

Engines of growth

The impact of research at
Russell Group universities

Russell Group Impact Series – Part 3, 2015



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Key facts

£21 billion

Of economic benefits from just one-fifth of our case study sample - delivering 100 times the initial investment

89%

Proportion of case studies in our sample with ongoing impact

2,168

Links to business in REF 2014

185 countries

Where research at Russell Group universities has had an impact

330

Spin-out companies generated from research at Russell Group universities in REF 2014

Foreword

The UK enjoys a world-leading position in producing excellent research, with the country's research-intensive universities at the heart of our success. But our universities are also focused on taking that further – constantly looking for ways in which research can deliver real world impacts for the economy and society.

This report highlights how research at Russell Group universities is generating billions of pounds in returns to the UK economy and delivering a wide range of economic benefits – from the creation of new businesses and jobs to efficiency savings for public services and private sector productivity gains.

We have identified at least £21 billion worth of economic benefits resulting from a sample of research projects at our universities – a return of £100 for every £1 of initial investment.

However, the research undertaken at our universities not only benefits the economy but also has an impressive impact on the health and quality of life of the nation, stimulates public engagement, influences policy, and contributes to our rich cultural life and heritage. And those research impacts can in turn generate even wider benefits that continue to deliver for years or even decades.

To illustrate this, we have picked out a small number of examples from the impact case studies submitted to the Research Excellence Framework (REF 2014) assessment that was conducted with universities in the UK last year.

These case studies tell a story of ground-breaking new therapies, transformative new technologies being developed with business and changes to policy and practice that have had a positive impact on millions of people in this country and around the world.

Our analysis shows how investing in excellent basic research is an indispensable component of the UK's economic competitiveness, and the key to its future growth.



Dr Wendy Piatt
Director General
and Chief Executive
of the Russell Group



Professor Sir David Greenaway
Chair of the Russell Group
and Vice-Chancellor of the
University of Nottingham

1 Executive summary

Russell Group universities are leaders in pioneering research and innovation. They undertake some of the most exciting and ground-breaking research being conducted anywhere in the world and then make that research work for the UK.

£21 billion

Of economic benefits from just one-fifth of our case study sample - delivering 100 times the initial investment

The critical mass of excellent research at our universities generates huge impact, links the UK into global knowledge networks, creates an environment for new ideas to be generated and developed, attracts investment and exploits technological breakthroughs for economic success.

This report¹ draws on new evidence made available through the Research Excellence Framework (REF 2014) to highlight how research conducted at our universities over the last twenty years helps to:

DRIVE economic growth and create new jobs and businesses

DEVELOP new technologies, products and services

IMPROVE quality of life and health, and promote social equality

STIMULATE public engagement and influence policy

CONTRIBUTE to the UK's rich cultural life

TACKLE global challenges and help to protect the environment

We have analysed a representative sample of 240 impact case studies from Russell Group universities, covering the breadth of discipline areas our institutions work in, and can show that research underpinning the case studies has resulted in at least £21 billion of wider economic benefits - 100 times the initial investment.

Our research has led to efficiency savings in public services, private sector productivity gains, the development of life-saving new treatments and drugs, the preservation of the UK's culture and heritage, and positive impacts on society right around the world - and in the process has created thousands of new jobs.

- In more than 1 in 10 case studies there is evidence of new businesses being created as a result of excellent research
- 11 new businesses alone created as a result of research at our universities directly generated over 4,300 jobs

While it naturally takes time to go from an initial research project to delivering wider impact, we find the average gap is only eight years, and there are many examples where time-to-impact has taken three years or less. However, this research typically builds on a body of previous research carried out over a number of years – highlighting the need for an ongoing commitment to basic research, which in turn requires proper public investment.

In almost all cases, impact is still being delivered long after the initial activity, so an investment in basic research now will continue to provide dividends for years or even decades to come.

- **Almost 90% of case studies in our sample showed evidence of the potential for ongoing impact**

Our universities have long-term strategic relationships with a range of organisations in the UK and overseas from multinational businesses to SMEs, charities and the public sector to deliver greater impact from their research. This includes maximising value from expensive capital investments by sharing facilities and equipment with industry, and bringing the best resources together to tackle the most complex challenges.

- **For every additional £1 of public investment in R&D, Russell Group universities leverage almost three times as much private funding as other universities**

Much of our research is interdisciplinary in nature, bringing together specialist skills and expertise from a very wide range of academic disciplines. This means we are able to draw on a combination of different research methods, knowledge and cultures to develop novel solutions to the most complex research challenges.

- **Nearly 70% of our case studies involve collaborative effort**
- **Three-fifths of the research spans two or more research disciplines, and this type of research results in enhanced levels of impact**

In most cases research has delivered multiple types of valuable impact.

For example, one piece of research might lead to an impact on health and on public policy; another could deliver commercial, environmental and wider societal benefits. Often there are unexpected outcomes: arts and humanities research delivering substantial economic benefits, for example, while biomedical research can have important cultural outcomes.

- **55% of case studies show an impact on policy, helping to inform and improve decision-making in the public and private sectors**
- **50% evidence economic or commercial impact**
- **47% show societal impact**
- **A third have a positive impact on health**

On average, each case study in our sample demonstrates more than two types of impact resulting from the research – meaning research conducted at our universities typically has dual or even multiple benefits.

The international reach of research impact from Russell Group universities is immense, extending to almost every single country, helping to attract inward investment and creating an unparalleled soft power influence for the UK.

Patients and sick people, children, disadvantaged groups, businesses, charities, policymakers and indeed all citizens have benefited and continue to benefit from our research.

Overall, our analysis shows how investing in excellent basic research is an indispensable component of the UK's economic competitiveness, and the key to its future growth.

It is also critical to our cultural identity and for understanding complex issues in society. However, the UK's position as a world-leader in research and innovation cannot be taken for granted and the maintenance of our competitive advantage depends on sustained long-term investment, focused on excellence and critical mass. Without this, we risk falling behind in the global race as our competitors increasingly invest to enhance their research capability.

1 in 10 case studies

In our sample show evidence of new businesses being created as a result of excellent research at Russell Group universities

4,300 jobs

11 new businesses alone created as a result of research at our universities directly generated over 4,300 jobs

2 Delivering impact from excellent research

Russell Group universities are world leaders in research and innovation, generating huge impact through critical mass and quality.

2 or more

Impact types identified on average in each case study in our sample, showing how research at our universities has multiple benefits

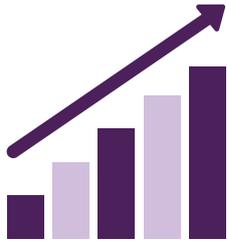
Impact case studies submitted by Russell Group universities to the Research Excellence Framework (REF 2014) provide a rich and impressive array of examples of how research conducted at our universities has led to significant real world benefits.

We have undertaken an in-depth analysis of 240 impact case studies as a representative sample, as well as reviewing the full set of 3,256 case studies our universities submitted overall to the REF 2014 and which have been published by HEFCE.²

The majority of case studies demonstrated multiple positive impacts. For example, many had both economic and another impact, such as on technology or policy. Some reported multiple economic impacts and a number had impacts on four or more areas such as societal, health, policy, environmental and cultural.

It is important to remember that these case studies only represent a snapshot of the excellent research that our universities do – but they provide a helpful window into the UK's research and innovation powerhouse.

Research highlighted in the Russell Group case studies has had far-reaching impacts across a wide range of areas (Chart1).



ECONOMIC IMPACT

Driving economic growth, generating new products and services and creating jobs.



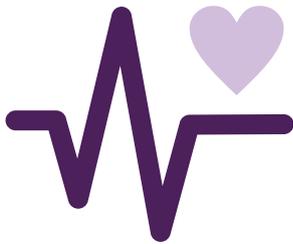
POLICY IMPACT

Informing, influencing and improving decision-making by government and public bodies, NGOs and in the private sector. Increasing the efficiency and/or quality of public services, directing investment to priority areas and raising business productivity.



SOCIAL IMPACT

Informing public debate, stimulating public interest, improving welfare, equality and inclusion, and improving quality of life and opportunities.



HEALTH IMPACT

Creating new drugs and treatments and developing new therapies. Improving education and training, public awareness, and access to health care provision, as well as policy, legislation, standards or guidelines.



CULTURAL IMPACT

Enhancing and preserving our cultural heritage, producing cultural artefacts, creating, inspiring and supporting new forms of expression, and enhancing our understanding of minority groups and communities.



ENVIRONMENTAL IMPACT

Delivering energy savings and reduced emissions, improving management and conservation of natural resources, stimulating public awareness and influencing policy, improving business and public service operations, and environmental risk management.



TECHNOLOGICAL IMPACT

Developing new and improving existing technologies.



LEGAL IMPACT

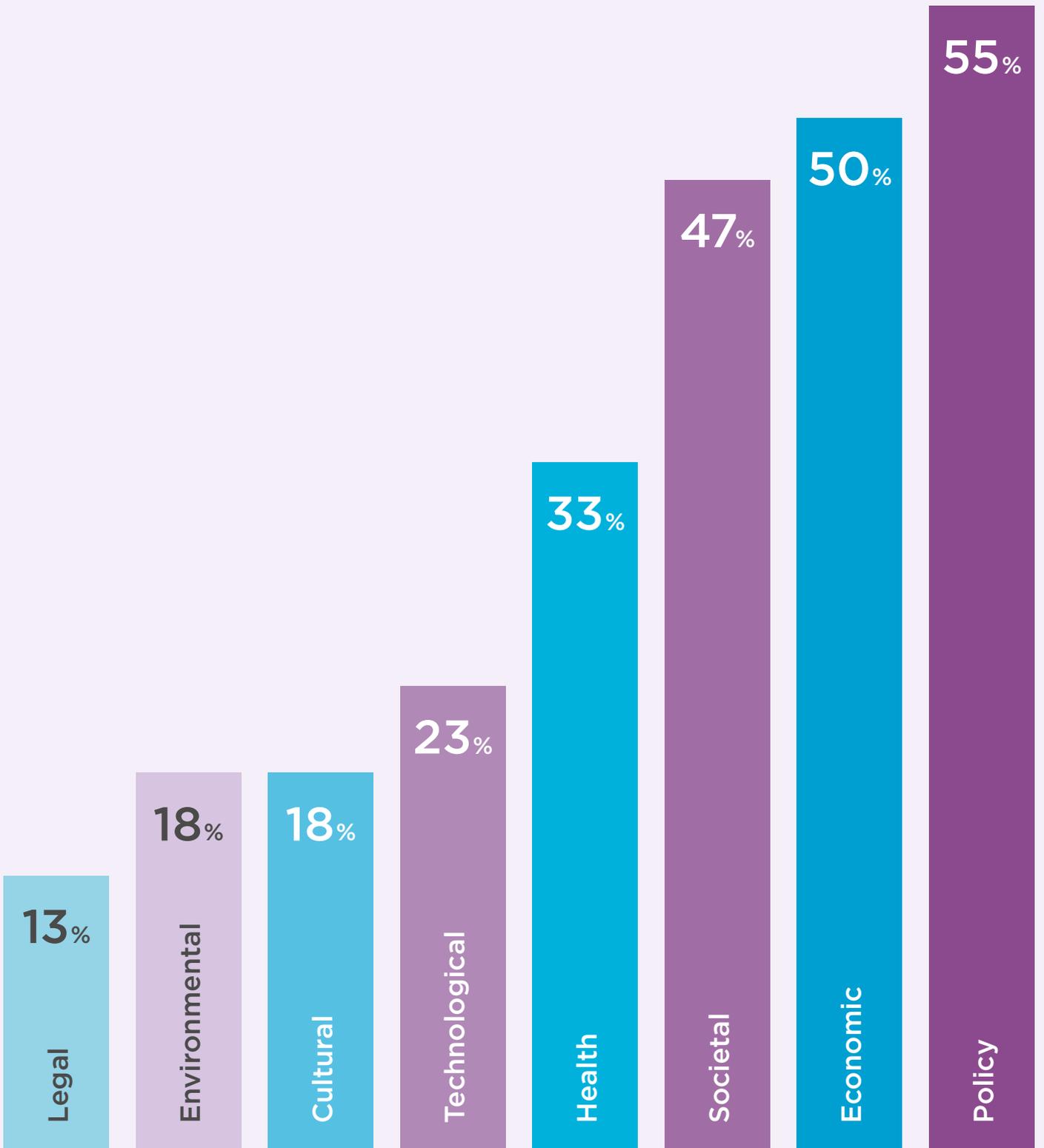
Improving law enforcement methods, effecting legislative change and improving legal practice and access to justice.



GLOBAL IMPACT

Delivering positive impacts from our research overseas including collaborating with partners in other countries.

Chart 1: Percentage of case studies in our sample delivering specific types of impact



3 Driving economic growth

Research conducted by Russell Group universities leads to breakthroughs that play a critical role in driving economic growth and creating jobs right across the UK.

Half of the case studies in our sample provided evidence of direct economic impact – for example through the development of valuable new technologies, the sale of new products and services and the creation of spin-out companies and jobs.

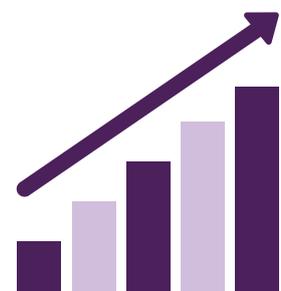
But when second and third order consequential impacts are factored in we can see that over three-quarters of case studies in our sample have economic impacts or clear potential to deliver economic impacts.³

For example, a piece of environmental research that demonstrates a positive impact on wildlife might lead subsequently to an increase in tourism with consequential economic benefits.

Our analysis also relates to impact demonstrated at the time that the case studies were written rather than a full assessment of expected impact.

So, for example a new drug or medical treatment still in development may have the potential to deliver significant benefits to health, quality of life and the economy in the future too.

Indeed, nearly 90% of case studies in our sample showed evidence of the potential for ongoing impact well beyond the REF 2014 timeframe.



330

Spin-out companies generated from research at Russell Group universities in REF 2014

71%

Of the intellectual property income generated by UK universities comes from the Russell Group

Delivering a substantial return on investment

Investing in excellent research provides an impressive return for public funders: a funding investment of £199 million (identified from 48 of the case studies where this information was available) created:

- **Indirect economic benefits worth £21 billion – 100 times the initial funding investment⁴**

While not all case studies were able to provide both funding and revenue details⁵, the return on investment in research at our universities ranges up to £2,735 for every £1 of initial investment.

Research in clinical medicine at **Queen's University Belfast** led to the development of a transformative new drug to improve survival and quality of life for cystic fibrosis patients – and delivered a 50:1 return on investment within a year of the drug being available. (See page 46)

Computer science and informatics research at the **University of Leeds** has led to major cost savings for bus and train companies, as well as a new spin-out company, with a return on initial investment of 317:1. (See page 44)

Genome sequencing technology developed from research at the **University of Cambridge** now generates an annual turnover of £750 million from initial public investment in basic research of only £274,196. This means for every £1 of public investment, the research has generated £2,735 every year, even without counting the wider economic and social benefits. (See page 39)

Developing pioneering products from concept to commercialisation

Our universities have an impressive track record in commercialising their research to deliver economic gains, spinning out and licensing technology for the economic, social and cultural benefit of the UK.

Despite representing only 15% of the UK's universities, in 2013-14 Russell Group universities generated:⁶

- **71% of the intellectual property income generated by UK universities (£93 million)**
- **61% of active spin-out companies which survived for three years (almost 500 companies)**

In the same year, active spin-outs and start-ups at Russell Group universities employed over 11,000 people.⁷ Across the full set of 3,256 Russell Group impact case studies, 330 included evidence relating to spin-out companies – almost 60% of all references to spin-outs made by UK universities in their REF 2014 submissions.

In our sample of 240 case studies more than one in every ten resulted in the creation of a new business (including spin-outs). Whilst not all of these case studies included information about job creation and value, of those that did:

- **11 new businesses alone directly generated over 4,300 jobs**
- **8 new businesses will have a total estimated value of £3.9 billion by 2017**
- **7 new businesses had collective annual revenues of £70 million**

Research conducted at our universities has also resulted in the creation of whole new business sectors, spawning the creation of many new companies and spurring investment from multinationals, SMEs and start-ups alike in new fields.

The discovery of graphene at the **University of Manchester** led to the creation of the graphene production industry, with \$200 million of recent commercial investment in graphene production across 210 companies from blue-chips such as IBM and Samsung to start-ups. Over 55 new companies have entered the sector with at least 24 formed since 2008. (See page 38)

University College London's pioneering research into multimedia communications over the internet has led to the development of techniques which are central to many of today's multimedia communications. These are now at the core of products made by Apple, Cisco, Siemens and others. (See page 45)

These case studies demonstrate the importance of long-term sustained investment in research in order to realise very significant economic impacts over time. In these cases, as in so many others, it is curiosity-driven fundamental research that provides the biggest pay-offs in the end – ultimately generating billions in revenue, developing new technologies which create whole new industries, and creating valuable new spin-out companies.

As well as the creation of new businesses, two-fifths of the case studies in our sample (51 out of 240) highlighted research that underpinned the creation of new products and/or new services.

Research at the **University of Southampton** has led to the creation of a new business sector in fibre laser technology and manufacturing, leading to improvements in production and manufacturing processes for industries from aerospace to food and consumer goods. (See page 42)

Research in disciplines within the physical sciences and engineering were of critical importance here. Two-thirds of new businesses in our sample and two-thirds of the new products and services were created as a result of research in the physical sciences and engineering, and in particular from basic research in physics and chemistry.

Research in physics and chemistry is also associated with the highest number of case studies evidencing technological impact – an indication of the importance of fundamental scientific research in underpinning technological developments at a later stage.

Research leading to the development of genome sequencing technology at the **University of Cambridge** has made a very significant contribution to the success of the global DNA sequencing market, which is projected to be worth \$10 billion by 2017. (See page 39)

However, our case studies show that businesses have been created in areas of research ranging from clinical medicine and biological sciences to music, drama, art and design, and that new products and services emerged from research conducted in areas ranging from English language and literature to architecture, built environment and planning, to psychology, psychiatry and neuroscience.

61%

Of active spin-out companies which survived for three years or more were generated by Russell Group universities

£3.9 billion

Estimated value by 2017 of 8 new businesses created as a result of Russell Group research

50%

Of case studies in our sample evidence economic impact by driving economic growth, generating new products and services and creating jobs

55%

Of case studies in our sample demonstrate an impact on policy through informing, influencing and improving decision-making.

Realising wider economic benefits

Research at our universities has far-reaching positive impacts, delivering significant cost savings for the public sector and businesses and driving productivity in the wider economy.

Research at Russell Group universities:

- **Provides businesses with access to new and improved technologies and skills, helping to increase productivity⁸ and enhance the private sector's ability to offer new goods and services – in turn, increasing the nation's output and GDP**
- **Adds to the absorptive capacity of the UK through the many international links and collaborations with research conducted overseas**
- **Informs the knowledge base within the public, private and third sectors, enhancing policy-making to achieve desired outcomes**
- **Provides the evidence base to avoid or mitigate environmental hazards**
- **Helps to provide a better quality of life for the general population through providing new goods and services and improved policy-making**

As highlighted above, wider economic benefits identified in our sample of case studies are worth at least £21 billion. This includes impacts on productivity, efficiency savings, business processes and the facilitation of investment by the public and private sector.

A long-term collaboration between mathematicians at the **University of Southampton** and GlaxoSmithKline (GSK) led to the adoption of a new statistical design for experiments and modelling methods. Indicative savings of more than £25,000 and three weeks of scientists' time have been made per experiment using the new methodology since 2011. Speeding up the process for developing new drugs not only saves on costs but frees up personnel to work on life-enhancing interventions elsewhere. As a measure of the value of Southampton's research GSK awarded the university nearly £200,000 in 2012 to fund further fundamental statistical research from which future pharma benefits may be obtained.⁹

Research at the **University of Exeter** into the accessibility of low-cost, evidence-based treatments for depression has been applied in an England-wide NHS programme, with significant improvement and recovery rates. These improvements not only directly and profoundly benefit depressed patients, but also have real benefits to the government and the general public through increased productivity and reduced welfare costs. (See page 40)

Influencing policy

One of the key ways in which research delivers wider economic benefits is through its influence on policy in the public, private and third sectors in the UK and internationally.

A striking 55% of our impact case studies demonstrate an impact on policy through informing, influencing and improving decision-making by government and public bodies, NGOs or the private sector.

Often, through this, the research leads to significant economic and other impacts, such as improved efficiency of public services and public spending or increased business productivity.

The creation of a new evidence-based resource for schools in England by researchers at **Durham University** has helped to ensure that billions of pounds worth of education spending is used effectively to support disadvantaged pupils. (See page 48)

Following the development of a new screening test for colorectal cancer by researchers at **Imperial College London**, the Government announced a £60 million investment over four years to incorporate the new test into the current nationwide programme. So far, this has led to colorectal cancer incidence being reduced by a third and mortality reduced by 43% in participants, with substantial savings for the NHS. (See page 43)

A better understanding of volcanic ash clouds following the Eyjafjallajökull eruption in 2010 meant that far fewer flights were disrupted or cancelled when Iceland's Grímsvötn volcano erupted in 2011. Direct cost savings from research by the **University of Bristol** were estimated to be nearly £3 billion, but there were also wider societal benefits as well as the research influencing policy in government and the private sector. (See page 41)

“Cancer Research UK does not often use the word ‘breakthrough’ but this (Imperial College colorectal cancer test) is one of those rare occasions when I am going to. It is extremely rare to see the results of a clinical trial which are quite as compelling as this.”

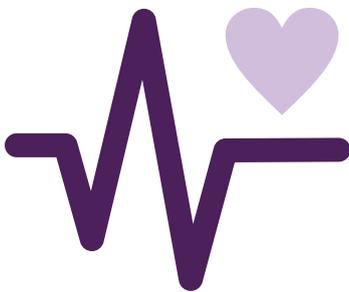
HARPAL KUMAR, CHIEF EXECUTIVE OF CRUK

“Research conducted at Bristol has made a very significant overall contribution that has improved our collective ability to react to a major volcanic event that threatens UK airspace.”

A CIVIL AVIATION AUTHORITY STATEMENT

4 Improving health and quality of life

Russell Group universities' research has an immense impact on the health of the nation and on the quality of life of citizens in the UK and overseas.



Research at Russell Group universities has led to the creation of new drugs and treatments, the development of new therapies and the prevention of disease, which benefits all UK citizens.

From the genetic sequencing of rare cancers to new treatments for cystic fibrosis, dementia and depression, Russell Group research is tackling many of the major health challenges facing the UK and countries around the world.

A third of our case studies evidence a positive impact on health.

As well as direct health benefits, medical research delivers:

- **Savings in treatment costs resulting from new treatments or vaccines**
- **Improved productivity and effectiveness of the workforce resulting from better training and education**
- **Sales and revenue from the development and marketing of new products**

Our universities work closely with businesses including pharmaceutical companies in order to develop new drugs that can offer substantial improvements in health and quality of life.

For example, discovery of neuroscience drugs has been improved through the application of human molecular imaging methods, initially pioneered by Imperial College London and expanded through collaboration between scientists at Imperial and GSK.¹⁰

Another example shows how research into new ways of preventing heart attacks at the University of Sheffield has contributed to the development of a new drug, ticagrelor, with AstraZeneca.

The research has supported the introduction of life-saving therapy as the new drug prevents one in five deaths in a broad spectrum of acute coronary syndrome patients compared to standard therapy. Of NHS Trusts in the UK that manage acute coronary syndrome, 50% have now adopted ticagrelor.¹¹

Researchers at the **London School of Economics and Political Science (LSE)** have helped pharmaceutical giant GSK to develop a better way to analyse vaccine trials using state-of-the-art statistical modelling techniques. Using this new approach, fewer patients are needed to detect whether a drug is safe or not, potentially speeding up vaccine development cycles.¹²

Influencing health policy

The effects of research in delivering education and training in health, and in improving health policy and guidelines, helps to boost the performance of the NHS and to deliver access to better health care provision for everyone.

Mathematics research at **Cardiff University** has engineered life-saving improvements to UK health care systems, lowering patient waiting times, increasing survival rates and improving patient care. So far, net efficiency gains of £1.6 million per year have been realised in one hospital emergency department alone (University Hospital of Wales). (see page 42)

Basic research in English literature at the **University of Sheffield** focusing on the interrelations between memory, trauma and narrative has influenced therapeutic practice and improved the mental health and well-being of patients in secure hospitals. (See page 47)

Research at **Newcastle University** has dramatically improved the quality of life for patients with Parkinson's as a result of changes to drug management. (See page 41)

1/3

Of the case studies in our sample showed a positive impact on health

“The recognition of Lewy bodies as a cause of dementia and its unique clinical characteristics have been made possible by the work and descriptions of the Newcastle group. This research has had a significant influence on clinical practice.”

NATIONAL CLINICAL DIRECTOR FOR DEMENTIA, NHS ENGLAND

5 Benefiting society and enhancing the cultural life of the nation

Research at our universities helps us understand our society and informs the infrastructure that supports social cohesion.



Basic research informs policy and practice across areas that touch all our lives directly, such as improvements to medical treatments and therapies and new innovations in education, and shapes our social environment through debate on topics such as preventing child abuse and safeguarding national security.

Nearly half (47%) of the case studies in our sample demonstrate impact on society, and of these over 35% originate from social sciences research.

For example, social sciences research has helped to engage the public and to advise policymakers and NGOs about new approaches to dealing with global challenges such as climate change and counter-terrorism.

Research into the development and transference of methods for climate readiness and resilience by **University College London** has engaged citizens and policymakers in the Global South, and in the UK (including the Department for International Development), to improve their understanding of climate change issues. The project is focused on improving assessment and management of the multiple environmental risks faced in the developing world – for example by providing a systematic evaluation for policymakers and funders of strategies to future-proof cities including Dhaka and Maputo.¹³

The application of a new sub-discipline of psychology, Investigative Psychology, by researchers at the **University of Liverpool** has led to new ways of managing risks such as terror attacks, prosecuting and convicting terrorists and preventing child sexual abuse. (See page 49)

However, we find that positive societal impacts are delivered from research right across the spectrum of disciplines covered by the REF 2014: 27% of the societal impacts identified in our sample were linked to biomedical sciences research and 24% to arts and humanities research.

Research conducted at Russell Group universities also helps us to preserve and appreciate our magnificent cultural heritage, playing a vital role in the UK's appeal to individuals, organisations and governments as a nation to visit and to do business with.¹⁴ And with that heritage, it is perhaps no surprise that research in archaeology featured strongly in the overall set of Russell Group impact case studies.

Research by the **University of Exeter's** inter-disciplinary Wetland Archaeology Group has transformed our understanding of the significance of wetlands. The researchers have played a major role in shaping management practices in the UK and internationally collaborating with English Heritage, the Department for Environment, Food and Rural Affairs, and others to preserve our archaeological and environmental assets.¹⁵

Over half (59%) of the case studies in our sample with a creative and cultural impact are in the field of arts and humanities research, with research in English language and literature and history resulting in some of the most significant cultural and creative impacts.¹⁶

Research conducted over several decades at the **University of Glasgow's** English department led to the compilation and publication of the Historical Thesaurus of the Oxford English Dictionary. The Thesaurus consists of the recorded vocabulary of English virtually in its entirety from c.700 AD to the present day and has so far generated £1.6 million from global sales. (See page 49)

Interdisciplinary research at the **University of Oxford** spanning historical studies, political science and sociology has focused on the history of how consumerism developed in China. The research has enabled both Western policymakers and business leaders, and a wider international public, to understand Chinese consumerism and its consequences better. It has influenced policy and practice in the private sector including at Royal Dutch Shell, Aviva and others, enabling these companies to adapt better to the changing expectations of individual consumers in China.¹⁷

47%

Of the case studies in our sample demonstrate an impact on society

59%

Of case studies in our sample demonstrating cultural impact were from arts and humanities research

“Old Weather has not only recovered a large number of historical observations, it’s also made the world’s climate scientists look at archives with new eyes... Working with the Zooniverse has been vital to our success.”

DR PHILIP BROHAN,
UK MET OFFICE

There are numerous examples of research in disciplines outside of the arts and humanities delivering cultural and creative impact often in ways that allow the public to engage with research in an interactive and enjoyable way.

The **University of Oxford’s** Zooniverse citizen science projects (developed from underpinning physics research) have engaged 1.4 million members of the public from 100 countries with astronomy and other areas of research. For example, a Zooniverse project with Cancer Research UK helped to crowdsource analysis of tumour samples, bringing analysis time down from 18 months to just three months. (See page 48)

The first demonstration of cloning from an adult mammalian somatic cell by **University of Edinburgh** researchers has stimulated rolling religious, ethical, cultural, political and scientific debates. Dolly the sheep has become a scientific icon entering the public and educational lexicons in addition to scientific ones. Dolly features in the Great Tapestry of Scotland; is a key exhibit at the National Museum of Scotland; her ‘death mask’ was exhibited at the Scottish National Portrait Gallery; she was the subject of an award-winning piece of poetry and even features in an episode of The Simpsons.¹⁸

University research has a close relationship with and major impact upon the UK’s cultural and creative industries – one of the most significant growth sectors of the UK economy, growing by 9.9% in 2013, higher than any other sector.

This impact comes through the creation of innovative new spin-outs and the provision of new technologies, as well as graduates with the skills and expertise across a range of disciplines to enter the cultural and creative workforce.

For example, fundamental blue-skies research into the control of body movement at the University of Oxford resulted in a successful mobile gaming spin-out, NaturalMotion, which has been sold for \$500 million.

The company’s technology creates some of the most hyper-realistic, intelligent animation in the video games industry.¹⁹

6 The importance of collaboration and interdisciplinary research

Increasingly, researchers work together within and across disciplines and with partners outside of academia in business, the public and third sectors to bring the best brains, knowledge and resources together to tackle challenging problems.

Collaboration in the UK and overseas is fundamental to delivering excellent research and 165 case studies out of our sample of 240 (69%) mentioned at least one collaborative partner.

Interdisciplinary research is often at the cutting edge, leading to novel approaches and often multiple benefits for the economy, environment and society as well as helping to advance knowledge.²⁰

Interdisciplinary research can lead to greater impact

Russell Group universities in particular are able to advance interdisciplinary and emerging areas of research as a result of the strength and breadth of their research excellence underpinned by the high quality of research staff, a critical mass of expertise and facilities and, in most institutions, a very wide range of academic disciplines.

But of course, they can only continue to do this where they have funding that allows them the freedom to explore new areas.

69%

Of case studies in our sample referenced at least one collaborative partner

72%

Of case studies in our sample involving three or more research areas generated economic impacts

The majority of research cited in our REF 2014 case study sample is interdisciplinary in nature (Chart 2):

- 59% of the sample (141 case studies) are underpinned by interdisciplinary research, spanning two or more research subject areas
- 25 case studies out of the sample (11%) are based on what could be termed 'highly' interdisciplinary research, spanning three or more different research subject areas

Case studies based on interdisciplinary research led to greater economic and technological impact than single discipline research.

59%

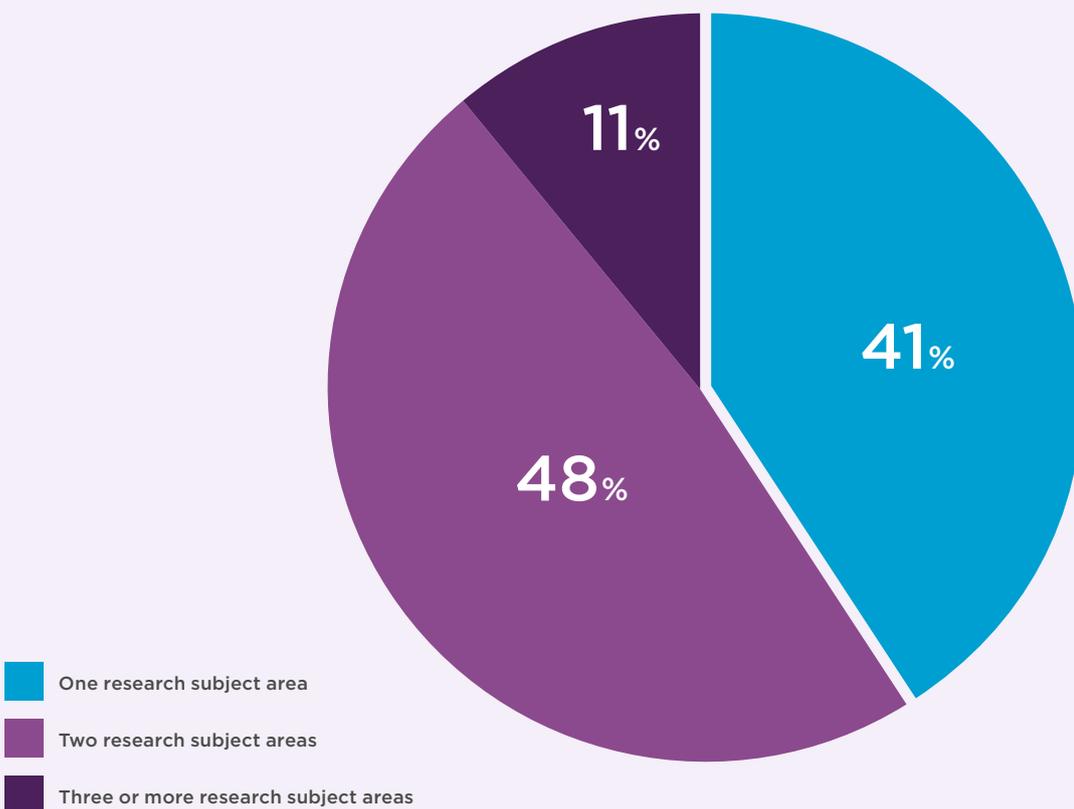
Of case studies in our sample are underpinned by interdisciplinary research

A new model for preventing violent crime developed by an interdisciplinary team of researchers in medicine, economics and psychology at **Cardiff University** has helped achieve big cuts in community violence including:

- Halving the number of violence victims treated in Cardiff Emergency Departments between 2002 and 2013
- Reducing hospital admissions and violence recorded by the police by over 40% in Cardiff compared to similar UK cities
- Saving around £5 million per year on Cardiff's health, social and criminal justice costs

The 'Cardiff Model' is an entirely new way of preventing violence in which data from hospitals is shared with the police and local authorities, and is now being rolled out across the UK with over two-thirds of Emergency Units and Community Safety Partnerships across the country adopting this approach.²¹

Chart 2: Proportion of case studies in our sample that are interdisciplinary



Of the case studies spanning two research subject areas, 44% had an economic impact and 22% had a technological impact, but where three or more research subject areas are involved, this increases to 72% delivering an economic impact and 40% having a technological impact (Chart 3).

The instances of interdisciplinary research range across disciplines and there are many examples of researchers collaborating across very different subject areas, often producing unexpected and life-changing results.

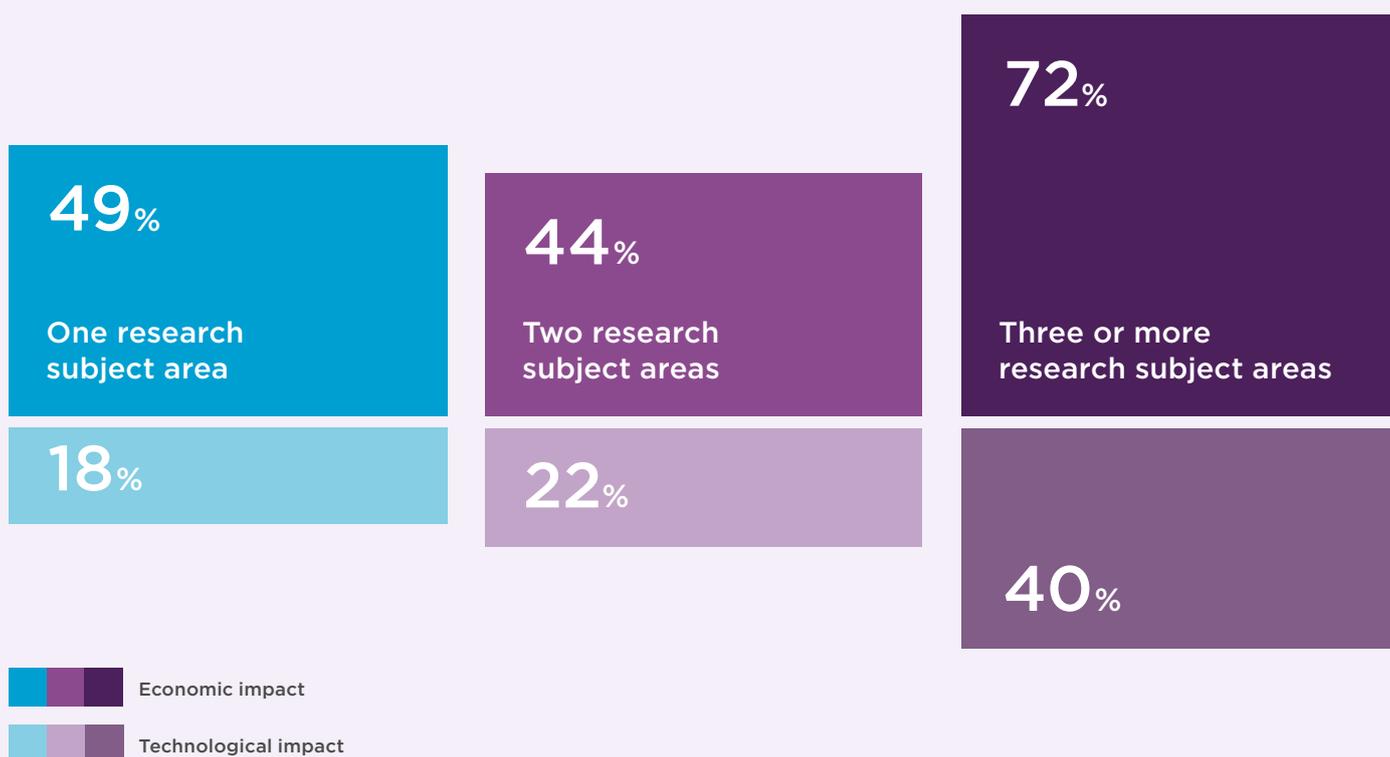
Researchers in the School of Engineering and Materials at **Queen Mary University London** worked alongside chemistry experts and surgeons to develop and bring to market synthetic bone grafts that now command 10% share of the global market. (See page 45)

NIRI Ltd – a successful **University of Leeds** spin-out company – is using Leeds’ research to sell and develop non-woven materials that were found to have major applications in industrial, health care and consumer markets. The underpinning research brings together PhD research students and research fellows with many different backgrounds, including textiles, materials science, chemistry, mathematics, design, nursing and engineering. NIRI’s global client base has grown rapidly with annual sales revenue at around £1 million. Among various innovations, the company has developed a revolutionary mosquito net which is effective against resistant mosquitoes, offering a longer-term solution to preventing the transmission of malaria.²²

“Entrenched global health problems, such as malaria, require innovative solutions... this research could produce an important new tool to fight malaria in the world’s poorest countries.”

DIRECTOR OF THE BILL & MELINDA GATES FOUNDATION’S INFECTIOUS DISEASES PROGRAMME

Chart 3: Proportion of single and interdisciplinary research case studies producing economic and technological impacts



317

Key collaborative links identified across 240 case studies

47%

Of physical sciences and engineering case studies in our sample had businesses as the primary beneficiary of the research

Collaboration and critical mass drive growth

Our universities work proactively to build and facilitate collaborative relationships with a range of partners including businesses, government, other universities and research organisations. They also engage with users of research including the public at a local, regional, national and international level in order to maximise the benefits of their research.

In particular, our universities are focused on delivering value from expensive capital investments, enabling the sharing of facilities and equipment with each other and with industry to enhance access and reduce duplication.

Our analysis shows that Russell Group universities work with a broad range of collaborative partners to produce excellent research and impacts that have outstanding reach and significance:

- **Within our sample of 240 impact case studies, 317 key collaborative links were identified**
- **The most common collaborative partners include other universities in the UK and overseas (33% of collaborations in the sample), public sector organisations (22%) and private sector companies (20%)**

With a critical mass of research excellence across a broad span of disciplines, Russell Group universities are well-placed to build relationships with business and adapt to the evolving needs of business partners (Chart 4 overleaf).

The development of polymer technology resulting from research at the **University of Warwick** is being used for therapeutics and nanomedicine, leading to ongoing collaborations with numerous industry partners including Syngenta and BP. (See page 44)

Research at the **University of Birmingham's** Chemical Engineering department has led to a wide range of new low-fat food products being developed by multinationals including Unilever, Kraft, PepsiCo and Cargill. The research is also contributing to reducing the incidence and health-related costs of obesity. (See page 40)

Our universities have the capacity to meet the strategic needs of businesses across a range of areas of activity, combining teaching and professional development with interdisciplinary research, for example. This enables them to introduce new areas of academic expertise to partnerships as the needs of business evolve.

The **University of Nottingham's** unique on-campus test-site of seven 'Creative Energy Homes' is helping researchers from many disciplines to collaborate with a range of partners from small builders to major multinationals. World-leading research is investigating the link between occupant behaviour and energy consumption as well as developing the next generation of smart-grid energy technologies. (See page 43)

Collaboration with business is a core part of the Russell Group mission and research conducted at our universities is proven to benefit private sector companies directly. Businesses were identified as the primary beneficiary of the research in 20% of the impact case studies in our sample - and this rises to 47% in physical sciences and engineering.

Collaborative research between the **University of York's** Structural Biology Laboratory and Novo-Nordisk, the Danish multinational pharmaceutical company, has led to the development of new insulin drugs used to treat millions of diabetics worldwide with drug sales of over \$6 billion annually. (See page 39)

The **University of Warwick's** Ultrasonics Group has developed cutting-edge techniques of non-destructive testing (NDT) – the ability to evaluate the properties of a material, component or system without causing damage – to address particular industrial needs. Warwick researchers have worked in collaboration with over 40 companies ranging from SMEs to multinationals across a range of sectors from heavy manufacturing to nuclear energy and power generation in order to assess NDT methodology and develop equipment for use. A successful spin-out company, Sonemat, has commercialised the technology developed by the research group.²³

Our extensive engagement with business and other private sector funders of research enabled our universities to attract £903 million in contract research in 2013-14 (76% of the total to UK universities) in addition to collaborative research arrangements where public funding is also involved.

A recent report for the Department for Business, Innovation and Skills (BIS) indicates that for every additional £1 of UK public investment in R&D, Russell Group universities leverage almost three times as much private funding as other universities.²⁴

This activity directly benefits the UK, attracting vital foreign direct investment, supporting high-value and high-skill research jobs, as well as underpinning the creation of new knowledge and innovations that deliver major social and economic benefits.

There is evidence that university engagement adds very significant value to business R&D activity, and in collaborative R&D projects can more than double the return on public investment:

- **Innovate UK projects with two or more academic partners deliver £9.67 per £1 invested; those with no academic partners deliver £4.22 per £1 invested²⁵**

Collaborating to improve public services

Russell Group universities play a key role in delivering efficiencies for public services and major public projects across the country through collaborating with a range of public service partners at local, regional and national level to maximise the impact of public investment.

A collaboration between Wrightbus and **Queen's University Belfast (QUB)** drove the development of the advanced eco-friendly hybrid diesel-electric bus and won the company the 'New Bus for London' contract worth £230 million, replacing the traditional Routemaster. QUB research into engine performance simulation has allowed designers to assess how a bus performs during the whole drive cycle in a city – with its numerous stops and starts and as it accelerates and slows down. Transport for London has said of the new buses that they 'improve the journey experience of passengers, enhance air quality, reduce vehicle noise and cut emissions, with associated health benefits.'²⁶

1/3

Of case studies in our sample referenced collaboration with other universities in the UK or overseas

76%

Of the total amount of contract research to UK universities is secured by Russell Group universities

“Cambridge University’s research is at the heart of government policy on making the country resilient to climate change.”

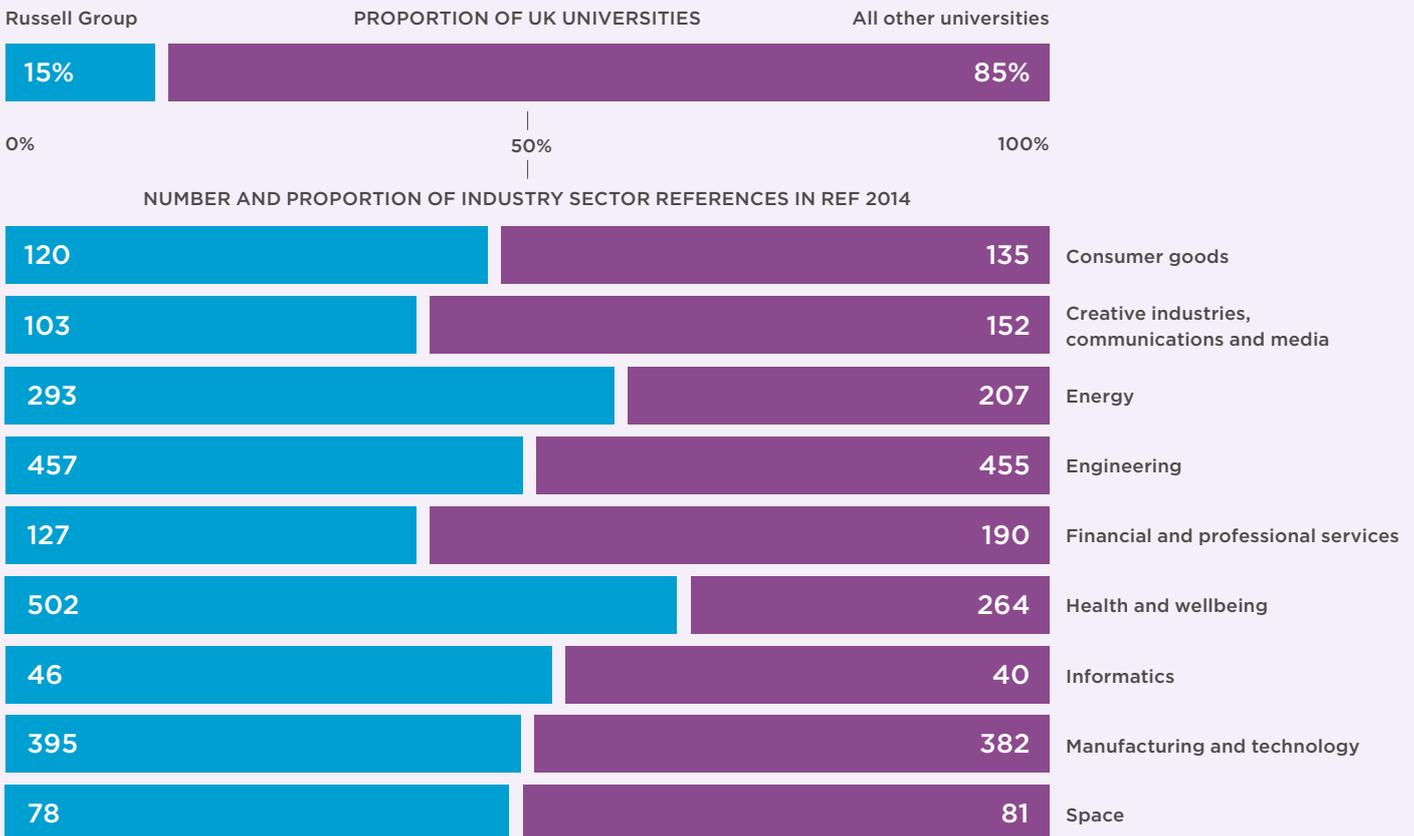
NHS’S ACTING DIRECTOR OF THE ESTATES & FACILITIES POLICY DIVISION

Award-winning innovations in zero-carbon design developed by the **University of Cambridge** are being used to help hospitals deal with the particular challenges associated with hot conditions, including deaths during heatwaves and the dispersal of airborne germs. Cambridge’s research will help to ensure hospital buildings have fresh air and stable temperatures whilst avoiding costly replacement of NHS stock. This will mean many hospitals can be equipped to cope with climate change relatively cheaply and easily. Cambridge researchers are currently advising on the redevelopment of Watford General Hospital and the building of the new Papworth Hospital.²⁷

The Olympic Park, Crossrail, St Pancras Eurostar Terminal and Heathrow Terminal 5 are all examples of major construction endeavours that have benefited from a new approach to project management pioneered by **Imperial College Business School**. Researchers have devised a new ‘systems integration’ model, designed to enable firms to improve the management of mega-projects and ensure that the delivery of such projects leads to better organisational capabilities. The model has now been fully adopted by firms including Laing O’Rourke and the lessons from projects such as Crossrail will be transferred smoothly to future mega-projects that will have a lasting impact on the UK economy.²⁸

Chart 4: Engagement with key industry sectors in REF 2014 by number and proportion

Russell Group universities make up just 15% of higher education institutions in the UK, but account for a much higher proportion of university-business engagements across a range of sectors.



7 Delivering global impact

Russell Group universities work with partners around the world to tackle global research challenges. As well as the direct benefits this brings for the UK's research standing and reputation, it also helps to strengthen the UK's soft power influence overseas.

International reach is a key aspect of the critical mass of research excellence at our universities, enabling them to attract the best talent from within the UK and from overseas.

There is clear evidence that research conducted at Russell Group universities has had a positive impact in almost every country in the world.²⁹

Almost 80% of all impact case studies in our sample demonstrate an impact which is international in nature and across the full 3,256 case studies submitted by Russell Group universities, there were 7,545 unique references to the research delivering impact in countries overseas.

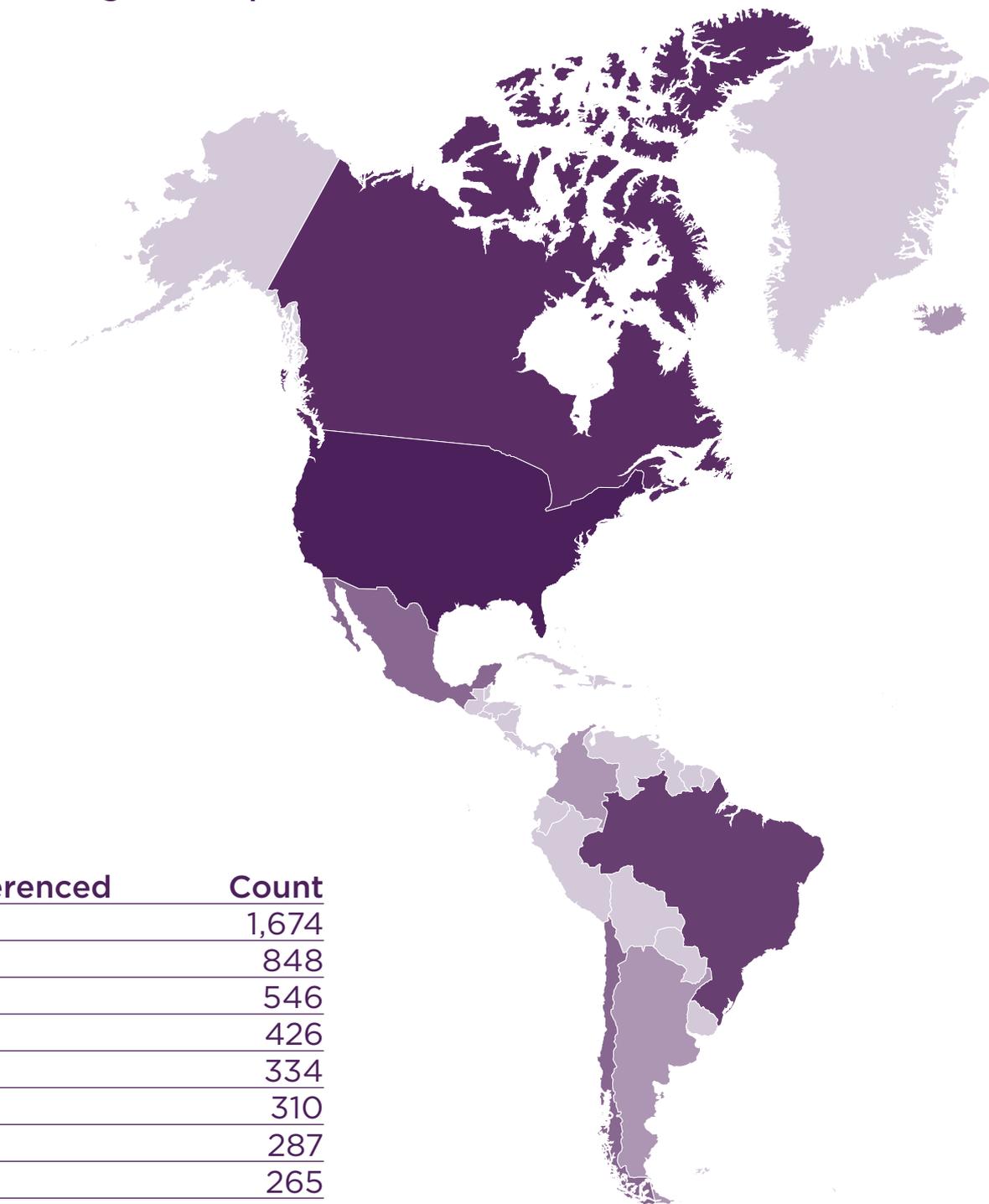
The table overleaf (Chart 5) shows the top ten countries where Russell Group universities have identified the most instances of their research making an impact on the economy, society, culture or policy in that country.

The **University of Glasgow** has led landmark clinical trials of three drugs that reduce mortality, reduce hospitalisation rates and improve quality of life for patients with heart failure. These trials led directly to revision of clinical guidelines on heart failure management globally (including in Europe, USA, UK, Australia and Canada). The Glasgow researchers also encouraged the introduction of specialist heart failure nurses that are saving the NHS an estimated £8 million per year.³⁰

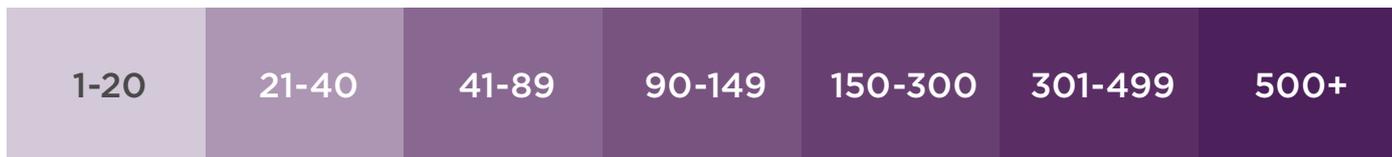


Chart 5: Mapping direct global impacts from Russell Group research

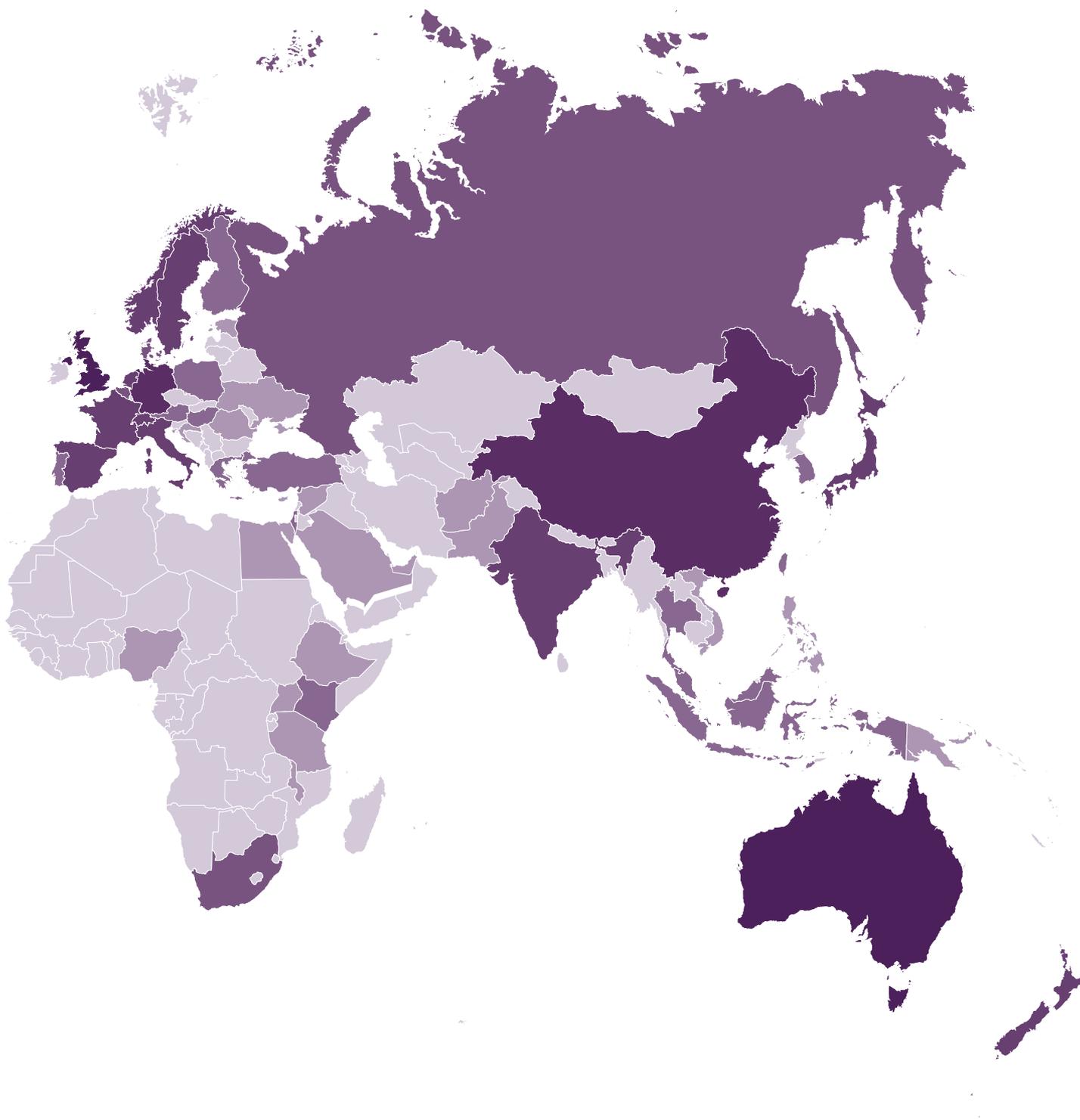
This map highlights countries where research impact is mentioned explicitly in Russell Group university case studies. This is in addition to case studies identifying broader global impacts.



Top 10 countries referenced	Count
UK	1,674
USA	848
Australia	546
Canada	426
Germany	334
China	310
Netherlands	287
France	265
India	234
Japan	223



Numbers of explicit references to countries



50%

Of all overseas impact highlighted in REF 2014 case studies stems from research at Russell Group universities

185 countries

Where research at Russell Group universities is known to have had an impact

In most cases, research that has a high impact internationally, will also have direct positive impacts for UK citizens and the economy.

Research undertaken on the physiological effects of the electromagnetic fields generated in magnetic resonance imaging (MRI) at the **University of Nottingham** has been used as evidence by the European Commission to avoid introducing major restraints on the use of MRI or significant modification costs being applied to the machines. The findings have enabled the continued operation of MRI scanners across Europe, safeguarding the access to MRI for 500 million people. The economic benefits arising from the manufacture of MRI equipment were also secured. The work has resulted in impact on public policy, the economy and health care. Nottingham has long been at the centre of developments in MRI techniques with much of the early pioneering work done by Sir Peter Mansfield who was awarded the Nobel Prize for his part in the development of MRI in 2003.³¹

The impact generated by excellent research at Russell Group universities accounts for over 50% of all overseas impact highlighted in the REF 2014 from research at UK universities. In other words, research conducted at Russell Group universities has a disproportionately high impact in other countries, as well as in the UK, compared to research conducted at other UK universities.

Impact in developing countries

Whilst the top collaborative partner countries are large, developed and often English-speaking nations, research at Russell Group universities has had a significant impact in developing countries too.

Through research into social, economic and structural barriers to maternity care carried out at **King's College London**, improvements have now been made to the delivery and design of maternal care in countries including Tanzania, Burkina Faso, Ghana, Bangladesh, Armenia and Ethiopia. (See page 50)

Research in biological sciences at the **University of Manchester** has led to conservation activities and biodiversity training in Sumaco National Park, Ecuador, including the creation of a research station which actively promotes the conservation of cultural identity in the local Payamino community as well as promoting gender equality. The research has also influenced policy development in the Ecuadorian Ministry of the Environment on the use of undeveloped forest.³²

Many of the challenges society faces are highly complex and global in nature, requiring international as well as multi-disciplinary approaches. In all areas of research and innovation, international collaboration is increasingly important, and research-intensive universities are at the leading edge in advancing knowledge and its application.

Critical mass enhances international collaboration

A recent analysis commissioned by the Department for Business, Innovation and Skills found that the UK occupies a central position in the global network of collaborative partnerships, with UK universities exhibiting high levels of international collaboration as well as researcher mobility overseas.

Russell Group universities have also been very effective at using their international links to tap into sources of funding that would otherwise be unavailable:

- **UK universities are highly internationalised in their outlook: 48% of all UK research is internationally co-authored (second only to France at 50% and ahead of the US, China, Germany and Canada among others)³³**
- **Through collaborations with European researchers, Russell Group universities secure over £500 million in research funding a year from EU sources, which accounts for 14% of the universities' collective research grant income³⁴**

Antibiotics resistance causes 25,000 deaths every year and costs over €1.5 billion in health care expenses and productivity across Europe. Research at the **London School of Economics and Political Science** created new incentives for investment in antibiotics R&D. The European Commission and the US Biomedical Advanced Research and Development Authority have both announced major commitments to antibiotic research as a result. (See page 46)

The critical mass of excellence and interdisciplinary power centred in Russell Group universities enables them to attract the most successful partners and collaborators from around the world. In turn this enriches the work they can do and creates a virtuous circle that enhances research excellence.

It is not possible to identify the full number of international collaborations within our sample of case studies as international co-authors are not necessarily named. However, there are numerous examples of international collaborative links which have allowed our universities to work with the best researchers overseas, access regional and local expertise and equipment, and so maximise the benefits to the UK.

University of Edinburgh researchers working in collaboration with Canadian scientists have discovered benefits from reducing the use of blood transfusions in intensive care and surgery, saving over £100 million annually across the UK, reducing patient risk through unnecessary exposure to blood transfusions, and ultimately, saving patients' lives by conserving limited blood supplies. (See page 47)

As a result of research at the **University of Manchester** mapping the socioeconomic value chain of cocoa, Cadbury launched the £45 million Cadbury Cocoa Partnership to support cocoa farmers in 2008. This was extended in 2012, under the 'Cocoa Life' programme, a \$400 million initiative to support cocoa farmers from 2012 to 2022. Spill-over impacts including a more than twelve-fold increase in fair trade cocoa products sold in the UK over a four year period, from £26 million in 2008 to £321 million in 2012. The research was undertaken in collaboration with in-country research partners who had detailed local knowledge in Ghana, the Dominican Republic and India.³⁵

48%

Of all UK research is internationally co-authored

£500 million

Per year secured in research grants and contracts from EU sources by Russell Group universities

1st

UK ranked top in Soft Power Index 2015³⁶

7,545

Unique references to Russell Group research delivering impact overseas across the full set of case studies

Soft power

An important spill-over impact from all of these international research connections is the breadth and depth of soft power influence this creates for the UK globally. Our research helps local communities, aid agencies and other international organisations.

We work with governments to improve policy-making and to introduce new and improved public services in education, health and the environment; while our cultural understanding enhances cooperation and can help to drive social progress.

Critically, we have academics with in-depth knowledge and local connections that can provide invaluable help for the UK in responding to major incidents internationally, such as the recent earthquakes in Nepal and the Ebola outbreaks in West Africa.

While these examples are too recent to have featured in REF 2014, they show how leading researchers can move fast to address challenges as they emerge:

Similarly, researchers at **Durham University** working with the British Geological Survey have used satellite imagery to map and characterise over 3,000 landslides triggered by the Nepal earthquake in April 2015, helping relief efforts by showing where roads or rivers are blocked and where villages have been affected by landslide debris.³⁷

Researchers at the **University of Bristol** and the **University of Edinburgh** have participated with others throughout the EU and in Guinea in a €1.8 million EU study concerning the effectiveness of current diagnostics and treatment for Ebola.³⁸

8 From underpinning research to impact

Sustained investment is needed to create the environment in which world-leading research can flourish.

Impact can be delivered over a relatively short timescale, but only where expertise has been developed through long-term, fundamental research.

The process of undertaking and developing research to the point where it has the potential to impact on the economy, health, society or culture can take many years.

The exact impact of blue skies research cannot be predicted in advance, but even where research sets out to explore an idea with obvious potential impact, it may take years of further investigation to develop the idea to the point where impact is able to be realised.

Analysis of our case study sample shows that the 'time-to-impact' from the start of research (measured by project start date, initial publication date or initial grant date) to the delivery of the first main non-academic impact is on average eight years, with time differences ranging from less than one year to 29 years.³⁹

Research that is closer to market – for example, conducted with industry or public sector service delivery partners – can in some cases deliver impact much more rapidly, such as important technological or management solutions. But the ability of our universities to do this invariably rests on the expertise developed through much longer-term, often fundamental research.

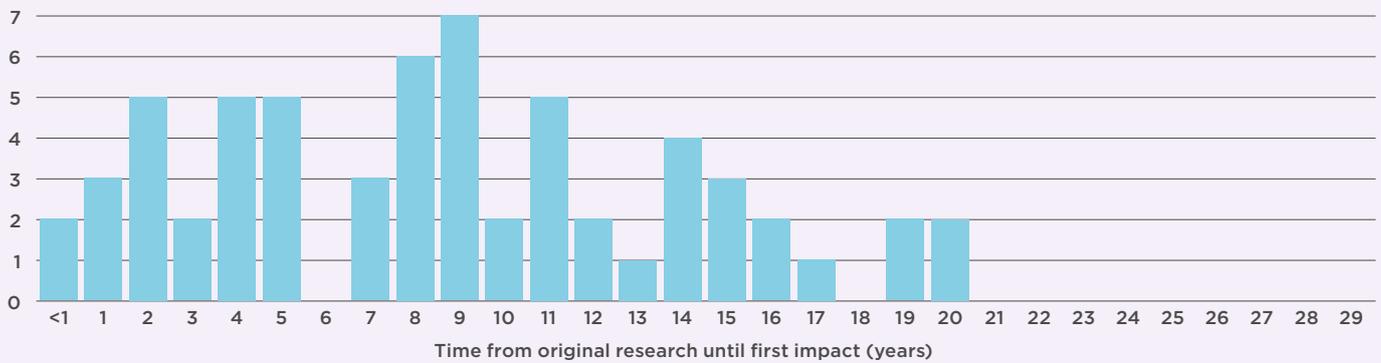
In fact, there are many examples where the research supporting a specific REF 2014 impact case study will itself have been underpinned by a body of research carried out over many years previously. The length of this pre-project lead-in research is very difficult to assess.

8 years

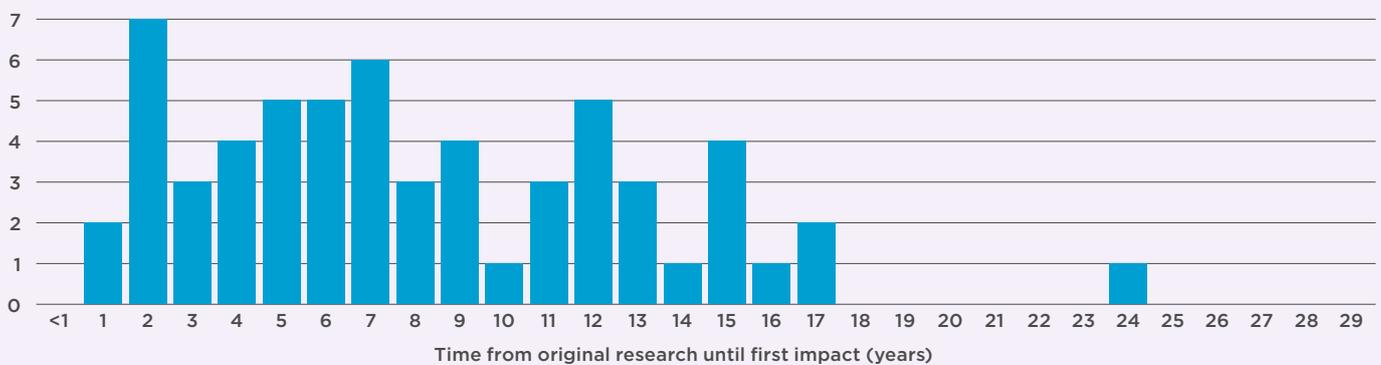
Average 'time-to-impact' identified in our sample

Chart 6: Time-to-impact across discipline areas in our sample of case studies

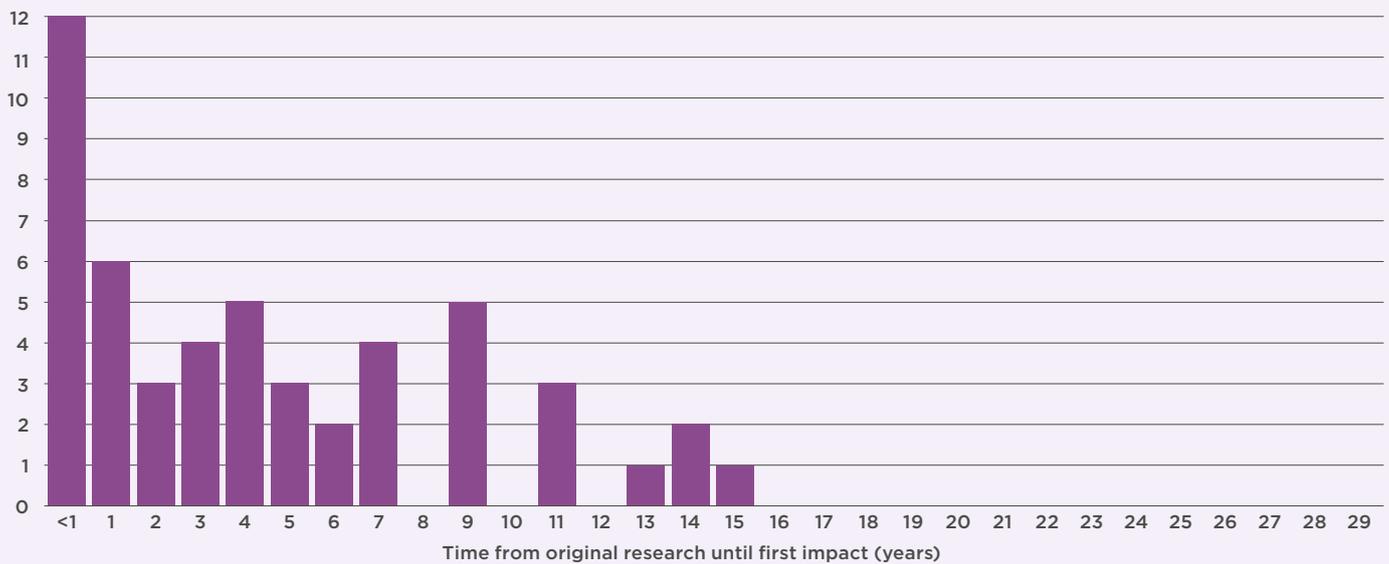
BIOMEDICAL SCIENCES



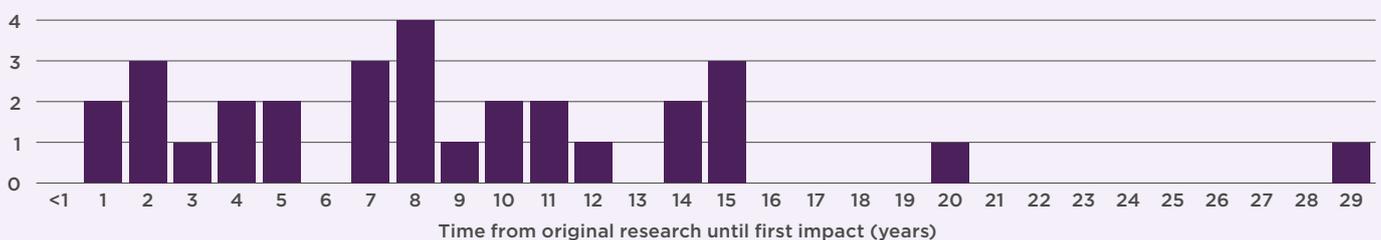
PHYSICAL SCIENCES AND ENGINEERING



SOCIAL SCIENCES



ARTS AND HUMANITIES



Time-to-impact

For both biomedical sciences and arts and humanities research, the average time-to-impact identified in our sample is nine years.

The average time-to-impact for social sciences research is significantly shorter at four years (Chart 6). Indeed, 41% of cases studies involving social sciences research in our sample reported impact in two years or less, compared to just 15-17% across other disciplines.

Our analysis shows a broad correlation between average time-to-impact in different disciplines and time-to-impact by type of impact.

For example, a shorter time-to-impact can be seen in the social sciences research case studies, which can be linked to the fact that the most common type of impact here was on policy.

Informing or influencing decisions made by government or other organisations can often take effect over a relatively short period of time, especially if researchers have been commissioned by public policymakers or business with the specific aim of feeding into policy development.

By contrast impacts such as the development of new drugs stemming from medical research or the formation of new technologies, most commonly resulting from physical sciences and engineering research, will generally take longer to achieve.

It is important to note that the benefits typically do not stop at the point of first impact. In the vast majority of our sample of case studies the research has led to ongoing impact with further benefits being delivered well after the eight-year mark.

The **University of Warwick's** long-standing collaborative relationship with Jaguar Land Rover has led to the establishment of the £100 million National Automotive Innovation Campus (NAIC) to enable academic and industry teams to work together and address the shortage of skilled R&D staff in the automotive supply chain.⁴⁰

Our analysis indicates that 89% of the impact case studies in the sample have an impact that is still ongoing. Indeed, we assessed all case studies in some specific disciplines, such as clinical medicine, biological sciences and chemistry as having ongoing impact.

Research in these areas often leads to improvements in treatments and new technologies which continue to impact on quality of life in the long term.

89%

Proportion of case studies in our sample with ongoing impact

41%

Of case studies involving social sciences research in our sample reported impacts delivered in two years or less

9 Supporting excellent research

Public investment is critical to supporting excellent research and taking this on to deliver significant impact.

20%

The average return public funding for research delivers after only three years

Our universities are adept at leveraging public investment to maximise its impact on the UK's economy and productivity, attracting additional income from businesses and other sources.

Direct investment in research through the Research Councils has been shown to deliver a greater market sector productivity impact than other types of spending (such as on civil or defence R&D). The rate of return on investment is high and research suggests the wider spill-over effects of Research Council funding are also likely to be very significant.⁴¹

As the Research Councils primarily support basic research, it follows that basic research has a significant impact on market sector productivity and delivers a high rate of return – which is exactly as we have seen in our analysis of the REF 2014 impact case studies.

The provision of public funding for excellent research also enables leading universities to strengthen their links with businesses and contribute to productivity growth in the private sector, delivering an average return of 20% after only three years.⁴²

As outlined above, Russell Group universities leverage almost three times as much private funding as other universities in the UK per £1 of public investment in R&D, demonstrating that public funding for research is most effective when distributed on the basis of true international excellence, with a clear recognition of the importance of critical mass.

Opposite: Businesses engaged with in the full case study set through 2,168 collaborations.



70%

The proportion of long term economic growth accounted for by innovation

2,168

Links to business in REF 2014

Importance of the dual support system

The UK's dual support system plays an essential part in sustaining research of the highest quality and needs to be maintained. Research suggests that a mix of funding sources allows institutions to be more flexible and adjust to changing environments.⁴³

Institutional block funding, such as quality-related (QR) funding currently provided by the Higher Education Funding Councils, provides universities with a stable basis for research activities, helping them to acquire funding from other sources and protecting institutional autonomy in the selection of research projects. In particular this means that expertise can be built up in new fields, investments can be made in new equipment and facilities, and postgraduates and early career researchers can get the essential training and development they need.

Project-based funding is complementary to this with a focus on responsiveness to socio-economic needs. Responsive mode grants through the Research Councils, for example, are particularly important.

Whilst not all of the case studies in our sample provided information concerning funding sources for the research conducted, of those which did (65% of the 240), the value of research grants received over the last twenty years was £435 million in total (an average of £2.8 million per case study) – with a broad mix of funding from central government, charities, industry, other parts of the public sector and also international sources.

Multiple funding sources were identified in nearly half of the sample of case studies for which funding information was provided, demonstrating the importance of a breadth of different income streams for research, particularly where a body of work is supported by a number of different funders at different stages of the research development.

Funding was also typically spread over a period of time, highlighting the importance of ongoing funding, rather than one-off funding just at the start of a project.

Innovation has been, and will continue to be, a key driver of UK growth and economic prosperity, accounting for up to 70% of economic growth in the long term.⁴⁴

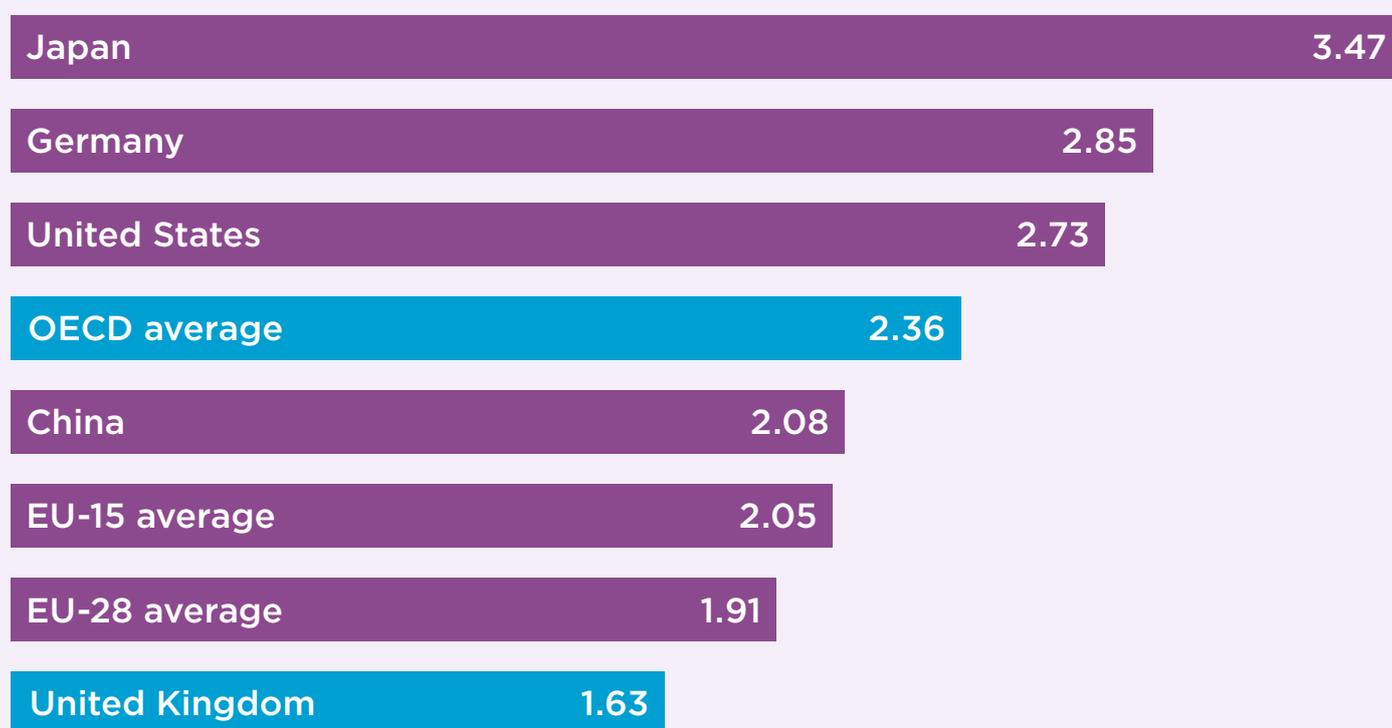
One of the UK's key strengths is in university-business collaboration and innovation in the higher education sector, which is reflected in the UK's consistently high ranking on this in World Economic Forum reports over many years.⁴⁵ Our strength in collaboration with business is also demonstrated in many of the impact case studies highlighted in this report.

Whilst the UK maintains a world-leading position in research excellence, public investment in our research base and universities is far lower than our international competitors. This underinvestment means it is increasingly difficult for the UK's leading universities to compete with better-resourced institutions internationally.

Indeed, the UK currently spends less on science than almost all of its main competitors (Chart 7)⁴⁶:

- **In 2013, the UK spent 1.63% of GDP on R&D, compared to 2.08% in China, 2.73% in the US and 2.85% in Germany, with the average in the OECD at 2.36%**
- **Whilst the UK has not committed to a target for investment in R&D, the European Commission's strategy for growth includes a target for 3% of Europe's GDP to be invested in R&D by 2020. Similarly, by 2020 China aims to spend 2.5% of GDP on R&D**
- **In monetary terms, the UK spent under 9% of the United States' annual investment in R&D in 2013, also spending less than China, Japan, Germany, Korea, France, and Russia**

Chart 7: International comparison of spending on R&D as a proportion of GDP, 2013



Countries such as China, France, Germany and South Korea have invested strategically in a small number of research-intensive universities in order to maintain and enhance their research and learning infrastructures, making such institutions more attractive as partners for multinational R&D businesses. China in particular has reaped the benefits of increased investment in science and research, growing its share of global research production from 5.6% in 2003 to 14% in 2012 and the number of research citations (long below world average) is steadily improving.

By comparison, the essentially flat-cash settlement for the science budget in the UK since 2010-11 has meant that the value of public investment in science and research has been steadily eroded over time as a result of inflation. If a flat-cash settlement is continued to 2019-2020, the value of the ring-fenced science budget will have declined by over £600 million per annum since 2010.

Securing future growth through investment in research

We have a world-class base of research in our universities to deliver future growth, but that future needs to be assured with a long-term commitment to invest in excellent research and innovation.

This report has shown that high quality research is strongly correlated with high quality impact, and that public investment to fund excellent research at the UK's leading universities is critical in order for us to continue delivering this impact for the future.

Future economic growth and the creation of new jobs, improved quality of life, health and well-being for the nation's population, and the delivery of wider cultural and social benefits all depend on our ability to conduct the sort of excellent research that we have highlighted throughout the report.

Case studies

Our case studies demonstrate how excellent research delivers substantial benefits for the UK, and global impact too.

UNIVERSITY OF MANCHESTER

Graphene: the transformative new material driving economic growth

“Carbon, the basis of all known life on earth, has surprised us once again.”⁴⁷

The discovery of graphene at the University of Manchester has led to a rapid global take-up of new technologies, with at least \$200 million in recent commercial investment being made in graphene production across 210 companies.

Graphene, a form of carbon, is only one atom thick but tougher than diamond and a better conductor than copper. Basic research started in 2001 by Manchester researchers Andre Geim and Konstantin Novoselov on properties of thin materials demonstrated the potential of graphene to underpin

huge technological changes across an incredibly broad range of industries. This work led to their award of the Nobel Prize in Physics in 2010.

Blue-chip companies including IBM, Samsung, BASF, Nokia, Sandisk, and Fujitsu are now actively developing graphene-based technologies. Between 2008 and 2012, 7,740 patents were published for everything from new materials to innovative electronics, and the first set of graphene-based products to reach the market are already generating revenues exceeding \$10 million per month.

The commercial activity surrounding graphene has been matched by global shifts in public research and innovation funding of at least

\$2.4 billion. A 2011 study found significant funding for graphene-related R&D in 26 European countries, while the USA, South Korea, Singapore and China have also committed substantial funds to graphene research and commercialisation.



UNIVERSITY OF YORK

Fast-acting insulin drugs transforming diabetes treatment

Diabetes costs the NHS over £1.5 million an hour or 10% of the NHS budget for England and Wales⁴⁸

New 'fast-acting' insulin drugs, used to treat millions of diabetics worldwide and which generate billions in sales annually, stem directly from work carried out in laboratories at the University of York.

Diabetes is a chronic disease that is becoming a growing burden in both developed and developing countries. Type 1 diabetes requires a daily dose of the hormone insulin to regulate the body's blood sugar levels.

Research at the world-class York Structural Biology Laboratory (YSBL) led to the development of fast-acting insulin.

Launched in 1999, these drugs mean diabetes patients need only administer one daily intravenous injection and are now the standard treatment for Type 1 diabetes for 35 million patients worldwide.

YSBL's extensive collaborative research with Novo-Nordisk, the Danish multinational pharmaceutical company, saw combined sales of the insulin drugs totalling over \$6 billion in 2012 alone.

Insights from YSBL's research are also expected to impact on the design of further forms of insulin in years to come.

This includes the prospect of insulin that can be taken orally, which could transform diabetes care once again.



UNIVERSITY OF CAMBRIDGE

Leading the world with genome sequencing

“Genome science will have a real impact on all our lives – and even more, on the lives of our children. It will revolutionise the diagnosis, prevention and treatment of most, if not all, human diseases.”⁴⁹

Genome sequencing technology developed at Cambridge has generated an annual turnover of over £750 million from an initial public investment in basic research of only £274,196. This means that for every £1 of public investment, the research now delivers £2,735 every year, even without counting the wider economic and social benefits.

The Solexa-Illumina genome sequencing technology, which accounts for 66% of the global sequencing market, is a method for decoding DNA which originates from 'blue-skies' DNA research started in 1995 in the department of chemistry at the University of Cambridge. It has led to the creation of new companies including Genome England, Personalis, Foundation Medicine and Immune System Profiling and to the development of more personal genomics services.

Use of the technology has the potential to have a profound impact on human health. For example, allowing the sequencing of rare cancers to be mapped for more effective treatment.

Over 4,000 publications and studies employing Solexa-Illumina sequencing are having a direct influence on public policy. In 2012, the UK government announced a new framework to support the development of genomic and bioinformatics technologies, which have the potential to improve patient care and generate significant economic value in the UK. The contribution of Solexa sequencing was cited as one of the reasons for the new framework.



UNIVERSITY OF BIRMINGHAM

Tackling the obesity challenge with novel low-fat food products

Over half the UK population could be obese by 2050, with costs to the NHS, business and society projected to reach around £60 billion a year⁵⁰

There is no simple solution to the obesity crisis, but what you eat can make a real difference.

Multinational food companies have used research at the University of Birmingham's chemical engineering department to develop new ranges of low-fat foods that are both highly profitable and are helping to tackle obesity.

The key to success has been in the microstructure engineering of soft solids to create foods such as spreads, cheese and mayonnaise that are low in fat but which retain the texture and taste expected by consumers.

Food giants Unilever, Kraft, PepsiCo and Cargill have used Birmingham's breakthrough work to develop and market a greatly expanded range of products. This has generated significant sales and profits in the multi-billion pound food sector, both in the UK and the US.

Household brands such as Flora, Hellman's and Walkers all use the new technology, which has also helped to make the manufacturing process more efficient.

As well as applying research that has been carried out already, industry partners have continued to invest in this research area, showing the value placed on this basic research by businesses.



UNIVERSITY OF EXETER

Improving the lives of those with depression

Around 350 million people live with depression globally which, according to the World Health Organisation, is the leading cause of disability worldwide

The UK is leading the fight against depression with new approaches to treatment thanks to the University of Exeter. Their research into the accessibility of low-cost, evidence-based treatments for depression has changed how we treat the condition.

It provided the rationale for a £700 million expansion by the NHS of its Improving Access to Psychological Therapies (IAPT) programme.

This England-wide programme offers patients psychological therapies as a first-line treatment for depression. In the first three years over a million people entered treatment, with 65% significantly improving and recovery rates of over 45%.

The vast majority of patients received treatments established and delivered through the research programme at Exeter. The research has also informed training provision, with the Exeter research team publishing the national curriculum and educational guidebooks for psychological wellbeing practitioners trained as part of the IAPT.

In addition to the health benefits and improvements to mental health service provision, the Exeter research is making a significant economic contribution. The new approaches to treatment have moved over 45,000 people off sick pay and benefits in the first three years of the IAPT programme, helping to improve productivity and reducing health care costs.



Revolutionising drug management for patients with dementia and Parkinson's

One in three people born this year could be affected by dementia in their lifetime. Costs are predicted to treble to over £50 billion in the next 30 years⁵¹

The Prime Minister has set up a 'Dementia Challenge' to transform dementia care, support and research by 2020.⁵²

Drug trials at Newcastle University have risen to this challenge with dramatic improvements in the quality of life of millions of dementia patients.

Research at Newcastle led to the application of cholinesterase inhibitors (CHEIs), originally licensed for use in Alzheimer's disease, to treat two other types of dementia – dementia with Lewy bodies (DLB) and Parkinson's disease.

This has revolutionised treatment for these patients, allowing the disabling symptoms of these diseases to be managed for the first time. Researchers found that CHEIs significantly reduce psychiatric symptoms and improve cognition, without substantial risk of side effects.

Where previously there had been no effective treatments, CHEIs are now recommended in national and international guidelines as a treatment for the cognitive and psychiatric symptoms associated with both DLB and Parkinson's disease.



Reducing the economic damage from volcanic ash clouds

Over a dozen volcanoes erupt more or less continuously around the world and another 20 are active every week, creating an ongoing risk to air travel⁵³

The eruption of Icelandic volcano Eyjafjallajökull in 2010 wreaked havoc on Europe's airways. The rapid spread of a huge cloud of ash led to over 100,000 flight cancellations, at a cost estimated at £3 billion.

Managing busy airspace during volcanic eruptions relies on having an accurate forecast of the quantity of ash likely to be discharged. At the time of the Eyjafjallajökull eruption, estimations were based on

the height of the ash plume – a measure that was only reliable in still air. In the immediate aftermath, researchers at the University of Bristol were able to show that the ash plume discharged by Eyjafjallajökull had been affected by strong winds, and that the volcano had released 100 times more ash into the atmosphere than originally estimated.

This improved understanding of volcanic ash clouds meant that when Iceland's much larger Grímsvötn volcano erupted in 2011, far fewer flights were cancelled or disrupted, with an estimated economic cost of around 1% of that associated with Eyjafjallajökull. The Bristol research has influenced research strategies at aero-engine

manufacturer Rolls-Royce and led to better management of airspace by airlines and major decision makers such as the Civil Aviation Authority. More accurate forecasting of ash clouds, and associated risk modelling, means safer skies and more reliable flights.



UNIVERSITY OF SOUTHAMPTON

Revolutionising industrial material processing

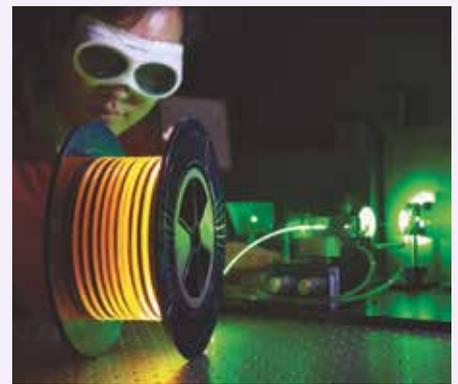
It is estimated the market for lasers in industrial processing will be worth \$17 billion globally by 2020⁵⁴

The integration of lasers into optical fibres by pioneering research at the University of Southampton has led to the creation of a new business sector in fibre laser technology and manufacturing, improving production and manufacturing processes for a huge range of industries. Fibre lasers allow for the precision engineering of complex shapes and have also been made with over 1,000 Watts of power (1kW) – more than enough to cut through an inch of steel.

Today, laser-based cutting and welding processes are giving us stronger, safer cars and lighter, faster planes. The technology of fibre lasers is also being applied to new challenges such as increasing internet capacity, creating renewable energy sources and improving health care diagnostics and treatment.

Makers of medical components have exploited the excellent beam quality and high power of fibre lasers to produce precision devices such as stents – the implants used in heart surgery. As a result of research by the university's Optoelectronics Research Centre (ORC) there has been a 30% increase in the number of surgical stents manufactured with fibre lasers worldwide.

Southampton's research is directly responsible for the success and growth of SPI Lasers Ltd, a spin-out company with an annual turnover of more than £40 million. The company continues to sponsor research into fibre lasers at the ORC, delivering a return on investment of £2.30 for every £1 of investment to the UK economy from SPI Lasers' revenues alone. However, the true return on investment has been much larger, impacting on the productivity of a range of manufacturing sectors.



CARDIFF UNIVERSITY

Maths research delivering life-saving results

Nearly 300,000 ambulances were left queuing outside hospitals in 2014, with patients waiting to be seen in A&E⁵⁵

Delays in emergency medical wards are a potential waste of time and resources for hospital managers, but more importantly they can cost lives. Researchers at Cardiff University have used mathematical modelling to identify the causes that lie behind the headlines of ambulance delays and A&E queues.

Their findings have brought about life-saving improvements to UK health care systems, lowering patient waiting times, increasing survival rates and improving patient care.

By studying patient flows in A&E departments, the modelling unit set up by the university's mathematics researchers has enabled managers to simulate different scenarios and match capacity to demand.

The data has helped to identify bottlenecks and where best to locate ambulances, as well as forecast ambulance demand and plan rotas of paramedics.

This work has been widely disseminated nationally and internationally, and included in hospital capacity planning tools across the UK.

Putting maths at the heart of medicine has helped save lives and cut costs. In one hospital emergency department, at University Hospital of Wales, net efficiency gains of £1.6 million per year have been realised.

Across south London the research has been applied to reduce the mortality of trauma patients by 54%, and to reduce the mortality of stroke patients by 60% through the creation of a new Stroke Unit.



Detecting bowel cancer early

Bowel cancer is the second most frequent cause of cancer death in the UK and the third most commonly diagnosed

One million new diagnoses of bowel cancer are made worldwide each year. This human tragedy is costing the NHS more than £1 billion annually.

However, a new, simple and cost-effective screening test developed by researchers at Imperial College London has proved so effective that this form of cancer could become a rare disease.

The one-off flexible sigmoidoscopy test, the 'flexi-sig', is less invasive than the standard colonoscopy as it examines just the lower part of the colon.

Carried out at the age of 60, the test can detect and enable the removal of the polyps which later cause colorectal cancer. Previous approaches to screening missed half of all instances of polyps – considerably reducing the chances of recovery and survival.

A UK-wide trial involving 170,000 people showed that 11 years after a single screening of men and women aged between 55 and 64, incidences of the cancer reduced by a third and mortality by 43%, with substantial savings for the NHS.

The success of the screening prompted a government investment of £60 million over four years to roll out the test nationwide from 2013, and this is expected to cover the entire population by 2016.

It has been estimated that the screening could prevent 3,000 deaths in the UK every year.



Energy efficiency technologies for our homes

The UK had 1.5 times the world average for CO₂ emissions per person in 2012⁵⁶

Our homes, and how we live in them, have a significant impact on the environment. The average household creates some six tonnes of CO₂ each year, and heating, lighting and power used in domestic buildings produces approximately 27% of the UK's CO₂ emissions.

How we design and build the sustainable homes of the future, and how we adapt existing buildings to become better energy savers – and bring down fuel bills – is now the major challenge in house construction.

A street of 'eco-houses' built on the University of Nottingham's campus is helping researchers to collaborate with construction companies of all sizes to meet that challenge.

The unique test-site of seven 'Creative Energy Homes' is a living laboratory, where researchers work with industry partners to develop new energy technologies by investigating the link between how people behave in the home and energy consumption. Their world-leading research is helping firms integrate energy-efficient technologies into house building.

As a result of this work, Lovell Homes has been able to establish itself as a low-energy house developer, winning a number of sustainable housing contracts.

The Midlands-based Roger Bullivant Group has developed and installed foundation systems that help improve insulation, while regeneration property developer Igloo Blueprint has built £7 million worth of new homes. The research findings have also informed the UK Government's 'Green Deal' strategy.



UNIVERSITY OF WARWICK

High-tech uses for designer polymers

From increasing the activity of biopharmaceuticals to improving the quality of printer ink – designer polymers are transforming products we use every day

A new way to grow designer plastics, devised and patented by research chemists at the University of Warwick, is now being tested by major companies for use in a range of products as diverse as hairspray, anti-obesity drugs and inkjet printer ink.

The technology, known as Living and Controlled Radical Polymerisation, can grow polymers

(plastics) cheaply and easily, to specific designs under precise control. The chemistry involved in the method devised at Warwick no longer needs the expensive sub-zero temperatures and extremely pure solvents used in previous designer polymer processes.

Warwick's pioneering polymer technology has already been used to produce designer polymers for high-value applications in adhesives, pharmaceuticals, biomaterials and medical devices for companies such as Unilever, Procter and Gamble and Geltex.

The collaboration with Unilever, for example, has resulted in new personal care products subject to large scale customer trials.

It has proved so successful that Warwick Effect Polymers Ltd, the spin-out company created by the university researchers, has generated revenues of more than £8.5 million annually. It attracted an initial investment of £3.77 million from a US business angel, and a further £13.5 million investment in 2012. Combined public and private investment has meant the research has already delivered a return of over £2 for every £1 of investment, with much more to come.



UNIVERSITY OF LEEDS

Innovation in transport systems

Passengers travelled 62.9 billion kilometres on the UK rail network in 2014-15 – an increase of nearly 60% since 2002-03⁵⁷

The UK has one of the busiest rail networks in Europe. Ensuring that trains and their crews are in the right place, to be able to leave at the right time, is crucial to the network running smoothly. In 2008, Tim Burr, head of the National Audit Office, said that train delays cost the UK economy over £1 billion a year.

Research by computer scientists at the University of Leeds led to the creation of software that is now used by more than 40 bus and train companies to construct effective crew timetables.

This is delivering cost-efficient public transport, improving services and saving over £230 million in the UK alone between 2008 and 2013.

The Leeds researchers have been working on producing optimising algorithms to tackle the complexities of rail crew scheduling since the 1990s.

A spin-out company, Tracsis, was formed in 2004 to commercialise the software, and since 2008 this has been used by bidders in all UK rail franchise tenders. It is used by 70% of the train companies currently operating in the UK as well as in Sweden, Australia and New Zealand, where the software was used to reschedule trains during the 2011 Rugby World Cup.

The company's success led to the Tracsis floatation on the London Stock Exchange in November 2007 with a market capitalisation of nearly £53 million at the end of 2013 and an annual turnover of more than £10 million.



UNIVERSITY COLLEGE LONDON (UCL)

Developing new methods of internet communications

Skype users spend more than 2 billion minutes a day connecting with each other and FaceTime is used 15-20 million times per day⁵⁸

Millions of people worldwide use 3G mobile phone networks to talk, send messages or take part in video-conferencing. These are all based on pioneering research at University College London.

In the 1990s the UCL computer science department developed protocols and prototypes to set up and ensure the quality of calls between multiple participants using internet-based networks.

Their work led to the development of modern communication techniques which use two internet standards created by UCL: Session Initiation Protocol (SIP) and Session Description Protocol (SDP).

UCL's research has directly benefited many global communications companies. Used in most 3G and newer mobile telephone networks, SIP and SDP are also used in communications systems and in software available for laptops and smartphones made by Microsoft, Apple, Cisco, Siemens and Polycom among many others. Apple's popular FaceTime videoconferencing software, which is included with every iPhone, iPad and MacBook, sets up calls using SIP.

Major telephone companies including BT and Vodafone use SIP to provide services which connect private exchange systems to the global phone network cost-effectively and avoid the need for conventional dedicated telephone lines - reducing costs and enabling advanced features. Cisco uses SIP as the core call signalling protocol across its portfolio, enabling interoperability between its products and with other vendors. Its collaboration division is a nearly \$4 billion business and represents 8% of revenue.



QUEEN MARY UNIVERSITY OF LONDON (QMUL)

Developing synthetic bone graft products through a successful spin-out

In England and Wales there are approximately 160,000 hip and knee replacement procedures performed each year⁵⁹

A synthetic bone graft (SBG) material created at Queen Mary University of London is now being used by orthopaedic surgeons worldwide as a bone replacement in hip surgery and in skeletal reconstructions for patients following trauma or disease.

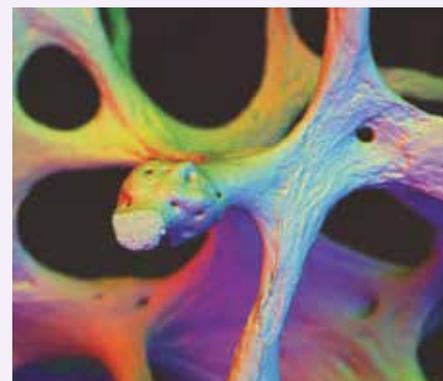
Researchers in the School of Engineering and Materials at QMUL worked alongside chemistry experts in the university's Interdisciplinary Research Centre in Biomedical Materials to develop the ground-breaking material, which is able

to speed up good quality bone regeneration safely and is more reliable than the alternative autograft procedures, which graft bones from elsewhere in the patient's body. Use of the material has reduced patients' post-operative risk of infections and improved their recovery rates.

Brought to market via the QMUL spin-out company ApaTech™, the range of synthetic bone graft products have given surgeons practical, cost-effective new options for many life-changing measures including regenerative medicine to fuse spines.

In 2010, just nine years after its creation, ApaTech™ had 4% of the US SBG market and was sold for £220 million. By 2012, the products

had a 10% share of the global SBG market, estimated to be around \$510 million. To date, ApaTech™ products have been used to treat more than 370,000 patients in more than 30 countries.



Reigniting research and development on antibiotics

Over-prescription of antibiotics leads to millions of cases of resistance to bacterial infection and causes 25,000 hospital deaths per year in the EU⁶⁰

Antibiotic resistance is a major global concern and, according to the UK Chief Medical Officer, poses a threat equivalent to terrorism. Yet investment in antibiotics R&D is low due to a lack of economic incentives.

Researchers at LSE analysed the incentives needed to get antibiotics R&D going again. Building on their work on the development of new vaccines for neglected diseases,

the team conducted an in-depth exploration of market failures in producing new antibiotics. This recommended new approaches to risk-sharing, particularly in clinical trials, alongside incentives to limit over-marketing and over-consumption of any new drug in the medium to long term.

This research led the European Commission to develop a comprehensive action plan, with concrete proposals concerning incentives to develop new effective antibiotics.

In early 2012, the public-private partnership between the European Commission and the European Federation of Pharmaceutical Industries and Associations announced a shared commitment

of €220 million for the development of new antibiotics. In addition, the research enabled the US Biomedical Advanced Research and Development Authority to award a series of contracts for antibiotic research.



Improving survival rates for people with cystic fibrosis

Cystic fibrosis is the most common inherited disorder in the UK

Cystic fibrosis (CF) is an inherited condition, caused by a genetic mutation, which affects 75,000 adults and children worldwide. Sufferers often die before the age of 40 as mucus from the disease damages their lungs, risking infection.

Research at Queen's University Belfast led to the development of a transformative new drug, Ivacaftor, which has brought outstanding improvements in survival and quality of life for people with the disease. The breakthrough was built on a series of 25 clinical trials over

10 years which have made the university the leading UK centre for CF research.

The new drug was trialled from 2009-2012 as the first approved therapy that corrects the basic defect in CF; as such it represents a completely new approach to treating people with the condition.

The Queen's-led team of scientists found patients receiving the new treatment had significant improvement in their lung function, leading to a reduced need for hospitalisation, as well as a reduction in disease flare-ups. Drug sales reached US\$113 million in the first nine months of 2012, and Ivacaftor is now licensed and funded in the USA, UK, Ireland, France and Germany.

The new drug has a very significant impact for people with CF, demonstrating real future hope that a wide range of mutations may be treatable.



UNIVERSITY OF EDINBURGH

Reducing blood transfusions to lower patient risk, reduce costs and save lives

The NHS in England alone carries out 8,000 blood transfusions every day

More than half a million people in the UK receive a blood transfusion each year and demand is increasing.

Our ageing population, and a stringent donor selection process, mean the supply of blood is limited. 40% fewer new donors came forward last year compared with a decade ago.⁶¹

In addition, transfusions come with risks: patients can develop antibodies to the transfused red blood cells, or their immune systems can be suppressed, increasing the risk of infections.

Recognising these challenges, researchers at the University of Edinburgh have shown the benefits of reducing the use of blood transfusions in intensive care and surgery. This led to savings of more than £100 million for the NHS annually across the UK, reducing unnecessary blood transfusions and ultimately saving patients' lives by conserving limited blood supplies.

Edinburgh's research produced clear evidence that restricted transfusion use leads to lower mortality rates for patients in intensive care.

As a result of substantial changes in clinical practice following the research, there was a 20% reduction in overall UK red blood cell usage between 2002 and 2012. This has led to 7,000 fewer patients being

exposed to red cell transfusion annually, and saved 500 lives.

The research has been incorporated into international guidelines and Edinburgh researchers have played a critical role in the development and implementation of national policies on blood use.



UNIVERSITY OF SHEFFIELD

Transforming public welfare and attitudes through narrative

Every year, 1 in 4 people in the UK experience a mental health problem⁶²

Research at the University of Sheffield focusing on the links between memory, trauma and narrative has improved the mental health and well-being of patients in secure hospitals. The 'Storying Sheffield' project, in which students collaborate with local people to produce, collect and record stories about their everyday lives, gives a voice to a diverse range of people including long-term users of mental health services, people with physical disabilities, older people with degenerative conditions, migrants, and people in areas of socio-economic disadvantage.

The project, which draws on the methodology and findings of a 12-year research cluster in the English department at the university, has influenced therapeutic practice through collaborations with Rampton High Secure Psychiatric Hospital, and with Sheffield Health and Social Care NHS Trust.

Evaluation of the Storying Sheffield course has shown improvements in participants' health, well-being and employability. Some 70% of participants with mental health issues make a measurable and significant change in their lives as a direct result, from being able to leave their house alone to enrolling in further study, getting a job or starting voluntary work.

Benefits to the wider community include increasing understanding between, and changing attitudes to, socially marginalised groups. The Storying Sheffield project has also influenced policy-making, informing City Council practices for developing sustainable community policies.



Introducing the Pupil Premium Toolkit

In England in 2012, only 38% of disadvantaged pupils received five good GCSEs, including English and Maths, compared to 65% for other pupils⁶³

An evidence-based guide for schools in England, developed by researchers at Durham University, has helped ensure that billions of pounds worth of education spending is used effectively to support disadvantaged pupils.

The Pupil Premium Toolkit provides guidance to schools on how to spend their Pupil Premium, a government funding stream worth £6.25 billion between 2011 and 2015, aimed at tackling the effects of poverty on attainment.

Recognising that there is no simple link between more spending and better learning, researchers devised the Toolkit to address the difficulties schools face in deciding how to spend this resource effectively. It does this by comparing the cost-effectiveness of different teaching approaches in schools, which can range from intensive tuition sessions for small groups to summer schools or specialised training for staff.

Using practical, concise language, the comparisons are shown in the extra months of development seen in children if these approaches are adopted and delivered effectively.

Endorsed by bodies such as the National Association of Head Teachers, the Toolkit is used by more than a third of school leaders in England in determining their

spending priorities and to review their support for disadvantaged children.

The Toolkit has also directly influenced Government spending and policy. In 2013 it was identified as a model for the 'What Works' network for social policy, which will inform over £200 billion of Government spending.



People-powered research engaging the public and leading to real discoveries

Nearly 1.4 million citizen scientists from over 100 countries are collaborating online with researchers in fields ranging from astronomy to zoology

Online collaboration platform Zooniverse was developed from astrophysics research and now supports nearly 40 projects.

From the exploration of WW1 soldiers' diaries to searching for unknown exotic particles in the Large Hadron Collider data, the projects turn volunteers' efforts into measurable results. The volunteers help professional researchers analyse information more quickly and accurately,

advancing the ability of computers to do the same tasks, speeding up results and saving time and resources. This people-powered research has led to some remarkable discoveries.

These include the discovery of a quasar-scale light echo, the first planet in a four star system and a sophisticated measurement of the dust distribution in the Earth's orbit.

In collaboration with Cancer Research UK, a Zooniverse project led to the development of new software that helped to crowd source analysis of tumour samples, reducing analysis time from 18 months to just three months. Oxford University's platform has led to increased public understanding of science and research methods.

In a survey of users, 88% agreed that Zooniverse had increased their understanding of how modern scientific research is carried out.

Teachers are also using the platform in the classroom to engage the next generation of scientists.



UNIVERSITY OF LIVERPOOL

Providing solutions to criminal justice and terror incidents

“We face a very serious level of threat that is complex to combat and unlikely to abate significantly for some time.”⁶⁴

Research by Liverpool psychologists has led to emergency and security services adopting new ways of managing risks such as terror attacks, prosecuting and convicting terrorists and preventing child sexual abuse.

A new sub-discipline at the university, Investigative Psychology, has had a significant impact on law enforcement as well as the emergency and security services, who now take an evidence-based

approach to linking crime scene actions to background characteristics.

The research has helped develop new practices in training senior personnel, including two immersive learning technologies now used in six countries to train and debrief law enforcement agencies and emergency responders dealing with major terrorist incidents.

MI5 calculate that as a result of these, 312 individuals were successfully convicted under the Terrorism Act between 2001 and 2012.

The new approaches have also been used in criminal investigations, disaster management, public order policing and child protection.

Since 2009, one of the Liverpool lead researchers in Investigative Psychology has worked with Kent Police to develop the Kent Internet Risk Assessment Tool, which has resulted in more than 300 children being protected from contact abuse.



UNIVERSITY OF GLASGOW

Compiling the recorded vocabulary of English since the middle ages

There are now more than 850 million English speakers worldwide

More than 1,000 years of the English language are captured in a unique publication that draws on decades of research at the University of Glasgow's English department.

The Historical Thesaurus of the Oxford English Dictionary gives the meaning of every recorded English word from 700 AD to the present day, preserving the UK's linguistic heritage for the public and providing an acclaimed resource for writers, linguists, historians and scholars. The Thesaurus is the work of over 230 people, taking approximately 320,000 person-hours to complete

– the equivalent of 176 years of solid work for one person.⁶⁵

The 800,000 word thesaurus was compiled and first published in print form in 2009, after 44 years of research at Glasgow. Considered to be the world's only complete historical thesaurus published in any language, it has so far generated £1.6 million in global sales.

The digital version – which is still being added to – is unique in both its coverage and method. By arranging the words in broad conceptual categories such as 'music' or 'thought', it allows a reader to understand not only which words were available to discuss any particular concept at any given moment in the history of English,

but also the full range and variety of words available to English speakers at the moment.

Now available via the Oxford English Dictionary website, the online thesaurus opens up the rich history of the English language to some six million visitors every year.



Improving access to maternity care in developing countries

A woman in sub-Saharan Africa has a 1 in 16 chance of dying in pregnancy or childbirth, compared to a 1 in 4,000 risk in a developed country⁶⁶

Of the thousands of maternal deaths worldwide each year, 99% occur in the developing world. This shocking marker of global inequality puts improving maternal health and reducing maternal mortality high on global policy agendas. Research into social, economic and structural barriers to maternity care carried out at King's College London, has led to improvements in the delivery and design of maternal care worldwide.

In Tanzania, King's researchers disseminated their findings directly with district medical and nursing officers, and influenced a change in national policy aimed at reducing the cost of midwives setting up maternity homes, thereby supporting independent midwifery practice in poor communities.

Their research into emergency maternal referral systems also informed the main UN Millennium Task Force report on transforming health systems for women and children, which has informed the design of maternal referral systems in Ghana, Bangladesh, Armenia and Ethiopia.

The lead researcher at King's co-authored a review of global evidence to underpin advice to

the UK and Norwegian governments on the best strategies to achieve the UN Millennium Development Goal on maternal health. The review has been widely disseminated and has guided UK Government policy on maternity care, family planning and safe abortion.



Background on the REF 2014 and our analysis

Background on the REF 2014 and impact

Over the last three decades, the quality of research conducted by UK universities has been assessed at regular intervals by the UK higher education funding bodies. The latest iteration of this exercise, the Research Excellence Framework (REF 2014) was conducted between 2008 and 2013, with the results published in December 2014.

Submissions to the REF 2014 could be made to 36 Units of Assessment (UoAs) under four main panels: A (biomedicine), B (physical sciences and engineering), C (social sciences) and D (arts and humanities). Each submission was peer reviewed and received a quality profile ranging from unclassified ('below the standard of nationally recognised work'), to four-star ('world-leading in terms of originality, significance and rigour'). The REF 2014 assessment had three components (with particular weights given to each):

- (a) Quality of outputs, based on originality, significance and rigour (65%)
- (b) Impact based on reach and significance of the research (20%)
- (c) Research environment, in terms of its 'vitality and sustainability' (15%)

For the first time, the REF 2014 assessed the impact of research conducted by UK universities through narrative case studies. In total, 6,679 non-redacted impact case studies were submitted to the REF 2014, including 3,256 from Russell Group universities. The case studies outline the benefits of research to the economy, society, culture, public policy and services, health, the environment and quality of life over the last 20 years. Each case study had to be linked to initial research classified as at least two-star quality ('recognised internationally in terms of originality, significance and rigour').

Russell Group universities produced over two-thirds (68%) of world-leading research in the REF 2014 originating from all UK universities and dominated the top ten places for all four REF 2014 panels. More than half of the research in our universities also resulted in outstanding impact, compared to less than a third at other universities.

Our analysis

We collected a sample of 240 original REF 2014 impact case studies, 10 from each Russell Group university. The case studies were chosen to reflect the diversity of research carried out at each institution and the broad range of impacts achieved. Each case study was analysed by a member of Russell Group staff and key information was extracted in the following areas:

- Type of impact generated (with 8 categories; multiple impact types could be identified): Policy/politics; Economic; Social/sociological; Technological; Legal; Environmental; Health; Cultural/creative

- Collaboration (including with public sector, charities, private sector, other Russell Group universities and other universities, as well as international collaboration)
- Scope/reach (local/regional, national, international)
- Funding source (Research Councils, HEFCE and equivalents, private sector, charities, learned societies, EU, UK Government, self-funded)
- Time-to-impact (years between initial research and beginning of impact)
- Beneficiaries (including all citizens, private sector/businesses, public sector, charities, children and young people, disadvantaged groups, patients/sick people.)

The sample of case studies is representative when compared to the distribution of all impact case studies submitted by Russell Group universities to within a 2% difference across UoAs and a 3% difference across the main panels.

The following UoAs are slightly over-represented in our sample (within 1% difference): clinical medicine, chemistry, agriculture and veterinary, computer science, geography, social work, sports and exercise, English language and communication. The following UoAs are slightly under-represented (within 2% difference): biological science, aeronautical engineering, area studies, modern languages, history, classics and philosophy. At panel level, panel B is slightly over-represented (+2%) and panel D is under-represented (-3%) in the sample.

References

- 1 This is the third Russell Group publication on research impact. The two previous reports are: 'The social impact of research conducted in Russell Group universities' (2012): <http://www.russellgroup.ac.uk/uploads/SocialImpactOfResearch.pdf>

'The economic impact of research conducted in Russell Group universities' (2010): http://www.russellgroup.ac.uk/uploads/RG_ImpactOfResearch2.pdf
- 2 The total of 3,256 includes the Institute of Education: it submitted case studies separately but is now part of UCL. See Background on the REF 2014 and our analysis (p. 54) for a note on the methodology used in our analysis as well as some more background information about the REF 2014 and the impact assessment component. The full range of impact case studies can be accessed through the Higher Education Funding Council for England (HEFCE) database: <http://impact.ref.ac.uk/CaseStudies/search1.aspx>
- 3 Unfortunately it is not possible to estimate the actual financial value of second and third order consequential impacts, but they will typically be more wide-ranging than direct impacts.
- 4 These include references to: business values, sales values, value to UK economy, efficiency savings for private and public sector, royalties and licensing.
- 5 It is difficult to calculate the full return on investment across our sample of case studies due to the lack of standardisation in the format in which they have been written. Initial analysis of all of the case studies commissioned by HEFCE and conducted by Kings' College London and Digital Science also highlights the lack of standardisation in the way in which numerical values are presented in the case studies, making them difficult to compare and synthesise so that economic impact and return on investment cannot be estimated at scale.
- 6 HESA data 2013-14
- 7 This includes spin-outs created by staff and students at Russell Group universities and not all of these will relate directly to research.
- 8 Analysis by the UK Innovation Research Centre (UKIRC), a joint venture between the University of Cambridge and Imperial College Business School, has identified a positive correlation between public R&D and private industrial productivity growth three years later, with the average rate of return on public investment in R&D after three years being 20%. Concentrating public funding on research excellence in universities leads to increased external income through collaborative and contract research with business, enabling universities to strengthen their links with business and contribute to productivity growth in the private sector. See: 'The Economic Significance of the UK Science Base', UKIRC (2014).
- 9 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=43013>
- 10 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=42228>
- 11 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=12331>
- 12 See: www.lse.ac.uk/researchAndExpertise/researchImpact/caseStudies/bergsma-making-new-drugs-safer-and-faster-to-develop.aspx
- 13 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=36411>
- 14 The 2015 UK attractiveness survey by Ernst and Young notes how 90% of foreign businesses rate the quality of life, diversity, culture and language as either very or fairly attractive to them when considering the UK as a place to invest. See: [http://www.ey.com/Publication/vwLUAssets/The_UK_Attractivness_Survey_2015_-_full_report/\\$FILE/1595088_UKAS_report_2015_FINALWEB.pdf](http://www.ey.com/Publication/vwLUAssets/The_UK_Attractivness_Survey_2015_-_full_report/$FILE/1595088_UKAS_report_2015_FINALWEB.pdf)
- 15 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=38820>
- 16 30% of all cultural and creative impacts in the sample have resulted from research in English language and literature and history research.
- 17 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=8858>
- 18 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?id=23870>
- 19 For more details, see: <http://www.ox.ac.uk/news/2014-02-12-oxford-digital-spin-out-completes-500m-sale>

- 20 A good example of how important this interdisciplinary approach can be is the investment made by GSK, the Wolfson Foundation and others in the Carbon Neutral Laboratories for sustainable chemistry (CNL) at the University of Nottingham. This will serve as the hub for ambitious interdisciplinary research that spans the fields of catalysis, energy efficient synthesis and advanced materials, while having a zero impact on embedded and operational carbon over the project's 25 year lifespan. See: <https://www.nottingham.ac.uk/chemistry/research/centre-for-sustainable-chemistry.aspx>
- 21 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=3669>
<http://www.cardiff.ac.uk/research/impact-and-innovation/research-impact/reducing-violent-crime>
- 22 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=6404>
- 23 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=2327>
- 24 What is the relationship between public and private investment in science, research and innovation? Economic Insight report for BIS (July 2015)
- 25 Source: Innovate UK
- 26 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=38370>
<https://www.qub.ac.uk/directorates/ResearchEnterprise/Impact/CaseStudies/EngineeringandPhysicalSciences/CaseStudyArticles/Name,498524,en.html>
- 27 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=23400>
- 28 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=42275>
- 29 The only countries which are not specifically referenced in Russell Group REF 2014 impact case studies are: Guinea Bissau, Grenada, American Samoa, the Cook Islands, New Caledonia and Palau.
- 30 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=41153>
- 31 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=32738>
- 32 The full case study is available here: <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=28071>
- 33 'International Comparative Performance of the UK Research Base - 2013: A report prepared by Elsevier for BIS'
- 34 HESA data
- 35 <http://impact.ref.ac.uk/CaseStudies/CaseStudy.aspx?Id=28123>
- 36 Index compiled by McGlory, J., The Soft Power 30: a global ranking of soft power (July 2015)
- 37 <https://www.dur.ac.uk/news/newsitem/?itemno=25502>
- 38 <http://www.bristol.ac.uk/news/2015/june/ebola.html>
- 39 It is important to note that the measurement of time-to-impact is limited by the nature of the REF 2014 exercise. In general, longer times-to-impact were not frequently demonstrated in our sample due to the rules around REF 2014 impact case studies, which require the underpinning research to have taken place in the 20 years preceding the REF 2014 (from 1 January 1993 at the earliest) and the specific impacts to have occurred during the assessment period (01/01/2008 - 31/07/2013). Furthermore, because institutions must demonstrate that the underpinning research is of 2* quality or higher, it was arguably easier in some cases to do this for more recent pieces of research than for research produced further back.
- 40 <http://www2.warwick.ac.uk/fac/sci/wmg/research/naic/>
- 41 Haskel and Wallis, 'Public support for innovation, intangible investment and productivity growth in the UK market sector' (2010)
- 42 'The Economic Significance of the UK Science Base', UKIRC (2014)
- 43 OECD 2011 and Institute for Prospective Technological Studies 2011
- 44 BIS, 'Innovation Report 2014: Innovation, Research and Growth' (March 2014)

- 45 See: The World Economic Forum's biennial Global Competitiveness reports.
- 46 OECD Main Science and Technology Indicators data
- 47 The Royal Swedish Academy of Sciences press release announcing the Nobel Prize for physics in 2010 http://www.nobelprize.org/nobel_prizes/physics/laureates/2010/press.html
- 48 <http://www.diabetes.co.uk/cost-of-diabetes.html>
- 49 US President Bill Clinton announcing the first sequencing of the human genome in June 2000 with British PM, Tony Blair.
- 50 Foresight obesity report: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/287937/07-1184x-tackling-obesities-future-choices-report.pdf
- 51 http://cdn.dementiablog.org/wp-content/uploads/2015/09/OHE_Consulting_ARUK_FINAL.pdf
- 52 <https://www.gov.uk/government/publications/prime-ministers-challenge-on-dementia-2020/prime-ministers-challenge-on-dementia-2020>
- 53 According to the Global Volcanism Programme at the Smithsonian Institution: <http://volcano.si.edu/>
- 54 <http://www.marketsandmarkets.com/PressReleases/laser-processing.asp>
- 55 <http://www.bbc.co.uk/news/health-28706796>
- 56 International Energy Agency key stats: <http://www.iea.org/publications/freepublications/publication/KeyWorld2014.pdf>
- 57 Office of Rail Regulation: http://orr.gov.uk/_data/assets/pdf_file/0009/19377/passenger-rail-usage-2015-16-q1.pdf
- 58 <http://www.bloomberg.com/news/articles/2014-06-25/mobile-web-siphons-revenue-from-cities-as-landlines-fade>
- 59 <http://www.njrcentre.org.uk/njrcentre/Patients/Jointreplacementstatistics/tabid/99/Default.aspx>
- 60 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/465843/2015_Oct_205_ImmunisationTimeline.pdf
- 61 <http://www.theguardian.com/uk-news/2015/jun/05/sharp-drop-new-blood-donors-uk-stocks-at-risk>
- 62 <http://www.mind.org.uk/information-support/types-of-mental-health-problems/statistics-and-facts-about-mental-health/how-common-are-mental-health-problems/>
- 63 Department for Education statistics 2012/13
- 64 <https://www.mi5.gov.uk/home/about-us/who-we-are/staff-and-management/director-general/speeches-by-the-director-general/director-generals-speech-on-terrorism-technology-and-accountability.html>
- 65 <http://historicalthesaurus.arts.gla.ac.uk/stats-and-figures/>
- 66 <http://www.unicef.org/mdg/maternal.html>

About the Russell Group

The Russell Group represents 24 leading UK universities which are committed to maintaining the very best research, an outstanding teaching and learning experience and unrivalled links with business and the public sector.

Our research-intensive, world-class universities play an important part in the intellectual life of the UK and have huge social, economic and cultural impacts locally, across the UK and around the globe.

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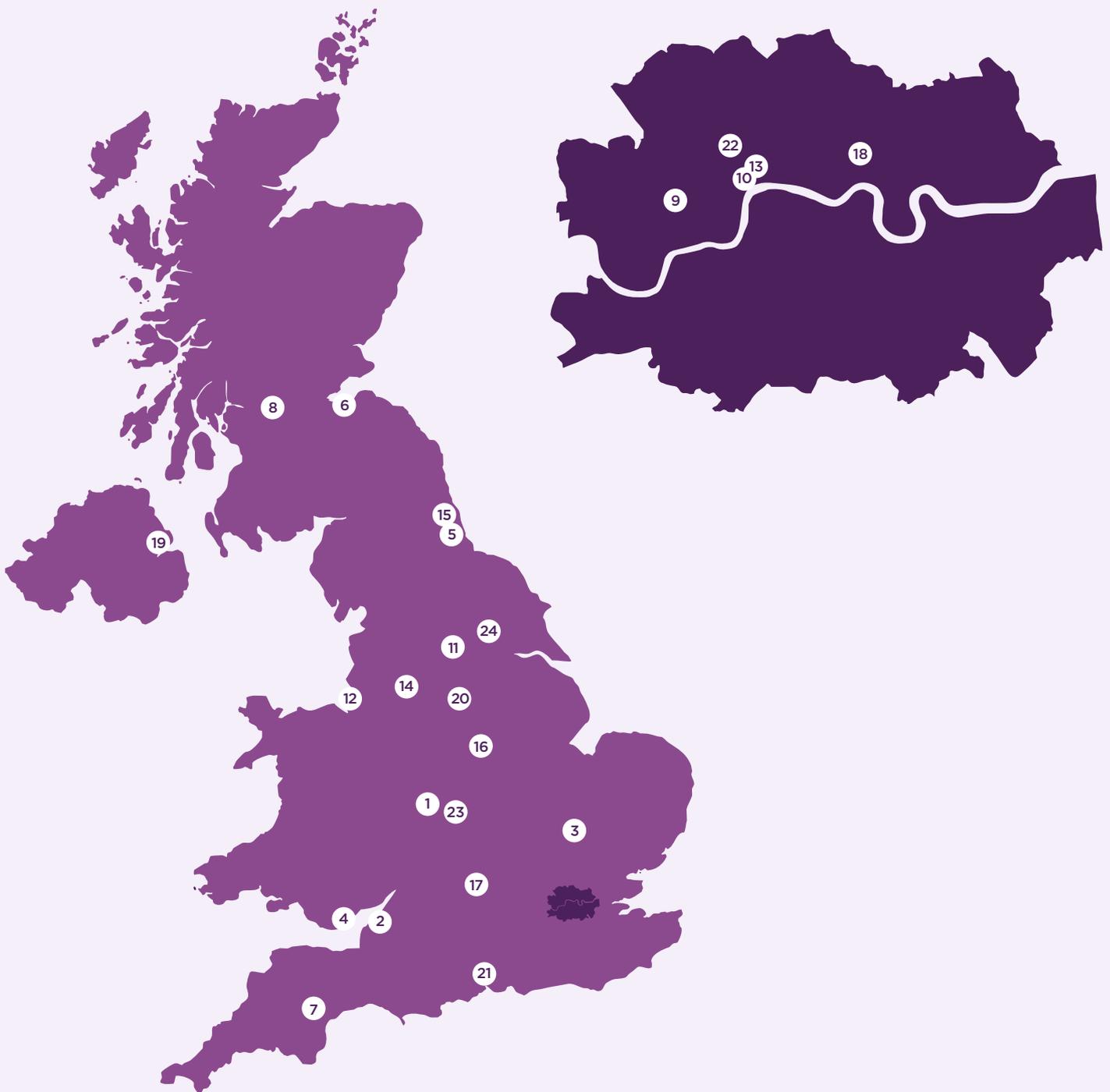
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