadvantaged backgrounds has gone up even more, year on year.

In the future, universities will have to move towards much more flexible learning – distance learning, open-access and serving a wider skills base. The traditional university model, at least in universities like Manchester, is for an individual

SUMMARY

- Universities exist for the public good
- As institutions they are facing massive change
- Universities have a large number of stakeholders with a wide range of expectations
- There should be a strong link between education and research in universities
- The contribution of universities to culture and local communities – nationally and locally – is often overlooked.

to complete their degree in a single subject, be it history, physics or mathematics. Students today have much wider expectations about training in things like entrepreneurship and they are likely to change their careers several times throughout their lifetimes.

As one example of the way Manchester is trying to address that, every student is offered the possibility to attend 'ethical grand challenges'. Some 5,000 come together on one day each year and learn about topics like environmental impact or social injustice. We also encourage physics students to learn something about Chinese culture, and history students to learn to code or to learn about outer space. The demand for this sort of education is increasing all the time.

I believe that in universities such as Manchester, there has to be a strong link between education and research. Students come to study at a particular university so that they can be taught by a leading scholar who is making discoveries. They want to do a research project as part of their learning (indeed many of them will take a year out to do such a project). That is incredibly valuable because it gets them out into the practical world. Even if they have no intention of pursuing a career in research, this stimulates a way of thinking that is critically important.

Grand Challenges

There is a sense in which the research focus has shifted somewhat towards the Grand Challenges of the UK's Industrial Strategy, innovating and translating. I and my colleagues accept the importance of this. Yet at the same time universities have to be places where fundamental knowledge is pursued and where discovery for its own



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Ethical grand challenges: some 5,000 students at the University of Manchester come together on one day each year and learn about topics such as environmental impact or social injustice

sake is valued. If that were not so, then nobody would be doing it, because very, very few companies do fundamental discovery now.

I have said to various funding bodies in the UK that there is too much competition in research. Everyone competes with each other for every research grant yet there is a lot to be said for building consortia – a team approach. While we are free to do this, it is not encouraged. Particularly for the very big projects, universities should look to work together rather than submit separate bids.

We teach in disciplines, yet increasingly research goes beyond these boundaries. Students still come to study maths or biology or English, although the way we do research often does not recognise such delineation.

There has been much talk about universities as businesses – which of course they are not. Most are charities and most are not private. On the other hand they have to behave in a business-like way, so innovation and improvement are, therefore, very important.

Collaboration with industry is crucial. I see much more of a partnership than I did previously. The role of entrepreneurship in universities is also much more to the forefront with many students now wanting to gain these skills. Staff and students are increasingly looking to start their own companies, but I do want to put in a word of caution: we should focus on what we are good at and not try to do everything.

However, universities must show not just what they have discovered but, in addition, what difference it made. University staff do want to make a difference and they want the wider public to know what they are doing. This last point is more



University of Manchester

important than ever, precisely because of the loss of trust and respect in our institutions.

At the University of Manchester, we have a goal of 'social responsibility' and the idea applies to universities in general. We are training citizens of the future. We are contributing to society more widely, though we may have failed to demonstrate clearly the impact we can have on society in recent times. Although the impacts universities have in science, engineering, maths and medicine are widely recognised, their role as places of culture and their engagement with cities and rural regions on matters of culture are sometimes overlooked. □

Most universities are charities and most are not private. On the other hand they have to behave in a business-like way, so innovation and improvement are very important.

Institutions with a host of roles

David Willetts



The Rt Hon Lord David Willetts FRS is the Chair of The Foundation for Science and Technology, and Executive Chair of the Resolution Foundation. He served as the Member of Parliament for Havant (1992-2015), as Minister for Universities and Science (2010-2014) and previously worked at HM Treasury and the No 10 Policy Unit. He is the Chair of the Sanger Institute and Chancellor of the University of Leicester. His book *A University Education* was published by OUP in November 2017.

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Over the centuries, universities have taken on more and more roles. Perhaps the first place to start in understanding them is their function of conserving knowledge and information. It is no accident that in many universities the biggest, proudest, most prestigious building is the library. Historically, in turbulent and difficult times, the place where knowledge and understanding were preserved (as well as cultural and intellectual objects) was the university. This role is, if anything, becoming more significant again today. So the university is custodian, conservator and trustee.

For many centuries people did not think of universities as places of research; indeed they were not clear whether knowledge advanced much at all. Insofar as there was a clear account of how knowledge progressed in the ancient and medieval worlds, it was deemed to be by the occasional solitary genius.

The debate about the role of universities in the English-speaking world has suffered from a classical distinction between liberal knowledge and menial education. Liberal knowledge was what a free man could access and share without requiring it for any merely utilitarian purpose. Hence one of the definitions of the university as ‘a place where nothing useful is taught’.

There was a school of thought that if it was useful then it was vocational education and not for the university. Rather, the university was for the education of a liberal mind which was not driven by the requirement to practise a trade or profession.

That view still lives on in some places but it does a lot of damage. While of course people can study liberal arts for their own sake, almost a half of all university students are studying for professional activities.

In the 19th century, Wilhelm von Humboldt envisaged the research-intensive university in his native Prussia. One German visitor to Oxford was asked by Matthew Arnold what he thought of the university. The reply was that “Oxford is a very distinguished gymnasium” by which he meant in Oxford people were taught. In his view, it did not do research, it was not a proper university but it was very good at teaching.

It was only the experience of the First World War and the policy debates leading to the Haldane Report of 1918, that led universities to take on a role in research and advancing knowledge in

SUMMARY

- The place of universities in society has changed overtime
- The distinction between pure and applied knowledge can be traced back centuries to the idea of the liberal arts
- The experience of the First World War provoked profound change in the idea and purpose of the university
- In the 1960s the expansion of Higher Education conferred on the universities the role of managing the transition of young people to adulthood
- The biggest challenge in English education is excessive early specialisation.

England, a century later than in Germany. The crucial moment was a media campaign driven by Britain’s frustration that America had stayed neutral for so long during the war.

One reason was that American academics who wished to gain any postgraduate qualification went to Germany. A third of the senior ranks of Harvard were people with doctorates from German universities: there were no doctorates in English universities because England did not do research.

The Foreign Office duly summoned our university leaders and challenged them to create their own postgraduate qualifications to rival German doctorates – hence the first DPhil from Oxford in 1917. That was the moment when universities started taking on a research role. 1918 was a crucial moment in the history of universities because, very astutely, when the Foreign Office summoned the Vice Chancellors to ask them to take on this role, the Vice Chancellor of Birmingham University said: “Of course, Foreign Secretary, we stand ready to take on this role but when overseas students arrive to study for these doctorates, they may be shocked by the poor quality of the facilities! There should be some public funding so that this is a worthwhile experience for them.”

The origins of the Higher Education Funding Council for England (HEFCE) go back to those university grants introduced in 1918, while the origins of Universities UK go back to the committee that Vice Chancellors and Principals created in 1919 in order to negotiate with the Government about the grants.

A great many things happened at the end of the First World War and one thing that soon became clear was the tension between pure and applied knowledge. I believe it is very important to keep space in the university both for blue skies research and for applied research. Sometimes, of course, the blue skies research turns out to be useful, a situation elegantly summed up by the observation of Abraham Flexner about the ‘usefulness of useless knowledge’.

I had the privilege of meeting the Nobel Prize winner Robert Almond who told me how he had wrestled with a problem to do with the shape of knots and had been proud of publishing a paper of no practical value whatsoever, describing how to model their shapes mathematically. That was until his grandson phoned him from university to tell him his formula was being used in the modelling of DNA – and he cursed! He had tried to write something totally useless and irrelevant, but it proved not to be the case. The distinction between useful and useless knowledge may, over time, be hard to sustain!

So universities became a location of research and there is a paradox here. England was late to the party for R&D (Germany had been doing it for a century) but Britain today has an unusual concentration of R&D activity in universities. In Germany, for example, there are the Max Planck, Fraunhofer and Helmholtz networks – publicly-funded labs independent of universities.

The British strategy, by contrast, is to have rather low levels of publicly-funded R&D spend outside universities, putting nearly all our eggs into one basket of Higher Education-based spend.

A new and increasingly significant role for universities has been to manage the transition of young people to adulthood. In 1963, the last conscript left the British Army. In the 1950s England had on average 150,000 conscripts and 50,000 university students. Being conscripted into the Army was the managed transition to adulthood. The Robbins report of 1963 and subsequent expansion of Higher Education, combined with the last conscript leaving the army, was the point at which the university took on the role that had, for much of the 20th century, been military. Before that again, apprenticeships had fulfilled that function. Today, 50% of young people go to university and, in my view, there is no alternative model on the same scale for that kind of semi-supervised transition to adulthood.

The institutions which are significant in a global economy, but are also rooted in a place, are the universities. Unlike businesses and other employers, these Anchor Institutions are embedded in local communities. If you live in a city where you are not sure whether institutions will leave or stay,

the university becomes very significant.

The only other example of that is the cathedral which were the Anchor Institutions in a global and integrated Christendom. Paradoxically, some of our great cathedral cities, which had no significant and sustained economic activity, are being transformed by investment in a university – Lincoln, Chester, Winchester and Chichester for example.

The future

There are three powerful forces shaping universities in this country. There is the digital revolution and I do believe that in the future data analytics will change teaching. The amount of data we will have about the teaching process means that pedagogy becomes a far more empirical, data-rich discipline than it has historically been.

Globalisation is very important with the flows of students to and from other countries, enriching the experience but also presenting new challenges.

The third item is the challenge of excessive specialisation. This is the biggest problem in English education today. The three A-level model is heavily shaped by university admission practices and I think it would be an enormous service if universities resumed their role of providing an education in the liberal arts – although today that extends beyond what we would call the ‘humanities’ into scientific disciplines as well. □

Sometimes blue skies research turns out to be useful, a situation elegantly summed up by the observation of Abraham Flexner about the ‘usefulness of useless knowledge’.

FURTHER INFORMATION

The right education for everyone, Speech by the Prime Minister on 19/2/18

www.gov.uk/government/speeches/pm-the-right-education-for-everyone

A University Education, David Willetts, Oxford University Press, 2017

www.resolutionfoundation.org/about-us/team/david-willetts/

Blog on the purposes of universities by Professor Jonathan Grant

www.wonkhe.com/blogs/a-positive-moment-of-uncertainty-for-universities

Universities UK on public perception of universities

www.universitiesuk.ac.uk/news/Pages/british-public-proud-of-uk-universities-new-poll.aspx

Demand for Higher Education to 2030, Bahram Bekhradnia and Diana Beech HEPI Report 105

www.hepi.ac.uk/2018/03/15/demand-higher-education-2030/

Augar Review of post-18 education

www.gov.uk/government/news/prime-minister-launches-major-review-of-post-18-education

National Committee of Inquiry into Higher Education, Ron Dearing, 1997

www.leeds.ac.uk/educol/ncihe/

Engaging with our stakeholders

We in the universities sector must really think about how to respond in a positive way to the many challenges facing us today. First, we have to come up with a new definition of the public purpose of a university. This has to be articulated in a way that builds trust and confidence. In reality, this involves rediscovering what we were founded to do in the first place.

Education is changing. One of the most exciting developments of the past few years concerns the social mobility agenda. Colleagues tell me that, over the past decade, some 60,000 students have experienced a university education specifically because of our widened participation programme. That is an extraordinary statistic. Universities are no longer just for the exceptional; we should be aiming to have participation up towards 80%.

There are very few other institutions which have the mandates universities have in communities. We can drive change by being socially responsible. At King's College, for example, all of our directly procured electricity now comes from

windfarms. We are also accredited with the Living Wage Foundation. As institutions, we must discover this social mission to complement our educational mission and our research mission. Through that process we begin to build trust and articulate our public purpose.

Generation Z are the 16-17 year olds of today who will be going to university in a couple of years. The Millennials are the 26-27 year olds. Mori asked the two groups the same questions about activities and preferences. Out of Generation Z, our future university customers, 50% said they had volunteered over the past two years, compared to 30% of the Millennials. A third of Generation Z say they will preferentially shop in social enterprises such as Fairtrade, compared to a fifth for the Millennials. As we look to rediscover and rearticulate and redefine what we want our institutions to be, I think our customer base is going to force us to be more socially responsible.

So this is my challenge: let's be more ambitious! □



After the speakers' presentations, Professor Jonathan Grant, Vice-President/Vice-Principal (Service), King's College London responded to the issues raised.

The debate

There is pressure to lower student fees and there have been suggestions that fee income might be replaced by teaching grants. Yet if the fees were, for example, reduced to £6,500, the Treasury would have to find £2.5 billion to compensate for the full funding loss. In current circumstances that seems unlikely. Capping student numbers as a response to any reduction in fee levels would be extremely regressive.

Loss of income

While the debate on the future of the funding system must focus on the consequences for students and wider participation, rather than the universities themselves, any overall loss of income will impact on research. Tuition fees, however, would be better described as 'university' fees, to underscore that universities provide a wide range of secondary benefits for students, such as sport and the arts.

Notwithstanding the progress achieved in widening participation, more needs to be done in reaching out to schools, pupils and parents. More programmes are needed to support students from disadvantaged backgrounds in accessing employment after university.

The growth in the number of universities has supported a growth in student numbers without creating massive institutions along the lines of universities in Europe. They can therefore offer distinctive contributions in teaching, research and in terms of engagement with local communities.

Some institutions with less depth in knowledge-based research are stronger on development, making a direct contribution to their local communities and industries by focussing on practical research questions relating to construction or other areas of applied science.

Industry partnerships

Universities will be key contributors in delivering the Government's commitment to raise national levels of spending on research to 2.4% of GDP. That will require stronger partnerships with industry, with funding sources in the private sector and more inward investment from outside the UK. Companies should be incentivised to locate employees involved in research and development closer to universities; and there should be an even stronger pipeline of postgraduate courses in STEM subjects. □

After the formal presentations, the audience was invited to contribute to the debate. Issues raised included: student fees; widening participation; links to the community and to industry.

Presentations and audio recordings from all meetings of the Foundation for Science and Technology are available at: www.foundation.org.uk

Delivering the Government's Maritime 2050 Strategy – the vision for science and technology

6 March 2019

Roger Hargreaves, Director for Maritime, Department for Transport
Sarah Kenny, Vice Chair, Maritime UK
Professor Ed Hill OBE, Executive Director, National Oceanography Centre
Professor Susan Gourvenec, Deputy Director, Southampton Marine & Maritime Institute, University of Southampton
Liz English, Group Development Manager, Associated British Ports

Can the goals of the Paris Agreement on the response to climate change be delivered?

16 January 2019

Nick Bridge, Special Representative for Climate Change, Foreign and Commonwealth Office
Professor Qi Ye, Director, Institute for Science and Technology
Baroness Worthington, Executive Director Europe, Environmental Defense Fund Europe
Emma Howard Boyd, Chair, Environment Agency
Professor Nick Robins, Professor in Practice for Sustainable Finance, Grantham Research Institute on Climate Change and the Environment, London School of Economics and Politics

Delivering the UK Industrial Strategy: the importance of place

19 December 2018

The Rt Hon Greg Clark MP, Secretary of State for Business, Energy and Industrial Strategy
Ken Skates AM, Minister for Economy and Transport, Welsh Government
Sir Mark Walport FRS FMedSci HonFRSE, Chief Executive, UK Research and Innovation (UKRI)
Katherine Bennett OBE FRAeS, Senior Vice-President, Airbus [Panellist]
Dr Julia Sutcliffe FRAeS, Chief Technologist and Head of Engineering Strategy, Air Sector, BAE Systems [Panellist]

Is the UK well prepared for a repeat of the 1918 influenza pandemic?

5 December 2018

Professor Chris Whitty CB FMedSci, Chief Scientific Adviser, Department of Health and Social Care
Katharine Hammond, Director, Civil Contingencies Secretariat, Cabinet Office

Dr Andrew Coburn, Chief Scientist, Cambridge Centre for Risk Studies, Judge Business School, University of Cambridge
Professor Rachel McKendry, Director, i-sense and Professor of Biomedical Nanotechnology, London Centre for Nanotechnology and Department of Medicine, University College London

What are universities for?

14 November 2018

David Sweeney, Executive Chair, Research England, UKRI
Professor Dame Nancy Rothwell, President and Vice-Chancellor, The University of Manchester
The Rt Hon the Lord Willetts FRS, House of Lords
Professor Jonathan Grant, Vice-President/Vice-Principal (Service), King's College London

What is the best way to achieve the Government's target of spending 2.4% of GDP on R&D by 2027?

17 October 2018

Sir Patrick Vallance FRS FMedSci FRCP, Government Chief Scientific Adviser, GO-Science
Chi Onwurah MP, Labour Shadow Minister for the Industrial Strategy, Science and Innovation and MP for Newcastle Central, MP for Central Newcastle, House of Commons
Dr Christopher Haley, Head of New Technology and Startup Research, Nesta
Dr David Halpern, Chief Executive, The Behavioural Insights Team
Rebecca Endean OBE, Strategy Director, UKRI

Civil Society and government – the next decade

28 September 2018

Ben Harrison MBE, Policy Manager, Office for Civil Society, Department for Digital, Culture, Media and Sport

Growing international research and development partnerships in a post-Brexit world

18 July 2018

The Rt Hon Norman Lamb MP, Chair, House of Commons Select Committee on Science and Technology
Dr Douglas Terrier, Chief Technologist (Acting), National Aeronautics and Space Administration (NASA)

How can the adoption of new technology be accelerated to improve the efficiency of the justice system? – The Rt Hon Sir Brian Neill Memorial Debate

20 June 2018

The Rt Hon Sir Geoffrey Vos, Chancellor, The High Court of England and Wales, Royal Courts of Justice
Susan Acland-Hood, Chief Executive, HM Courts & Tribunals Service
Professor Richard Susskind OBE FRSE, President, The Society for Computers and Law
Andrea Coomber, Director, Justice [Panellist]

Is the rate of change of GDP the best way to measure economic growth?

23 May 2018

Professor Jonathan Haskel CBE, Professor of Economics, King's Business School, King's College London
John Pullinger CB, National Statistician, Head, Government Statistical Service and Chief Executive, UK Statistics Authority
Tera Allas CBE, Senior Fellow and Director of Research, McKinsey Center for Government
Clare Lombardelli, Chief Economic Advisor to the Treasury and joint head of the Government Economic Service, HM Treasury [Panellist]
Professor Martin Weale CBE, Professor of Economics, King's Business School, King's College London [Panellist]
Professor John Kay CBE FRSE FBA, Economist [Panellist]

The impact of distributed ledger technology on trading, finance and insurance

25 April 2018

Chris Corrado, Group Chief Operating Officer and Chief Information Officer, London Stock Exchange Group
Shirine Khoury-Haq, Chief Operating Officer, Lloyd's of London
Dr Mike Short CBE FREng FIET, Chief Scientific Adviser, Department for International Trade
Keith Bear, Vice President, Global Financial Markets, Global Markets, IBM [Panellist]
Tim Smith, Consultant, Credit Suisse [Panellist]

Securing environmental benefits from farming while meeting the demand for food

21 Mar 2018

Professor Ian Boyd FRSE FRSB, Chief Scientific Adviser, Department for Environment and Rural Affairs
Minette Batters, President, National

EVENTS

Farmers Union (NFU)
Helen Browning, Chief Executive, Soil Association
The Lord Cameron of Dillington, House of Lords [Panellist]
Richard Hebditch, Government Affairs Director, The National Trust [Panellist]

UKRI leaves the starting blocks: the management of government funding of research and innovation

28 February 2018

Sir Mark Walport FRS FMedSci HonFRSE, Chief Executive, UKRI
Sir Alan Wilson FBA FRS, Chief Executive, the Alan Turing Institute
Kirsten Bound, Executive Director of Research Analysis and Policy, NESTA [Panellist]
Jonathan Neale, Chief Operating Officer, McLaren Technology Group Ltd [Panellist]

The Hackitt Review of Building Regulations and Fire Safety

24 January 2018

Dame Judith Hackitt DBE FREng, Chair, Hackitt Inquiry into Building Regulations and Fire Safety
Graham Watts OBE, Chief Executive, Construction Industry Council (CIC)
Peter Baker, Director, Construction Division and Chief Inspector of Construction, Health and Safety Executive
Dr Peter Bonfield OBE FREng, Member, Grenfell Expert Panel, Ministry of Housing, Communities and Local Government and Chief Executive, BRE Group [Panellist]
Turlogh O'Brien CBE, Chairman of the Governing Board of the Chartered Institute of Housing and Post-Grenfell Expert Working Group, Construction Industry Council (CIC) [Panellist]

The impact on society of machine learning – an opportunity or a threat?

14 November 2017

Dr Mike Lynch OBE FRS FREng, Founder, Invoke Capital
Dr Claire Craig CBE, Director of Science Policy, The Royal Society
Amir Saffari, Head of AI, BenevolentAI
Dame Wendy Hall DBE FRS FREng, Regius Professor of Computer Science, University of Southampton
Professor Chris Bishop FRS FREng, Laboratory Director, Microsoft Research, Cambridge [Panellist]

A business strategy for Scotland

6 November 2017

Professor Iain Gray CBE FREng FRSE, Vice President for Business, The Royal Society of Edinburgh
Nora Senior CBE, Chair, Scottish

Government's Strategic Board for Enterprise and Skills
Dame Susan Rice CBE FRSE, Chair, Scottish Water
Paul Wheelhouse MSP, Minister for Business, Innovation and Energy and Member for South Scotland, Scottish Parliament

Searching for the Holy Grail of a science and innovation strategy that makes a difference

18 October 2017

The Lord Hennessy of Nympsfield FBA, House of Lords
The Rt Hon the Lord Heseltine CH, House of Lords
The Rt Hon the Lord Willetts FRS, Executive Chairman, The Resolution Foundation

Cancer diagnostics: can cancer be diagnosed earlier and if yes what are the consequences?

11 July 2017

Sir Harpal Kumar, Chief Executive, Cancer Research UK
Billy Boyle, Chief Executive Officer, Owlstone Medical
Dr Clare Turnbull, Clinical Lead, Genomics England 100,000 Genomes Cancer Programme
Dr Suzanne Jenkins, Diagnostics Expert (Director), Personalised Healthcare and Biomarkers, AstraZeneca [Panellist]
Sara Hiom, Director of Early Diagnosis and Health Professional Engagement, Cancer Research UK [Panellist]

The impact of demographic and medical trends on the health and social care systems of the UK

21 Jun 2017

Professor Chris Whitty CB FMedSci, Chief Scientific Adviser, Department of Health, Deputy Government Chief Scientific Adviser
Sir Robert Lechler PMedSci, President, Academy of Medical Sciences
Professor Marcel Levi, Chief Executive, University College London Hospitals NHS Foundation Trust

Making cities work – the application of technology, science and infrastructure improvements to create a place where citizens wish to live

24 May 2017

Professor The Lord Mair CBE FRS FREng, Sir Kirby Laing Professor of Civil Engineering, Department of Engineering, University of Cambridge
Tom Saunders, Principal Researcher, International Innovation, Nesta
Councillor Peter Marland, Leader, Milton Keynes Council

What constitutes an effective industrial strategy for the UK?

10 May 2017

Professor Graeme Reid, Specialist Adviser to the House of Lords Select Committee on Science and Technology
Professor Dame Ann Dowling DBE FRS FREng, President, Royal Academy of Engineering
Andrew Barker, Head of Investor Relations, International Airlines Group
Anthony Lilley OBE, Chief Executive and Chief Creative Officer, Magic Lantern
Dr Andrew Harter FREng FIET FBICS, Chair, Cambridge Network and Founder and CEO, RealVNC [Panellist]

What needs to be done to meet urban air quality targets and what are the consequences if the targets are not met?

26 Apr 2017

Elliott Treharne, Air Quality Manager, Greater London Authority
Dr Stephen Bryce, Vice-President, Fuels Technology, Shell Projects and Technology
Professor Frank Kelly, Professor of Environmental Health, King's College London
Dr Christa Hasenkopf, Chief Executive and Co-Founder, OpenEQ [Panellist]

How can skill levels be raised to meet the needs of society and the economy?

1 March 2017

Sir Mark Walport FRS FMedSci, Government Chief Scientific Adviser, Government Office for Science
Sir Adrian Smith FRS, Chair of the Smith Inquiry into mathematics education for 16 to 18 year olds and Vice Chancellor of the University of London
Dame Judith Hackitt DBE FREng, Chair, EEF (formerly the Engineering Employers' Federation)
Stephen Metcalfe MP, Chair, House of Commons Select Committee on Science and Technology [Panellist]

Making good use of science and innovation in overseas development programmes

14 December 2016

Professor Charlotte Watts FMedSci, Chief Scientific Adviser and Director Research and Evidence Division, Department for International Development
Jon Ridley, Head, M-KOPA Labs, M-KOPA Solar
Rowan Douglas CBE, Chief Executive, Capital, Science & Policy Practice and Chair, Willis Research Network, Willis Towers Watson

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Technology Organisations (AIRTO)
AstraZeneca
AXA XL

B

BAE Systems
Babcock International Group
Biochemical Society
Biotechnology and Biological Sciences
Research Council
BP International Ltd
BPE Solicitors LLP
BRE Group
British Academy
British Geological Society
Brunel University London
BSI Group

C

Canterbury Christ Church University
Chartered Association of Building
Engineers
Chartered Institute of Credit Management
Chartered Institute of Linguists
Chartered Institute of Plumbing and
Heating Engineering
Chartered Institution of Water and
Environmental Management
Comino Foundation
Cranfield University

D

Defence Science and Technology
Laboratory
Department for Environment, Food and
Rural Affairs
Department of Health and Social Care

E

Economic and Social Research Council
EEF (Make UK)
EIB Institute
Elsevier b.v.
Energy Institute
Engineering and Physical Sciences
Research Council
ERA Foundation

G

Genomics England
GlaxoSmithKline
GO Science

H

Heads of University Centres of Biomedical
Science (HUCBMS)
Health and Safety Executive
High Value Manufacturing Catapult

I

IBM (UK) Limited
Imperial College London
Innovate UK
Institute of Biomedical Science
Institute of Food Science and Technology
Institute of Materials, Minerals & Mining
Institute of Mathematics and its
Applications
Institute of Measurement and Control
Institute of Physics
Institute of Quarrying
Institution of Chemical Engineers
Institution of Engineering and Technology
Institution of Mechanical Engineers

J

JISC
Johnson Matthey Plc
JSPS

K

King's College London
Kingston Smith
Knowledge Transfer Network Limited

L

Lloyds of London
London Mathematical Society
Luminance Technologies Ltd

M

McLaren Technology Group Ltd
Medical Research Council
Met Office

N

National Physical Laboratory
Natural Environment Research Council
Natural History Museum
Network Rail
Nottingham Trent University
Nutrition Society

O

Open University

P

Palaeontological Association
Parliamentary and Scientific Committee
Peter Jost Charitable Foundation
Publishers Licensing Society

Q

Queen's University Belfast

R

Recruitment and Employment
Confederation
Research England
Rolls-Royce
Royal Entomological Society
Royal Geographical Society (with the IBG)
Royal Society of Biology

Royal Society of Chemistry
Royal Society of Medicine

S

Science and Technology Facilities Council
Shell International Limited
Society for Applied Microbiology
Society for Editors and Proofreaders
Society of Maritime Industries
Society of Operations Engineers
Sovcomflot (UK) Ltd
SPTS Technologies Ltd
STEM Learning

T

The Academy of Medical Sciences
The Alan Turing Institute
The Foundation for Professionals in
Services for Adolescents
The Geological Society
The Haskel Family Foundation
The IET
The Lady Butterworth
The Medical Schools Council
The Royal Academy of Engineering
The Royal Commission for the Exhibition of
1851
The Royal Society
The Wellcome Trust

U

UK Innovation & Science Seedfund
UK Research and Innovation
UK Statistics Authority
University Alliance
University College London
University of Birmingham
University of Chichester
University of Dundee
University of East Anglia
University of Edinburgh
University of Glasgow
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