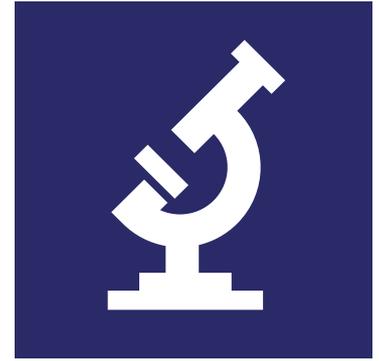


Investing in science, research & innovation



The opportunity

For an advanced economy, the path to competitiveness is not to copy what others are doing. It is to do things that others cannot do, or to do things in different and better ways.

Higher levels of investment in innovation correlate with faster growth and higher income levels, both within different areas of the United Kingdom and internationally. Research and development leads to the creation of new products and services, more effective processes and better ways of doing business. These improvements are the essence of economic growth. The Government has an important role to play in driving investment in innovation. Some types of research are important, but too far away from being market-ready; these will mostly be funded by government. It can take action to invest and introduce tax incentives to encourage businesses to invest in R&D. The Government also has a key role to play in facilitating the exchange of ideas and collaboration between business, universities and government laboratories.

Innovation is not just about breakthrough technologies or scientific and engineering processes. Effective adoption of technology throughout businesses and improvements in management and workforce skills are just as important, as are new ways of providing services, from financial services and retail to professional advice. Innovation can sometimes be disruptive, but ultimately we must embrace

innovation to keep ahead of the competition, create more good jobs, and make sure jobs in the UK are secure.

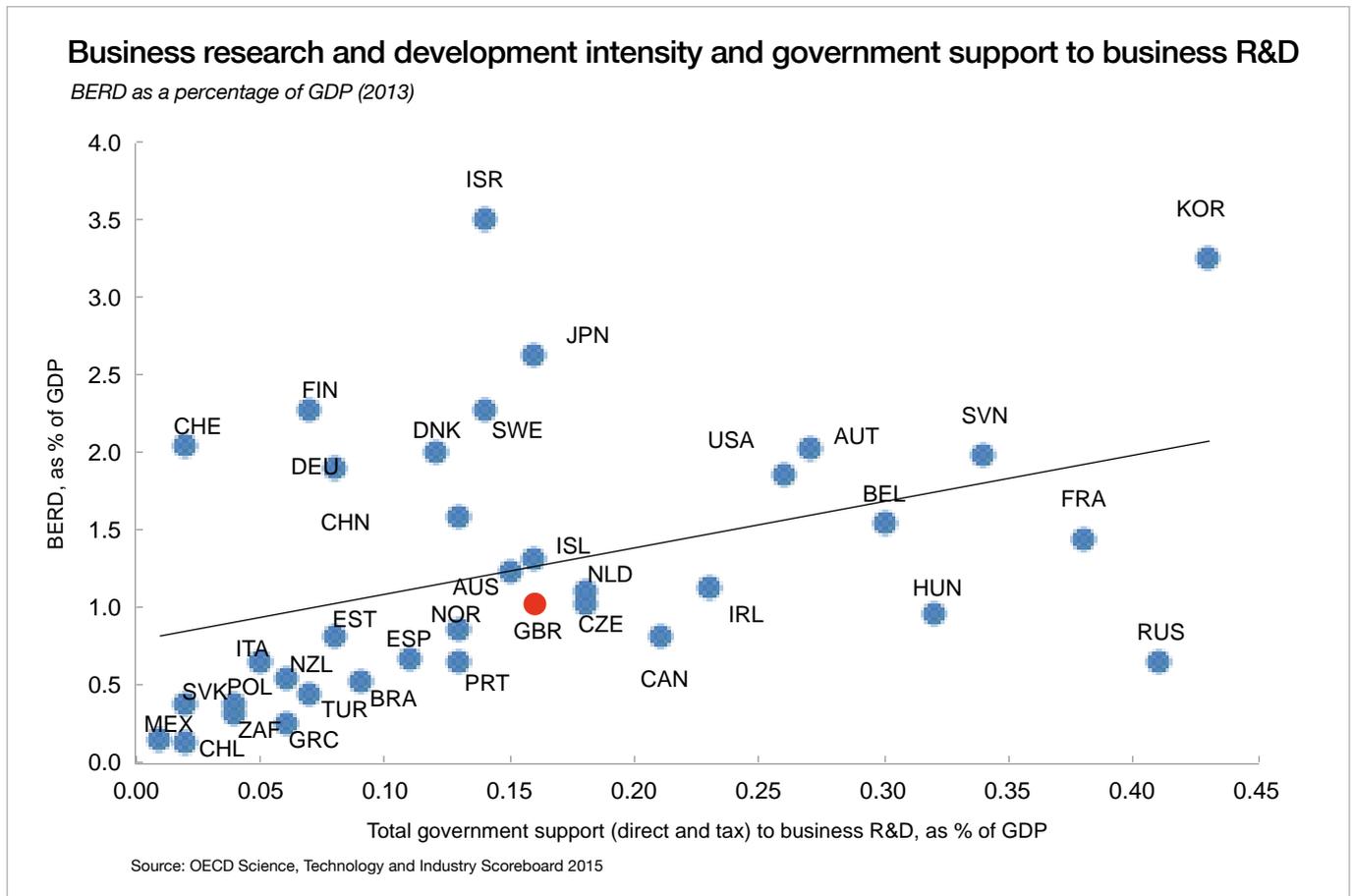
At a time when the pace of scientific discovery and innovation is quickening across the world, the UK is fortunate to be a nation of science and technical progress. We have three of the world's top 10 universities, and 12 of the top 100²⁶. Of the G7 countries, the UK has the most productive science base and we rank first in many key global measures of research quality²⁷.

These academic achievements have practical benefits for our economy, with firms investing into the UK to access our research – such as IBM, which has invested £200 million in the Hartree Centre in Cheshire to boost 'big data' research.

The challenge

Excellence in science, research and innovation is recognised by our international competitors as an important source of future competitive advantage and many are taking significant steps to increase their own investment in this area.

The Government has protected the public science budget since 2010, despite having to make substantial savings to reduce the inherited deficit. But other countries have been increasing their investment in research and development in relation to GDP.



The UK invests in total 1.7 per cent of GDP in private and public R&D funding. This is below the OECD average of 2.4 per cent and far behind the leading backers of innovation – South Korea, Israel, Japan, Sweden, Finland and Denmark – which contribute over 3 per cent of their GDP to this area.

The graph above shows this challenge. Business investment in R&D (BERD) is just over one per cent of GDP in the UK, close to half the rate in Germany and substantially below the OECD average²⁸. Though there is variation, there is a correlation between government investment and tax support for R&D, and the amount that private businesses invest²⁹.

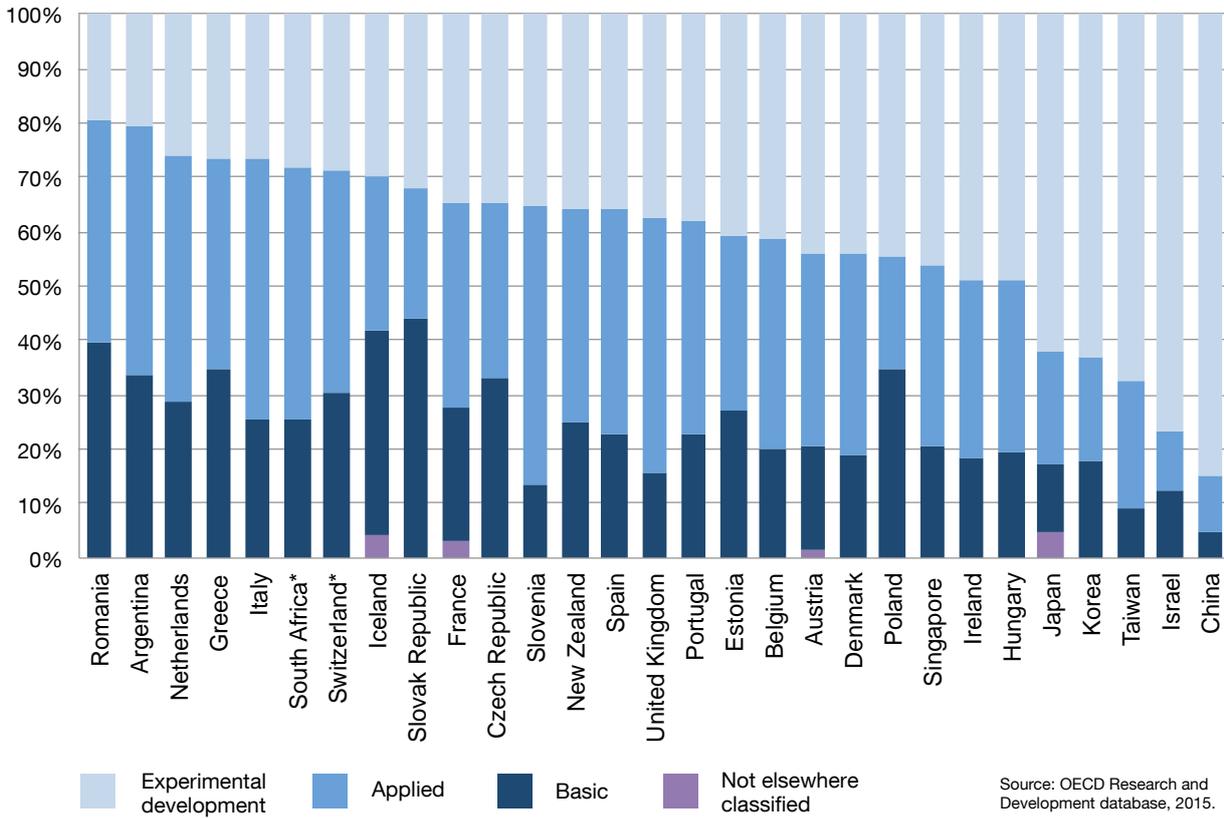
The graph also shows that the ratio of business to public investment varies considerably. In some countries like Germany and Japan the ratio of business investment to public investment is far higher than in the UK.

We have a challenge, too, in translating our leadership in global research into commercial outcomes – a longstanding weakness relative to other countries. From the development of medical imaging technologies to biotechnology, the UK has too often pioneered discovery but not realised the commercial benefits.

This may reflect in part the balance of funding. While the way we distribute funding across different stages of R&D is not out of line with other European countries, it is striking that in leading innovation nations, such as Israel and countries in Asia, a greater proportion of total R&D investment is on later-stage, experimental development. China, for example, currently spends twice the share of the UK. This may amplify the industrial impact of such countries' funding commitments to R&D³⁰.

Type of research and development spending at different stages of research

As a percentage of total research and development expenditure (2013)



Source: OECD Research and Development database, 2015.

We have already taken action to address the UK’s historic relative weakness in commercialisation, through the establishment of new, more industrially focused institutions such as Innovate UK, and by strengthening support for universities to commercialise their research ideas. We have also protected Government spend on basic science, in recognition of its central role in generating new knowledge and breakthrough discoveries. We will also ensure allocation of additional research investment takes full account of the need to continue our world-class dual support system.

The UK now produces a similar number of spin-off companies as US universities, and substantially more than Japanese institutions, when measured per unit of research funding³¹. But we register far fewer patents³². We have world-class research universities, but not one

features in the ‘Top 10’ list compiled by Reuters covering innovation and commercialisation³³.

This illustrates the need to do much more to build on the progress to date. The so-called ‘golden triangle’ of institutions and businesses between Oxford, Cambridge and London is internationally revered, and rightly so. We must do more to replicate that success in other parts of the UK, building on research strengths in businesses as well as universities. The chapter of this Green Paper on local growth describes how we can use additional R&D investment to back world-class research and innovation, supporting local economies across the country.

Our strengths need to be seen against the backdrop of an increasingly global and mobile research community. The proportion of the UK’s business R&D investment financed from abroad



is considerably higher than other countries: 22 per cent in 2013, compared to seven per cent in the OECD³⁴. Under the current European Union programme, Horizon 2020 (2014-2020), the UK has to date secured €2.63 billion, the second highest level of funding³⁵.

As the Prime Minister has outlined, we are determined to continue to be one of the best places in the world for science and innovation and will welcome agreement to continue to collaborate with our European partners on major

science, research and technology initiatives. As the UK prepares to leave the EU we remain committed to maintaining and building on our strengths in R&D to continue attracting world-class people, skills and foreign investment – as set out in the chapter that follows on trade and investment.

Our approach

Our industrial strategy will launch a major upgrade in the role of science and innovation in our economy for the years ahead. It will build on our world-leading science base and hardware innovation into our businesses, schools, workforce and individuals.

We will:

Substantially increase investment in R&D and ensure that UK research continues to be world class. We will provide an additional £4.7 billion of funding by 2020-21 – an increase of around 20 per cent to total government R&D spending, and the biggest increase in any parliament in almost 40 years. We will also explore how we can best use this additional funding and the tax environment for R&D to drive up the level of private investment in science, research and innovation across the economy.

Strengthen our strategic capability through the creation of UK Research and Innovation (UKRI) which will bring together the Research Councils and later-stage innovation funding through Innovate UK. UKRI will develop and deliver a clear strategy from fundamental research through to business innovation. It will enable us to identify future opportunities and keep the UK at the cutting edge of new technologies and developing solutions to global challenges.

This paper seeks initial views on the priorities for this increased investment, and UKRI will consult in more detail in early 2017.

For example, increased R&D funding could allow us to:

- **Keep improving how we translate our world-class research into commercial outcomes.** We could look to expand successful mechanisms such as Higher Education Innovation Funding (HEIF), which supports universities to patent their
- **Capitalise on local strengths across the UK.** At present 46 per cent of Research Council and Higher Education Funding Council for England (HEFCE) funding is spent in Oxford, Cambridge and London. We have the Research Partnerships Investment Fund (RPIF), which supports capital projects in universities with an eye to local economic strengths, with co-funding from industry. However, there are constraints: RPIF funding from government is for capital infrastructure only, and it only applies to a particular range of project sizes – providing between £10-£50 million project funding. Most importantly, it has to be led by a university, and we have no equivalent fund that can take bids from groups of companies. We could create new funding streams to support world-class clusters of research and innovation in all parts of the UK, whether they are led by business or universities, and for large or small projects where they meet quality thresholds. In some cases, this could involve creating new research institutions to back local strengths in world-class research. In this way we will use some of the additional R&D funding to help boost growth across the economy, as well as growing it overall.
- **Build the pipeline of talent for an innovative economy.** Demand for higher level qualifications is growing strongly, and today's PhD students are often tomorrow's research leaders, entrepreneurs and industrial researchers. Existing funding

discoveries and work with local businesses, or expand Knowledge Transfer Partnerships, which place PhD students into companies. This would allow universities to provide greater support for their local economy and small businesses. We could also identify potential new types of interventions to enable research and business to collaborate (such as skills, or funding time away from the laboratory in businesses).

programmes for PhDs and post-doctoral researchers are heavily over-subscribed (for example, the most recent round of Medical Research Council “CASE” awards had a success rate of just 31 per cent³⁶).

This means many excellent candidates are not able to get places, so we will consider with stakeholders the best way to substantially increase the number of PhDs and research fellowships in STEM subjects (science, technology, engineering and maths).

- **Ensure that the UK attracts top international talent.** Researchers have shown that the presence of academic “stars” acts to pull in other researchers and private businesses³⁷. Other countries have active programmes to attract leading academics who can anchor strong departments. We could explore a similar programme for the UK.
- **Deliver the institutions and infrastructure we need for a world-leading research and innovation base.** UKRI could develop a new capital spending roadmap to provide the modern infrastructure to support fundamental research.
- **Deliver sector-specific funding to support business investment in R&D.** We will look at the value for money and effectiveness of such approaches compared to other funding mechanisms. This could include examining the value of sector-specific innovation funds matched by industry, like the funds created for the auto, aerospace and life sciences sectors through the Advanced Propulsion Centre, Aerospace Technology Institute and Biomedical Catalyst. We could explore similar arrangements for further sectors or deepen existing funds.

- We could create ring-fenced funding for **innovative procurement** schemes, like the Small Business Research Initiative, discussed further below.
- The Prime Minister has announced that we will create a new **Industrial Strategy Challenge Fund** to help Britain capitalise on its strengths in research and innovation such as robotics, clean energy and biotechnology. This builds on the creation of UKRI. The Industrial Strategy Challenge Fund creates a new funding stream which will enable UKRI to back technologies at all stages where the UK has the potential to take an industrial lead, from early research to commercialisation. This is additional funding and will not require reductions in existing research priorities to pay for it. Some challenges may well cut across the boundaries of existing research councils, and the creation of UKRI will enable us to take an effective overview of the development of new technologies unrestricted by traditional silos.

The new fund will draw on the experience of the US Defense Advanced Research Projects Agency (DARPA) programme and support business-led collaborations with coordinated research efforts and focus on the challenges, opportunities and technologies that have the potential to transform existing industries and create entirely new ones.

The Industrial Strategy Challenge Fund will focus on challenges where:

- the global market is potentially large, or fast growing and sustainable;
- the UK has capabilities to meet market needs in terms of research strength and business capacity;

- there are significant social and economic benefits; and
- there is evidence that government support will make a difference
- Based on these criteria, and analysis of the UK’s research strengths, including through the Eight Great Technologies initiative, areas from which specific challenge could be drawn include:
 - Smart, flexible and clean energy technologies (such as storage, including batteries, and demand response);
 - Robotics and artificial intelligence (including connected and autonomous vehicles and drones);
 - Satellites and space technologies;
 - Leading-edge healthcare and medicine;
 - Manufacturing processes and materials of the future;
 - Bioscience and biotechnology;

- Quantum technologies; and
- Transformative digital technologies including supercomputing, advanced modelling, and 5G mobile network technology.

These are early suggestions for potential challenge areas and there may be more opportunities – for example, in the creative industries. Innovate UK and the Research Councils are currently engaging with academics and businesses across the country to gather evidence on the challenge areas and identify where government support can make the biggest difference. We want to hear your ideas through this consultation in order to develop these further.

The Industrial Challenge Strategy Fund will enable UKRI to support a range of industrial R&D activities: joint research projects between businesses and academic researchers; placing graduate students into companies; setting up demonstrators to test near-to-market technologies in real-world environments; and creating centres to bring together academic



experts with entrepreneurs to promote commercialisation. In some cases a challenge could lead to the creation of a new institution to drive forward a priority technology.

As an early example of a new institution to support a key technology, the government has asked Sir Mark Walport to review the case for a new research institution to act as a focal point for work on battery technology, energy storage and grid technology, reporting in early 2017.

Battery technology is of huge importance to a range of new technologies, including the automotive sector, smart energy systems and consumer electronics. Electric vehicles are less polluting and cheaper to run, and have the potential to provide electricity storage and demand flexibility that could provide benefits to consumers and our electricity system. Drawing together these battery, energy storage and grid technologies is sensible because step-changes in innovation will likely involve all of them. For example smart grids that respond to the demands of consumers could potentially use new battery technologies, particularly storage in electric vehicles, to deliver power efficiently and at lower cost.

A new institution would build on existing strengths in this field that exist in universities and companies across the UK.

Increasing the effectiveness of technology transfer

As well as increasing overall funding for research and development, the Government will continue to work with universities and research institutions to further improve the economic impact of research investment.

We need to ensure that university spin-outs have the best chance to survive, attract investment and grow over the long term. With a view to spreading best practice the Government will commission research on different institutions' principles and practices on commercialisation of intellectual property, including how they approach licensing intellectual property and take equity in spin-outs.

For example, the size of equity stakes taken in spin-outs varies considerably, with little consensus over what is appropriate. Too large a stake can hamper future investment prospects, but some new companies will have to rely heavily on university funds for initial support. This research will explore the approaches taken by different institutions and examine the impact these have on spin-out creation and growth. The Government will then use the findings to identify and spread best practice among universities' technology transfer offices.



Investing in science, research and innovation

Actions under way:

- **We are increasing research and development investment** by £4.7 billion in total, an extra £2 billion per year by 2020-21.
- We are creating a new **Industrial Strategy Challenge Fund** to help the UK capitalise on its strengths in science and innovation such as robotics, clean energy and biotechnology.
- We have committed new **investment for R&D facilities and knowledge sharing** with £100 million until 2020-21 to extend and enhance the Biomedical Catalyst and a further £100 million until 2020-21 to incentivise universities to collaborate on technology transfer and partnering with business.
- We have announced that we will be supporting further **Science and Innovation Audits** in eight new locations across the UK to help develop the evidence base of their research strengths and innovation capability. We have launched the call for bids for the next wave of audits.
- We have launched a **review of the tax environment for R&D** to examine whether there is more we should do to stimulate private sector investment and make the UK an even more competitive place to do R&D.
- We have established a **high-level forum on EU Exit, Universities, Research and Innovation**. It will advise on how best to build on the excellence of UK research and innovation, maximising the opportunity of the UK's exit from the European Union.

New commitments:

- This paper starts the consultation on the priority challenges for the **Industrial Strategy Challenge Fund**, and other opportunities we can address using the increase in R&D funding. UKRI will then consult in more detail in early 2017 based on feedback to this Green Paper.
- Given its importance to a range of new technologies, including the automotive sector, the government has also **asked Chief Scientific Adviser Sir Mark Walport to review the case for a new research institution to act as a focal point for work on battery technology, energy storage and grid technology**, reporting in early 2017.
- We will be commissioning **independent research on approaches to commercialisation** in different institutions, including how they approach licensing intellectual property and taking equity in spin-outs.
- We will seek to harness the potential of the UK's **home-grown inventors** and stimulate user led innovation by launching a challenge prize programme. This prize, which will be piloted through the NESTA Challenge Prize Centre, will help inform our support to the 'everyday entrepreneurs' operating in companies and at home – such as through supporting enabling environments, incubators and maker spaces.
- We are reviewing how **to maximise the incentives created by the Intellectual Property system** to stimulate collaborative innovation and licensing opportunities – including considering the opening up of registries to facilitate licensing deals and business-to-business model agreements to support collaboration. We will place **Intellectual Property Office representatives in key UK cities** - starting with pilots in the Northern Powerhouse and Midlands Engine to build local capability to commercialise intellectual property.
- We will set out a **UK Measurement Strategy**, establishing a framework to capitalise on our National Measurement System which provides UK industry with world-leading measurement science and technology. The new strategy will ensure we have the knowledge and facilities to support all sectors to benefit from measurement – helping them to trade, manufacture and export.

Questions for consultation

5. What should be the priority areas for science, research and innovation investment?
6. Which challenge areas should the Industrial Challenge Strategy Fund focus on to drive maximum economic impact?
7. What else can the UK do to create an environment that supports the commercialisation of ideas?
8. How can we best support the next generation of research leaders and entrepreneurs?
9. How can we best support research and innovation strengths in local areas?