



EUROPE

Evidence synthesis on measuring the distribution of benefits of research and innovation

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Preface

The National Academies have recognised the need to better understand the range of benefits that research and innovation (R&I) bring to the UK, the distribution of those benefits across the country and its population, how those benefits are achieved and how best to measure them. Rather than simply refining the case for more investment, the aim is to understand the benefits of this investment across the UK and its population and to develop new analysis to allow government to spend smarter. To this end, RAND Europe was commissioned to conduct an evidence synthesis to understand (i) the range of benefits of research and innovation; (ii) how these benefits are currently assessed or measured in the UK and limitations of these approaches; (iii) the distribution of these benefits (by geography, sector, population groups, and over time); and (iv) novel approaches to measuring these benefits, including international examples and how these methods may apply in a UK context. This evidence synthesis covers these four areas and helps to characterise the range and nature of benefits resulting from research, how these can be measured, gaps in the existing evidence and how they might be addressed.

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Executive summary

The aim of this study is to understand the range of benefits from research and innovation (R&I), how they are measured, and the gaps in the evidence. RAND Europe was commissioned by the Steering Group of the National Academies to synthesise evidence on:

- The range of benefits of research and innovation, for example across economic benefits, health and wellbeing, sustainability, and social and cultural enrichment;
- How such benefits of R&I are currently assessed or measured in the UK, looking at both the datasets that are available and the limitations of the current data;
- The distribution of benefits, economic and beyond, across the UK, viewed for example through the lenses of population, place or sector and looked at over time; and
- Alternative metrics and approaches that have been developed in other countries or contexts.

What are the benefits of R&I?

There are many diverse benefits from R&I. Although a key benefit is the generation of new knowledge, the aim of this report is to consider the non-academic benefits of R&I. Existing evidence shows significant returns from R&D investment, estimated to be in the region of 20–30%. A 30% rate of return suggests that for a one-off investment, there are benefits equivalent to getting 30p back on every pound invested, every year, forever. In fact, the benefits may be even greater than this, since economic approaches do not fully capture some of the harder-to-measure benefits from R&I across society, including benefits to culture, public engagement, social cohesion and the environment. There is also good evidence that public sector investment in R&D ‘crowds in’ private sector R&D investment, with every £1 invested in publicly funded biomedical and health research being associated with an additional £0.83–1.07 of private sector research investment.

Although the existing evidence provides a compelling case for the benefits that R&I can deliver, there are numerous benefits from R&I that are not well measured or, in many cases, not well understood. A more holistic way of measuring the benefits from investment in R&I would be beneficial, both to better capture and illustrate the ways in which research benefits society, and to facilitate better analysis to make sure investment is targeted towards achieving the full range of these goals, not just those which are most easily measured. With this in mind, we propose a broad framework, the impact index, which aims to more broadly conceptualise the range of benefits and impacts that can result from investments in research and innovation. This framework is shown in Figure 1.

How are the benefits of R&I currently measured in the UK?

Mapping existing evidence and the methods and data used onto the impact index, we note some gaps. Although there are a few pockets of more innovative work, methodologically most evaluations of the benefits from R&I are dominated by a few methods, notably total factor productivity-based economic analyses, case studies, and portfolio-specific evaluations (largely in health). We also note that the potential of some key datasets is not being realised. For example, Researchfish provides a dataset, albeit with some limitations, across the spectrum of much of UK R&I. However, data so far has only been analysed in a limited way and funders have not typically shared data to facilitate interesting cross-disciplinary analysis that could better inform investment decisions. There are also other useful datasets, such as those held by the Higher Education Statistics Agency (HESA), Research Excellence Framework (REF) case studies and others, that could be used more creatively and effectively to understand where and how R&I investment could best be targeted. These limitations partly reflect a lack of resources invested in evaluation overall, which has limited the scope for methodological innovation and underpinning research.

What evidence exists on the distribution of impacts?

There is limited evidence on the distribution of impacts of R&I by region or population groups and over time. However, there are some interesting examples in specific sectors or fields which could be expanded upon and translated to different contexts. For example, economic analyses in the development sector have explored the impact of R&I on different groups and populations. There are also analyses of regional economic benefits of large infrastructure projects, which provide useful information on jobs directly created, but are not able to fully characterise the range of benefits from these investments. Evidence on commercial benefits of R&I covers geographic distribution, using a range of approaches. Longitudinal analyses are limited, with most evaluations providing a 'snapshot' of the benefits from R&I investment rather than acknowledging how these benefits may emerge and develop over time. Researchfish offers a growing longitudinal dataset that could be explored. The SIAMPI (Social Impact Assessment Methods for research and funding instruments) framework and the commonly-used Payback Framework also address time lags and could provide a basis for further work in this area.

	Impact on the economy	Commercial impact	Impact on public policy and services	Impact on health and wellbeing	Impact on education and training	Impact on public engagement, awareness and perceptions	Cultural impact	Impact on social cohesion	Impact on safety and security	Impact on the environment
Aggregate benefits										
Benefits by region/ geography										
Benefits by sector										
Benefits for different population groups										
Benefits over different time periods										

Impact category	Examples
Impact on the economy	Increased productivity; GDP gains; attracting capital investment; improving resilience and diversification of the economy
Commercial impact	Generating revenue; improving processes; opening up new markets; creating employment in industry
Impact on public policy and services	Informing policy debate within the general public, in a government body, or at a non-governmental organisation; increasing public engagement with the policy process; improving efficiency of or access to public services; improving the equity of public service provision
Impact on health and wellbeing	Improving health outcomes; changing healthcare practice; improving health equity; increasing patient/user choice; increasing access to health services; improving the management of healthcare performance; improving patient/user satisfaction
Impact on education and training	Changing curricula; improving training materials, text books or other teaching resources; creating materials for specialised teaching contexts; changing the structure of a course; increasing access to education; improving educational outcomes
Impact on public engagement, awareness and perceptions	Shaping the nature of public debate; increasing public engagement with research findings; increasing public awareness; creating publicly available tools or resources; increasing public curiosity about science, technology, the arts or other disciplines
Cultural impact	Preserving cultural heritage; increasing accessibility of culture; improving artistic/cultural methods; improving the quality of cultural events/activities
Impact on social cohesion	Reduced inequality; reduced bias and intolerance; improved social integration; increased social capital
Impact on safety and security	Improving infrastructure security/resilience; improving policing practices; creating new tools for policing; improving safety in the workplace, at home or in other settings; increased regional security
Impact on the environment	Reducing pollution levels; improving measures of environmental condition; contributing to conservation; improving waste management, environmental efficiency or environmental management; reducing the depletion of a natural resource; developing adaptations to environmental conditions/changes

Figure 1 The 'impact index' summarising the range of potential benefits of R&I and their distribution

How can we improve the evidence base and build on innovative practice?

There are examples of novel practice in the literature, as well as useful and underutilised datasets both within and beyond the R&I space, which could help develop a more comprehensive, nuanced picture of the range of benefits of R&I in the UK. Key to achieving this will be increased openness and sharing of learning and data. Engagement across the R&I sphere will also be crucial, and may be facilitated by a more integrated approach and careful consideration of the potential burden of evaluation. Fundamentally, more effective, holistic and innovative practice in the assessment of the benefits of R&I will require consistent and targeted funding in this area. Evaluations and the methodological development underpinning them have been consistently under-resourced, which has stifled creativity and innovation. As the UK government expands its investment in R&D, it will be important to consider whether adequate investment is being made in evaluation of the benefits of R&I.

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Abbreviations

AHRC	Arts and Humanities Research Council
AI	Artificial intelligence
BBSRC	Biotechnology and Biological Sciences Research Council
DoD	Department of Defense
EPSRC	Engineering and Physical Sciences Research Council
ESRC	Economic and Social Research Council
EU	European Union
GDP	Gross Domestic Product
HE	Higher education
HEFCE	Higher Education Funding Council for England
HEI	Higher education institution
HESA	Higher Education Statistics Authority
MOPAC	Mayor's Office for Policing and Crime
MRC	Medical Research Council
NCPPE	National Coordinating Centre for Public Engagement
NERC	Natural and Environmental Research Council
NICE	National Institute for Health and Care Excellence
NIHR	National Institute for Health Research
OECD	Organization for Economic Co-operation and Development
ONS	Office for National Statistics
QALY	Quality-adjusted life year
RAE	Research Assessment Exercise
REF	Research Excellence Framework
R&D	Research and development

R&I	Research and innovation
SIAMPI	Social Impact Assessment Methods for research and funding instruments
STFC	Science and Technology Facilities Council
TFP	Total factor productivity
UKRI	UK Research and Innovation
WHO	World Health Organization

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1. Introduction

1.1. Study context

The aim of this study is to understand the range of benefits from research and innovation (R&I), how they are measured, and what the gaps are in the existing evidence on the subject. Better evidence will be beneficial as the UK government works towards its commitment to increase investment in research and development (R&D) to 2.4% of gross domestic product (GDP) by 2027. Alongside this increased investment, the recent creation of UK Research and Innovation (UKRI) as a focal point for publicly funded research and innovation offers opportunities to better measure and characterise the overall benefits that R&I brings to the UK.

The targets set for spending on R&D represent a significant increase in investment. In 2016, UK investment in R&D was £33.1bn, an increase of 4% from the previous year.¹ However, this is only 1.67% of GDP. To match the average among Organisation for Economic Co-operation and Development (OECD) members by raising spending to 2.4%² will require an increase of over 40%, or an extra £14bn – or likely significantly more, taking into account GDP growth. At present, just over half of this investment comes from UK businesses, with a further quarter from government and the higher education (HE) sector, 5% from private non-profits (notably medical research charities), and the rest from overseas investment, including from non-UK businesses and European Union (EU) funding streams.³

It is worth noting that this target is for R&D, rather than R&I, spending. In this review, we focus on R&I, which is a broader concept than R&D. *Innovation* is defined as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations.⁴² Innovation often draws on R&D, but R&D is not always part of the activity of innovation. Innovation encompasses new technology as well as new ways of doing things. Although in this review we focus on the broader concept of R&I, many studies only cover R&D, and the latter is the focus of the UK investment target.

¹ ONS (2018) UK gross domestic expenditure on research and development, 2016.

² OECD Main Science and Technology Indicators (2016).

³ ONS (2018) UK gross domestic expenditure on research and development, 2016.

1.2. Why measure the benefits of R&I?

There are a number of reasons why attempts are made to measure the benefits from research and innovation. Among these are the ‘four A’s’: to facilitate funding allocation, for advocacy, for analysis and learning, and to provide accountability (Morgan Jones and Grant, 2013). The purposes of an evaluation, and the trade-offs that need to be made between these, should be taken into account when developing a research evaluation approach. Many of these benefits will come through the development of new knowledge and other advances in skills, techniques and experience within the academic sector. However, in this report we are focusing on the non-academic benefits of research. A more comprehensive understanding of the non-academic benefits of research can help the public better understand what taxpayers’ money is being used to produce for society. Outlining the full process of R&I inputs, outputs and benefits creates a clear story that can be used to advocate for further investment in R&I to grow and maximise these benefits. In the context of private sector research, analysis can help focus investment, measure the effectiveness of strategies and interventions to support R&I, and serve accountability and advocacy functions to investors and shareholders.

1.3. Challenges in measuring the benefits of R&I

While there are many reasons for attempting to measure research’s benefits to society, there are also a number of important challenges. One such challenge is the difficulty of establishing the link between R&I and the resulting benefits, which can be direct or indirect. This is often characterised in the literature in terms of attribution – in other words, whether the piece of research can be directly linked to the change observed, and the benefit apportioned in terms of the different studies from which it resulted. This is typically challenging since changes across many of these spheres will result from a wide range of R&I and other social and economic factors, meaning that specifying the extent to which one stream or piece of research is responsible is not feasible. To mitigate this, an approach that is often used is to consider instead the contribution of R&I to changes in society – i.e. whether it is plausible to demonstrate that the work made a meaningful contribution to that change. This links to the ‘pathway to impact’ concept – it is not necessary to prove exactly how much difference a particular piece of work made, but rather to demonstrate a plausible pathway through which it supported or contributed to a particular benefit.

In this context, the concept of absorptive capacity is relevant. Absorptive capacity is the ability to value, assimilate, and apply knowledge (Cohen and Levinthal, 1990). In the context of R&I, it is assumed that conducting research and innovation activities can facilitate the uptake of advances from elsewhere. The piece of research or innovation that leads directly to a benefit for society or the economy may come from another country, but the fact that research and innovation is happening within the UK enables us to have the capacity – whether that be in terms of skills, mindset or access to knowledge – to capitalise on the benefits of that new thinking or evidence. This is often less well captured in approaches to analysing the benefits of research. For example, many of the national-level frameworks, such as the Research Excellence Framework (REF) or Researchfish, look to capture benefits to which research conducted by particular researchers made a material contribution. But benefits from R&I in the UK also result from the ability to

build and capitalise not only on the evidence produced in the UK, but on wider learning from colleagues, collaborators and innovators on an international level.

It is generally understood that the benefits that come from R&I are not instantaneous. The time taken for benefits to accrue, known as time lags, can be a challenge in measuring the benefits of R&I. The time lags associated with a research or innovation activity and the associated benefits can span decades – one measure for biomedical and health sciences suggests that the typical pathway from bench to bedside could take around 17 years (Morris et al. 2011), and it is likely that time lags will vary between sectors. This can make conducting evaluations challenging. If conducted too early, the full benefits from R&I investments will likely not yet have emerged. If conducted too late, the challenges of recall, data collection and tracing the pathway from investment to outcomes become increasingly significant.

The complexity of pathways, along with the diversity of both outcomes and routes to those outcomes, also make measuring the benefits of R&I difficult both conceptually and practically. Evaluation frameworks and methods must balance the need to be both comprehensive and nuanced, and to collect meaningful, comparable data across contexts. Non-linearity makes modelling the R&I-to-impact process difficult, and developing a set of metrics that is comprehensive and appropriate, yet comparable and feasible to collect, is extremely difficult (Morgan Jones et al. 2017).

Linked to this is the challenge of burden. Burden of evaluation can fall on several different parties. There is the time required to plan and conduct an evaluation, which typically falls on research funders. There is also the burden on researchers themselves, who hold much of the information necessary for such evaluations and are often consulted through surveys or interviews. There may also be a burden on research users, who are a key source of information on the way in which R&I is being employed and its contribution to changes in society. The balance of burden across these groups varies depending on the design of the evaluation and methods used.

In industry, there may be limited appetite to respond to external requests for information, and in any case information on the benefits from R&I investment may be commercially sensitive. Even more challenging is the definition and conceptualisation of R&I in an industry setting. The way in which R&I is conceptualised, and even the understanding of who exactly is engaged in R&I activities, may be poorly defined, and may differ significantly across sectors (Ioppolo et al. 2017). This partly reflects the differences in the extent to which innovative activities are structured or ‘open’ in different sectoral contexts.⁴ In particular, it should be noted that the majority of the evidence identified and reported in this document is focused on academic R&I.

⁴ This is explored in more detail in the other commissioned report on the conditions for the translation of R&I.

1.4. Aims and scope of the study

RAND Europe has been commissioned by the Steering Group⁵ of the National Academies⁶ to complete an evidence synthesis to understand what is known about:

1. The range of benefits of research and innovation, for example across economic benefits, health and wellbeing, sustainability, and social and cultural enrichment;
2. How such benefits of R&I are currently assessed or measured in the UK, looking at both the datasets that are available and the limitations of the current data;
3. The distribution of benefits, economic and beyond, across the UK, viewed for example through the lenses of population, place or sector and looked at over time; and
4. Alternative metrics and approaches that have been developed in other countries or contexts.

This project aims to identify benefits to certain population groups, geographies and sectors. The project also aims to understand the way in which benefits of research can be distributed over different timescales, reflecting the time lags in research translation which can be variable and often lengthy (Morris et al. 2011).

1.5. Approach and methods

Our approach to this work consisted of five main tasks:

- **Task 1: Reviewing the existing evidence.** Based on the Royal Society and Academy of Medical Sciences' principles for evidence synthesis (inclusive, rigorous, transparent, accessible) we reviewed existing evidence regarding the benefits from R&I, including:
 - Frameworks to structure and characterise benefits
 - Methods used and datasets available
 - Information on the distribution of benefits by region, sector or population group.

This was based on four methods: a review of grey literature, telephone interviews with funders, a review of academic literature, and a review of datasets.

- **Task 2: Development and population of a conceptual framework.** Based on the evidence identified in Task 1, we developed a conceptual framework to classify the range and nature of the benefits from R&I. The framework is theoretical rather than empirical. We aimed to characterise

⁵ Membership of the Steering Group on a fresh case for investment in research and innovation was as follows: Lord David Willetts PC, FAcSS (Chair); Professor Brian Foster OBE, FRS (Royal Society lead Fellow); Professor Julia Black FBA (British Academy lead Fellow); David Eyton FEng (Royal Academy of Engineering lead Fellow); Dr Patrick Vallance FMedSci, FRCP, FRS (Academy of Medical Sciences lead Fellow); Professor Sir Drummond Bone FRSE, FRSA; Professor Diane Coyle OBE, FAcSS; Dame Clara Furse DBE; Professor Richard Jones FRS; Dr Fiona Murray; Lord Jim O'Neill; Professor Sir Martin Sweeting OBE, FEng, FIET, FRAeS, FRS; Professor Simon Tavaré CSci, CStat, FMedSci, FRS; Professor John Van Reenen OBE, FBA.

⁶ The National Academies are the Academy of Medical Sciences, the British Academy, the Royal Academy of Engineering and the Royal Society.

the range of potential benefits rather than limiting ourselves to what is already being measured. We then used the framework to map the evidence, datasets and approaches identified. Based on this mapping, we were able to compare UK practice, data and evidence to the international picture, and identify gaps in methods/data at the UK/international level.

- **Task 3: Critical review of methods.** It is important to assess the extent to which data and methods that have been used are credible, appropriate and transferable. We therefore conducted a critical review of the approaches used to measure the benefits of R&I in each of the areas of the framework, reviewing the key methods used, key caveats/limitations and strengths of the approaches, the extent to which they address distributional issues, and transferability to other contexts. Based on this critical review we were able to refine our analysis of evidence gaps to include gaps in evidence underpinning key approaches, or where quality issues require the development of more robust approaches. In this review, we also drew out interesting examples of novel practice in each area.
- **Task 4: Cross-cutting approaches.** We conducted a focused analysis of five cross-cutting approaches/datasets that are important in the UK and international contexts in order to understand their utility in the UK context and how they apply across fields. These datasets were the REF case study database, Researchfish, big data approaches, interaction-based models, and case studies.
- **Task 5: Synthesis and reporting.** We synthesised our findings across the tasks and held internal team workshops and discussions to draw out the main findings and insights presented in this report.

The questions addressed and approaches used in the different stages of the work are presented in **Figure 2** below. More details about the methodology can be found in Annex A.

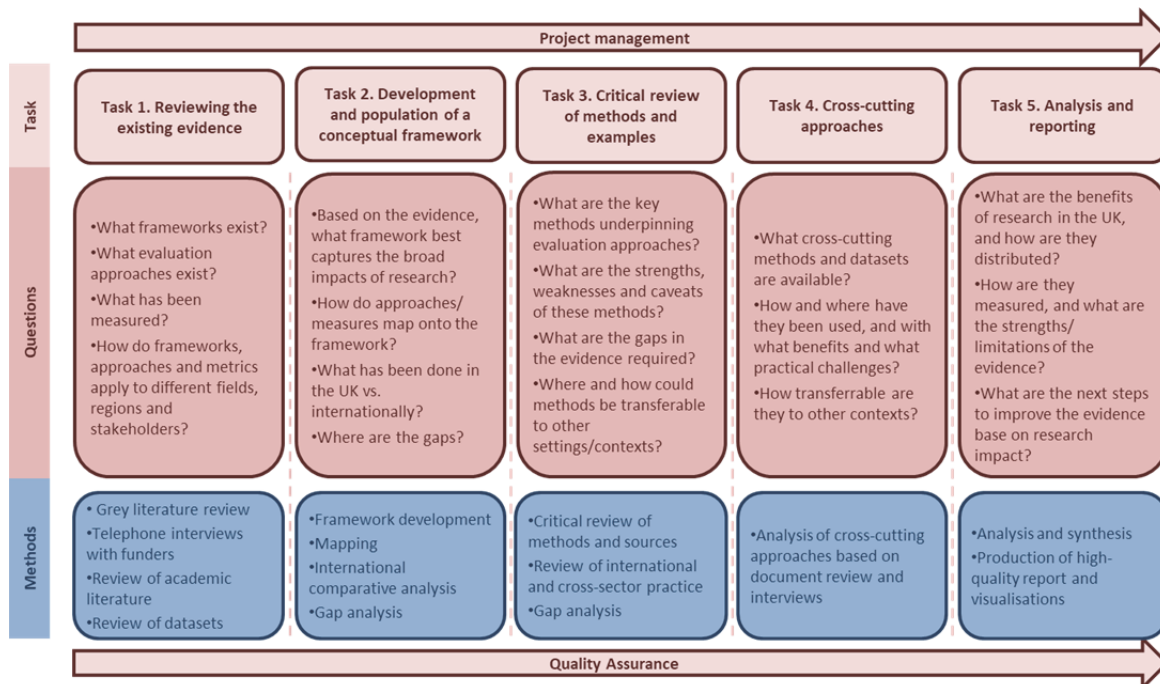


Figure 2 Overview of our approach

1.6. Structure of this report

The remainder of the report sets out the findings of our study as follows:

- **Chapter 2** provides an overview of the benefits of R&I, summarising the existing evidence and developing a framework for characterising the impact of R&I in the form of the ‘impact index’.
- **Chapter 3** maps existing evidence and methods against that framework, and provides a description and critique of the methods used in each context.
- **Chapter 4** provides an overall analysis of the state of the evidence and methods available to measure and characterise the benefits of research, and identifies the challenges, gaps and potential areas of focus for future action to address these.

Additional methodological details are available in Annex A, and a review of frameworks for assessing the impact of R&I is provided in Annex B.

2. What are the benefits of R&I?

In this chapter we review the existing evidence on the benefits of R&I, and develop our own framework to conceptualise those benefits in the form of the ‘impact index’.

2.1. Existing evidence on the benefits of R&I

There are significant rates of return from investment in R&D, likely in the range of 20–30%, with some estimates as high as 85%, as summarised in Table 1. A 30% rate of return suggests that for a one-off investment in innovation, there are benefits equivalent to getting 30p back on every pound sterling invested, every year, forever. However, no such studies exist estimating the overall returns from R&I investment, in part because fewer data are available for innovation activities than R&D.

Table 1 Estimated returns on R&D investment: summary of some key studies since 2000

Public or private R&D investment included	Country	Sector	Estimated return	Source
Public	UK	All	20%	Haskel et al. (2014)
Public and/or private	Summary across multiple studies in various countries	Varied	22–85% ⁷	Frontier Economics (2014), based on Hall et al. (2009) and EC (2005) ⁸
Public	US	Agricultural sector	30–40%	Salter and Martin (2001)
Public	UK	All	20%	Haskel and Wallis (2010, 2013)
Private	12 OECD countries	13 sectors	>40%	Griffith, Redding and Van Reenen (2000)
Public	US	Pharmaceuticals	>30%	Cockburn and Henderson (2000)
Public and private	OECD	All	60%	Frantzen (2000)
Public and private	13 countries	All	68% ⁹	van Pottelsberghe

⁷ Range of mean and median values at different levels of analysis. Full range within all studies analysed is much wider.

⁸ Note that this is an aggregate analysis across previous studies.

⁹ For G7 countries. For non-G7 countries the rate was 15%.

Modelling approaches used to produce the estimated in Table 1 typically focus on the returns from investment in terms of their benefits to private sector productivity, and therefore are likely to understate the overall return to investment. These estimates also focus on R&D rather than broader types of innovation. Nesta's (2009) analysis of the contributions of investment in innovation to the UK economy suggests that innovation was responsible for two-thirds of the UK's private-sector labour productivity growth between 2000 and 2007, increasing productivity by an average of 1.8 percentage points per year. This was based on a broad definition of innovation, taking in elements such as design, skills and organisational structures as well as R&D-based innovation.

There is strong evidence that public R&D investment, whether in terms of fiscal incentives (Falk, 2006), public subsidies for private R&D (Aerts and Schmidt, 2008; Falk, 2006), or R&D conducted by the public sector (Guellec and de la Potterie, 2003; Falk, 2006; Sussex et al. 2016; Hughes and Martin, 2012), 'crowds in' private sector R&D. For example, in biomedical and health research in the UK, every additional £1 of public research investment crowds in an additional £0.83–1.07 of private sector spending, and more than 40% of that investment happens within the first year (Sussex et al. 2016). This suggests that returns might be higher than some of the estimates presented above (Haskel et al. 2014). This type of analysis, however, is not available for R&I as more widely conceptualised.

There is limited evidence on marginal returns on investment – that is, would increased spending on R&I in the UK yield the same, or diminishing returns? One study suggests that the existence of strong positive feedback points to the possibility of increasing returns to scale (Allas, 2014). Another suggests that returns may taper off beyond a certain point, with optimal investment falling around 2.3–2.6% of GDP (Coccia, 2009), close to OECD averages¹⁰ and encompassing the UK's 2.4% target.

The form that this investment should take is also the subject of debate. There is evidence that public funding of business R&D may provide the best returns (Guellec et al. 2001). There is also a suggestion that public R&D funding yields higher returns when provided through the Research Councils (rather than through government departments or higher education institutions (HEIs)) and supporting science-based and applied research (Frontier Economics, 2014). Haskel and Wallis (2010; 2013) suggest that this might be because of the greater similarity to private sector R&D investments.

However, the role of absorptive capacity should also be noted here. Estimates suggest that around 80–90% of the productivity benefits from R&I are based on research conducted in other countries (Crafts, 2012; Eaton and Kortum, 1999; Griffith et al. 2003 and 2004; Mancusi, 2004; Westmore, 2013). The role of R&I investment, beyond supporting the next breakthrough, is also to provide the skills, capacity, resources and knowledge needed to capitalise on that breakthrough, wherever it occurs.

As noted above, the social returns are likely underestimated by economic models, since there a wide range of benefits from R&I, not all of which are readily quantifiable in terms of their overall contribution to the

¹⁰ OECD Main Science and Technology Indicators

economy (Frontier, 2014). One field where research has made significant and demonstrable contributions is in health and healthcare. Evidence-based medicine is core to the NHS. This is perhaps represented most visibly by the National Institute for Health and Care Excellence (NICE), which provides rigorous, evidence-based guidance to UK clinical staff and healthcare professionals on current best practice across a wide range of areas. This advice is strongly underpinned by UK research – not just in the delivery of rigorous evidence syntheses to support their recommendations, but also in terms of the underpinning science. 17–30% of publications cited in a sample of UK clinical guidelines across a range of fields were conducted at least in part by UK researchers (Glover et al. 2014 and 2017; HERG et al. 2008). Building on this, estimates suggest that the health benefits from publicly and charitably funded UK research investment across a number of fields are equivalent to returns of around 7–10p per year, forever, for every £1 invested (Glover et al. 2017).

Attempts to extend this strength in evidence-based medicine to evidence-based policy across the UK have been made through the ‘What works’ centres network.¹¹ An evaluation of the network over the last five years indicates that evidence generated by the centres is having a positive impact on policy (What Works Network, 2018). Overall, use of evidence is increasingly impacting on policies and services in many areas, such as criminal justice, traffic policy and drug policy (Oliver et al. 2014).

Research also engages the public on a large scale. For example, almost 1.5 million people attended free public lectures at Russell Group universities in 2016, and more than 5.5 million people attend exhibitions at museums and galleries located within Russell Group universities every year (Russell Group, n.d.). It also underpins cultural activities and events with wide-ranging benefits, including many high-profile artistic outputs such as award-winning games, BAFTA award-winning documentaries and acclaimed exhibitions (AHRC, 2016). Contributions of R&I to society across industry, society and culture are too numerous and diverse to concisely summarise based on the existing evidence, but some examples of the range of impacts observed are set out in Table 2, based on annual impact reporting from the Research Councils. This is neither a complete nor a representative sample; rather, it is designed to provide an illustration of some of the wide-ranging benefits that can result from research across disciplines.

Table 2 Summary of a range of impacts from R&I in the UK

Impact summary	Source
Arts and Humanities Research Council (AHRC) funding to the National Portrait Gallery led to a comprehensive exhibition of portraits of Tudor Monarchs, ‘The Real Tudors’ (September 2014 – July 2015), which was then also shown in extended form in Paris at the Musée du Luxembourg (March 2015 – July 2015), attracting over 120,000 visitors. The project also supported the development of non-invasive techniques for testing the history of paintings which are being used internationally.	AHRC annual report 2015/16
Award-winning game development studio, The Chinese Room, is an AHRC-funded start up and their BAFTA-winning game ‘Dear Esther’, built on AHRC-funded research, has sold 850,000 copies to the value of US\$2m.	AHRC annual report 2015/16
AHRC-funded research on innovative filmmaking methods to explore recollection and description of acts of genocidal violence has underpinned and inspired award-winning documentaries including the 2014 BAFTA-winning and Oscar-nominated ‘Act of Killing’ and Oscar-nominated ‘The Look of Silence’ (2016).	AHRC annual report 2015/16

¹¹ See <https://www.gov.uk/guidance/what-works-network>

Impact summary	Source
Research funded by the Biotechnology and Biological Sciences Research Council (BBSRC) has led to reductions in the prevalence of lameness in UK sheep from 10% in 2004 to 5% in 2013, saving UK farmers £700m and preventing 7.5 million sheep from becoming lame.	BBSRC Impact Report 2016
ESRC-led research underpins new solid oxide fuel cell technology which led to the development of a combined heat and power unit by Ceres Power that generates cheap, reliable, low-carbon electricity. This technology can replace central heating boilers, reducing energy bills by 25% and saving around 1.5 tonnes of CO ₂ per annum per household.	EPSRC impact report 2016
Off-grid energy kiosks for electrification in rural Africa have been developed by BBOX, a spin-out from Imperial College London, to address unreliable energy supply in the developing world. BBOX now has a staff of 140 globally and its products have saved over US\$2m in energy costs and offset over 40,000 tonnes of CO ₂ .	EPSRC impact report 2016
VocalIQ, a University of Cambridge spin-out building on artificial intelligence (AI) research funded by the Engineering and Physical Sciences Research Council (EPSRC), was bought out by Apple in 2015 in a deal estimated to be worth up to US\$100m. The software has applications including video gaming, smart watches and glasses.	EPSRC impact report 2016
An app developed at Newcastle University, FeedFinder, helps women find and share places for public breastfeeding and has been used by 4,000 people to review over 2,000 locations in the UK. The app is recommended by several NHS Trusts as part of their community midwifery service.	EPSRC impact report 2016
The AHRC-led cross-council Connected Communities programme supports collaborative research with communities with benefits including: increased confidence, self-esteem and engagement for individual project participants; 'products' such as guidance for practitioners, software and apps; and cultural changes including the development of networks and relationships both within communities and with universities.	AHRC annual report 2015/16
ESRC-funded research has raised the profile of issues underlying food poverty in the UK and the use of foodbanks, informing policy debate and shaping the terms of reference for the April 2014 All-Party Parliamentary Inquiry into hunger and food poverty.	ESRC Research Performance and Economic Impact Report 2013/14
ESRC-funded research supported the design the 'Product-Mix Auction', which has been used by the Bank of England to rapidly allocate money to the banks and building societies since the 2007 financial crisis. In 2013, Bank of England Governor Mark Carney announced that the Bank would expand the use of the approach to larger auctions.	ESRC Research Performance and Economic Impact Report 2013/14
The PROUD study, funded by the Medical Research Council (MRC) demonstrated that PrEP is effective in reducing the risk of HIV infection by 86% for a specific high-risk group. PrEP is now available to all patients in Scotland and has been trialled in 10,000 patients in England. It is estimated that PrEP could save the NHS more than £1bn over an 80-year period (£12.5m per annum).	MRC Impact Report 2017
MRC-research demonstrated that a GP intervention aimed at people who were overweight led to 40% taking meaningful action to lose weight. Since 2016, over 26,000 people have been referred to the programme from almost half of the Clinical Commissioning Groups in England, and the programme is scheduled to roll out to the whole country by 2020.	MRC Impact Report 2017
Improved understanding and expert advice supports more effective and cost-effective flood defence provision, saving 90% on flood defence costs (£2.25m) at Belford, Northumberland, and preventing flooding that would cost the local economy £94m per day by informing decisions on when to close the Thames Barrier.	NERC Impact report 2017
Science and expertise from Natural and Environmental Research Council (NERC)-funded scientists and other UK experts helped to lift the flight ban caused by the 2010/11 Icelandic volcanic eruptions earlier, saving airlines up to £290m per day and reducing delays without compromising safety.	NERC Impact report 2017
NERC ocean models enable prediction of average weather conditions up to four months in advance, and airborne atmospheric measurements have improved snow and rainfall forecasting. Incorporating these better predictions into Met Office models has delivered a range of benefits to a variety of stakeholders, including the Environment Agency, the NHS, local authorities, and agriculture and transport stakeholders. Examples include: £76m (£127m per year) reduction in flood damage; reduction in the £500m per day cost to the economy of heavy snow; reduction in cold-related deaths among vulnerable people and in unnecessary stockpiling of road salt.	NERC Impact report 2017
Innovative outputs from the Science and Technology Facilities Council's (STFC) Sci-Tech Daresbury Campus in 2017 included 75 new products (829 in total since 2010), with 20% of companies filing patents. Across STFC's National Laboratories, £7.7m was generated from patents and intellectual property in 2017, and since 2002, 19 spin-outs have been created, raising more than £73m in investment. An example is Cobalt Light Systems, which was sold for £40M to Agilent Technologies Inc.	STFC impact report 2017

2.2. Broadening our conceptualisation of the benefits of R&I: the 'impact index'

There are a variety of existing frameworks for the benefits of research, R&D, and R&I, which can both classify the range of impacts from R&I and model the pathways through which they occur. They provide a structured format for thinking about the benefits of research and support effective evaluation and analysis. A detailed review of the range and scope of existing frameworks is provided in Appendix B. Based on this review, we have developed a framework, the 'impact index', which is designed to offer a broad conceptualisation of a wide range of benefits of R&I. In the remainder of this section we set out the process through which we developed the impact index, and then present and describe the impact index itself.

2.2.1. Development of our comprehensive framework for the benefits of R&I

In this section we describe our approach to developing a broad and comprehensive impact index to capture the potential benefits of research. Our aim was to produce an index which provided a broad, cross-cutting conceptualisation of the benefits of R&I to facilitate more holistic evaluation. We also intended to address one of the aims of this study, which was to understand how these benefits are distributed. The process of developing the impact index consisted of the following steps:

A. We identified a wide range of approaches to characterising the benefits of R&I nationally and internationally, and mapped these into broad categories to create an overview of the different types of benefits mentioned in the existing literature.

The work by Pollitt et al. (2016), described in appendix A, inspired this analysis. However, that study focused on health research. To conduct our analysis of the range and nature of R&I benefits, we reviewed a wider range of approaches and frameworks across different disciplines nationally and internationally, and so were able to identify a much broader typology of benefits measured in the different frameworks. We aimed to develop a broad, comprehensive set of categories for the range of potential benefits of research and one which would resonate with the current UK policy environment by drawing on UK approaches such as the REF and Researchfish. The frameworks that we covered in our analysis of R&I impacts are:

- REF definition of impact (UK Higher Education Funding Councils, 2011)
- Snowball Metrics: <http://www.snowballmetrics.com/>
- Research Councils UK Outcomes System (ROS):
http://www.esrc.ac.uk/_images/Output_types_on_ROS_tcm8-14587.pdf
- US National Science Foundation (NSF) Grant Proposal Guide:
http://www.nsf.gov/pubs/policydocs/pappguide/nsf16001/gpg_index.jsp?org=NSF
- Consortia Advancing Standards in Research Administration Information (CASRAI):
<http://casrai.org/>
- Researchfish (UK): <https://www.researchfish.com>
- Payback Framework (Buxton and Hanney, 1996)

- Research impact framework (Kuruvilla et al. 2006)
- US National Institute of Environmental Health Sciences (NIEHS) logic model (Drew et al. 2013)
- EU framework programme (Arnold, 2012)
- Excellence in Research for Australia: <http://www.arc.gov.au/excellence-research-australia>
- Regional impact framework (Lendel, 2010).

B. We looked at two definitions or characterisations of quality of life (from Eurostat and the World Health Organization (WHO)) to include a more comprehensive picture of the areas of quality of life that research and innovation might be able to influence.

A limitation to a mapping approach based solely on existing frameworks is that it only considers what is already being measured, which might limit the analysis to what is easy to measure and not capture important but less easily measurable benefits from R&I. With this in mind, mapping only existing frameworks had the potential to be too limited for the purposes of this study. Therefore, we also looked at two definitions or characterisations of quality of life from Eurostat (2015) and WHO (n.d(b)) with the expectation that these approaches might give a more comprehensive picture of the areas of quality of life that research and innovation might be able to influence. The overall mapping is shown in Table 3.

Table 3 Mapping of the types of impact identified in a range of existing frameworks against a range of impact categories

	Economic	Safety / security	Cultural / artistic	Policy	Health	Commercial/ innovative	Environmental	Quality of life	Skills and education	Public engagement	Broader societal	Other
REF	Impact on the economy	Prevention and reduction of harm and risk	Impact on culture	Public policy / services	Health	Industrial and commercial impact	Environment	Quality of life	Teaching and learning beyond submitting HEI	Relevance to needs of the public	Impact on society	
Snowball metrics	Enterprise activity					Enterprise activity						
Research Outcomes System						IP and exploitation				Dissemination and communication		
National Science Foundation (NSF)	Increased economic competitiveness of the United States;	Improved national security				Increased partnerships between academia, industry, and others;		Improved wellbeing of individuals in society	Improved STEM education; Competitive STEM workforce	Participation of minorities in STEM; Increased public scientific literacy and engagement;		
CASRAI	Impact on productivity; Direct or indirect economic benefits to society		Broader cultural benefits		Broader health benefits	Quality of direct or indirect knowledge and innovation production; Quantity of derived knowledge and innovation production	Broader environmental benefits		Human, leadership		Impact on society: Broader social	
Researchfish			Artistic	Policy impacts		IP, products, spin outs			Skills	Dissemination		
Payback Framework	Broader economic benefits			Informing policy	Health/ health system impacts	Informing product development						

RAND Europe

	Economic	Safety / security	Cultural / artistic	Policy	Health	Commercial/ innovative	Environmental	Quality of life	Skills and education	Public engagement	Broader societal	Other
Research impact framework				Policy impact; Service impact								
NIEHS logic model	Improved allocation of resources; commercial benefit/ healthy workforce			Translation into policy, guidelines	Health gain	Commercial development; new and improved products and processes	Environmental quality and sustainability	Welfare gain			Societal impact; magnitude and duration of social change; social welfare gain	
EU framework programme	Strengthened competitive position of EU industry			Innovation in policymaking		Diffusion of innovation in products, processes or services; industrial innovation						Creating common European markets and technologies
Excellence in Innovation for Australia	Economic development impact	Defence sector impacts					Impact on the environment				Societal impact	
Regional impact framework			Cultural products			New products and industries; entrepreneurial culture		Quality of life	Trained labour; education			
Eurostat quality of life indicators	Material living conditions; economic safety	Physical safety		Governance and basic rights	Health	Productive or main activity	Natural and living environment	Overall experience of life	Education		Leisure and social interactions	
WHO QOL-100			Spirituality/ religion/ personal beliefs		Physical/ psychological health; independence		Environment				Social relations	

Source: RAND Europe

3. We analysed the different frameworks to generate a comprehensive list of R&I benefits. The different frameworks, to differing extents, cover benefits from R&I in the following areas:

- Economic
- Safety/security
- Cultural/artistic
- Policy
- Health
- Commercial/innovative
- Environmental
- Quality of life
- Skills and education
- Public engagement
- Broader societal
- Other.

We note two main observations here. Firstly, two of these areas appear to be very broad – impact on society and impact on quality of life are areas which could capture almost any impact, including those within the other categories. For example, impacts on the environment, health or culture are also likely to impact on quality of life and on society. As such, these categories are duplicative and will not be separately included in the impact index.

Secondly, we have two additional benefits noted under ‘other’. The first is international development, from the REF definition of impact. This is not captured in other frameworks and seems to focus largely on geographical location rather than type of impact. For example, impacts falling in the ‘international development’ category could include impacts on the environment or on health, but outside of the UK context. We intend to capture the geographical distribution of impact separately and prefer not to include this as a specific category. The second is ‘creating common European markets and technologies’ from the EU framework programme evaluation. To some extent this is about international integration, and could arguably contribute to economic impacts. However, it is too specific to the requirements of an EU programme to be broadly applicable to the wider categorisation of R&I. Therefore, we also do not include this in the impact index.

Based on this analysis, we have identified ten major benefit categories which we then use to form the basis of the impact index.

2.2.2. The ‘impact index’: our comprehensive framework for the benefits of R&I

In this section we present our own impact index for capturing the benefits of R&I. Building on the mapping above (see Table 3), and the overall aims and approach of this project, we propose the new impact index set out in **Figure 2** below for capturing the benefits of R&I. Examples of the types of impacts falling within each domain, drawing on examples from the literature and interviews conducted, REF case study database, and our own experience working with UK HEIs and other research-intensive organisations, are set out in Table 4. Note that these are illustrative and as such are not intended to be comprehensive. This structure aims to capture the range of different types of impact that can result from

research covering the full spectrum as set out in the previous chapter. We also propose categorisation by the distribution of those benefits in order to reflect the aims of the study, which are not only to analyse evidence on the benefits of research, but also to understand how these are distributed across geographies, sectors and population groups, as well as over time.

There are some important caveats to this framework. Firstly, although we have attempted to provide separate and unique classifications, due to the non-linear, multifaceted nature of research translation and the complexity of each of these areas of benefit, there will inevitably be some overlap and interrelationship between benefits in the different categories. For example, we anticipate that cultural impacts might be closely related to public engagement activities, and might also link to benefits to social cohesion. Moreover, we note that approaches to measurement may well span categories. This is particularly important in terms of economic benefit.

As discussed previously, there are many studies which attempt to capture the benefits from R&I in terms of their economic returns on a national or sectoral level. These analyses may span and attempt to capture benefits from a diversity of different routes, either explicitly or implicitly. For example, improvements in education might lead to economic gains in a number of ways – for example through improvements in lifetime earnings of the individuals benefitting, or through increased productivity. Similarly, improvements in health can result in reduced NHS costs, or increased earnings and productivity as people are able to return to work. Economic benefits might, therefore, in some ways be considered to be the ultimate measurable benefit of R&I, and as such a different order measure to the other categories.

However, this approach needs to be treated with some caution. Some benefits are much more easily converted into monetary benefits than others. Taking a primarily economic perspective can skew perspectives on R&I and fail to adequately value many of the benefits of R&I which are not so easily characterised in this way. Education is not just intended as a way to increase job prospects, but can enrich and benefit people in a much wider range of ways. In health, most new interventions typically cost more to deliver than those they replace, but bring greater health benefits in the long term. In addition, given an ageing population with complex co-morbidities, many interventions may improve quality of care and quality of life, but are unlikely to get as many people back to work. However, health is one area where an effective measure for monetising health and wellbeing benefits has been generated. The quality-adjusted life year (QALY) gives an aggregate measure of health benefit which can be converted to an economic benefit (see section 3.5). However, comparable metrics in other fields have proved elusive. For example, work to produce a comparable measure in social care using the ASCOT framework is still ongoing and yet to be monetised.¹² As such, although economic analyses can provide an aggregate picture, as explained in more detail in section 3.2, it should be acknowledged and recognised that this is by no means a complete picture of the benefits that can result from R&I.

¹² <https://www.pssru.ac.uk/ascot/>

	Impact on the economy	Commercial impact	Impact on public policy and services	Impact on health and wellbeing	Impact on education and training	Impact on public engagement, awareness and debate	Cultural impact	Impact on social cohesion	Impact on safety and security	Impact on the environment
Aggregate benefits										
Benefits by region/ geography										
Benefits by sector										
Benefits for different population groups										
Benefits over different time periods										

Figure 3 The impact index: A conceptual framework for capturing the benefits of R&I

Table 4 Examples of the types of impacts falling within each domain of the conceptual framework

Impact category	Examples
Impact on the economy	Increased productivity; GDP gains; attracting capital investment; improving resilience and diversification of the economy
Commercial impact	Generating revenue; improving processes; opening up new markets; creating employment in industry
Impact on public policy and services	Informing policy debate within the general public, in a government body, or at a non-governmental organisation; increasing public engagement with the policy process; improving efficiency of or access to public services; improving the equity of public service provision
Impact on health and wellbeing	Improving health outcomes; changing healthcare practice; improving health equity; increasing patient/user choice; increasing access to health services; improving the management of healthcare performance; improving patient/user satisfaction
Impact on education and training	Changing curricula; improving training materials, text books or other teaching resources; creating materials for specialised teaching contexts; changing the structure of a course; increasing access to education; improving educational outcomes
Impact on public engagement, awareness and perceptions	Shaping the nature of public debate; increasing public engagement with research findings; increasing public awareness; creating publicly available tools or resources; increasing public curiosity about science, technology, the arts or other disciplines
Cultural impact	Preserving cultural heritage; increasing accessibility of culture; improving artistic/cultural methods; improving the quality of cultural events/activities
Impact on social cohesion	Reduced inequality; reduced bias and intolerance; improved social integration; increased social capital
Impact on safety and security	Improving infrastructure security/resilience; improving policing practices; creating new tools for policing; improving safety in the workplace, at home or in other settings; increased regional security; improving national security and defence capabilities
Impact on the environment	Reducing pollution levels; improving measures of environmental condition; contributing to conservation; improving waste management, environmental efficiency or environmental management; reducing the depletion of a natural resource; developing adaptations to environmental conditions/changes

Source: RAND Europe

3. Mapping existing evidence and methods for capturing the benefits of research and innovation

This chapter provides an overview of the areas in which evidence on the benefits of research has been collected, based on an analysis of the literature and interviews with key stakeholders. The categories of impacts presented are not a comprehensive list, but rather are meant to be illustrative of the potential benefits that could arise from R&I, based on our analysis.

3.1. Overview and conceptualisation

As described above, the impact of research can be classified broadly across a wide range of domains. As noted in an analysis of REF case study submissions (Kings College London and Digital Science, 2015), the range of benefits achieved through R&I, specifically in the UK, is also extremely broad. The analysis identified 60 impact topics across the case study set. However, the existing evidence in the literature about the contributions that have resulted from research – beyond the academic sphere – falls primarily into the areas of economic growth, improved health and wellbeing, improved public services and policies, and cultural benefits. In this chapter we describe the existing evidence in terms of the benefits across these categories, as well as exploring the extent to which evidence is available for different sub-groups and populations – for example by geographic region, sector or population group, as per the framework defined above. We also explore and critique in detail the methods used to characterise the benefits in each of these areas, illustrating this with some case study examples. Each column of the impact index is reviewed in turn in sections 3.2–3.11. In the remainder of this section (3.1) we review the overall distribution of the existing evidence across the impact index and discuss some cross-cutting issues. Finally, in section 3.12 we provide additional detail and context on several cross-cutting methodologies and approaches.

3.1.1. Mapping the distribution of evidence across the impact index

Figure 4 below provides an overview of the areas in which evidence of the benefits of research has been collected, based on our analysis of the literature, noting whether this has been collected on a national level, or for specific programmes or portfolios of research, and whether this has taken place in the UK or internationally. It is important to note that though extensive, our searches are likely not exhaustive. It is possible, or indeed likely, that there is some work that we have not identified that covers some of the areas of the framework. However, based on a fairly broad survey of the literature, and conversations with most major funders in the UK, this provides our best estimation of the current picture regarding the evidence on the benefits of research.

Light red shading indicates that we have identified at least one review at a portfolio level that assesses benefits within that area in the UK. Where this is observed outside the UK, the box is shaded light blue. Dark red shading is used to indicate that we have identified at least one study looking to assess benefits in that area on a national level in the UK. Similarly, where there are examples of national-level analyses but not in the UK, dark blue shading is used. National-level assessments take precedence over portfolio assessments in this analysis, and UK examples take precedence over international examples.

A second important caveat is that we have excluded evidence based on case study examples from this assessment. It is likely that there are case study examples in the REF case study database covering impacts in all of these boxes. Equally, in our assessment a majority of evaluations of research portfolios include a number of case study examples which may cover some of these elements. Case studies can and do provide an important source of information on the impact of research, and in particular the routes through which these impacts can occur. However, we do not include them in this analysis as their ability to provide an aggregate or portfolio-level picture is limited. For example, there may be specific case studies illustrating examples of the impact of R&I on culture in a particular region or for a particular population group. However, this does not give an indication of ways in which the benefits of R&I as a whole, or even from a particular portfolio, are distributed by location or population group. More discussion on the use, benefits and challenges of case studies is provided in section 3.12.5.

In terms of the analysis in Figure 4, this means that there are some notable gaps. For example, we do not identify any studies that assess benefits to safety and security at a portfolio level, though individual examples of such benefits are seen in some of the research council impact reporting in the case studies presented. Similarly, we see many examples of regional environmental benefits presented in evaluations and reviews, but have not identified any studies that systematically look to assess the geographic spread of environmental benefits from R&I at a national or portfolio level. Typically, most geographical analyses look at input rather than outcome measures, with some exceptions as noted in the figure and explained in more detail in the rest of the chapter. It is also worth noting, though not formally illustrated on the diagram, that many studies focus on research or R&D in their analysis rather than R&I as more widely conceptualised for the purposes of this study.

3.1.2. The impact index provides cross-cutting insights on the distribution of evidence

An initial observation from the distribution of evidence across the impact index is that there is generally broad coverage across impact areas at the aggregate level for specific portfolios of research. This is unlikely to be comprehensive in its coverage of each type of benefit. For example, an evaluation of a particular portfolio of research may well capture, through surveys or through interviews with a sample of relevant research users, impacts on a particular type of policy or evidence of examples of changes to education and training that are identified. However, the full range of ways in which research across all fields and disciplines can impact on education and training are unlikely to be captured through these portfolio-specific analyses.

A second important observation is that national-level analyses have only been conducted in three areas of impact: health and wellbeing, commercial and economic. These make up the majority of evidence in the literature and are the areas in which there has been most methodological innovation. These are also the only areas where we see studies attempting to conduct analyses beyond the aggregate level. Finally, we

note that there are some areas where studies have not yet been conducted in the UK but where there is scope for learning from other countries, particularly in terms of looking at benefits at a disaggregated level.

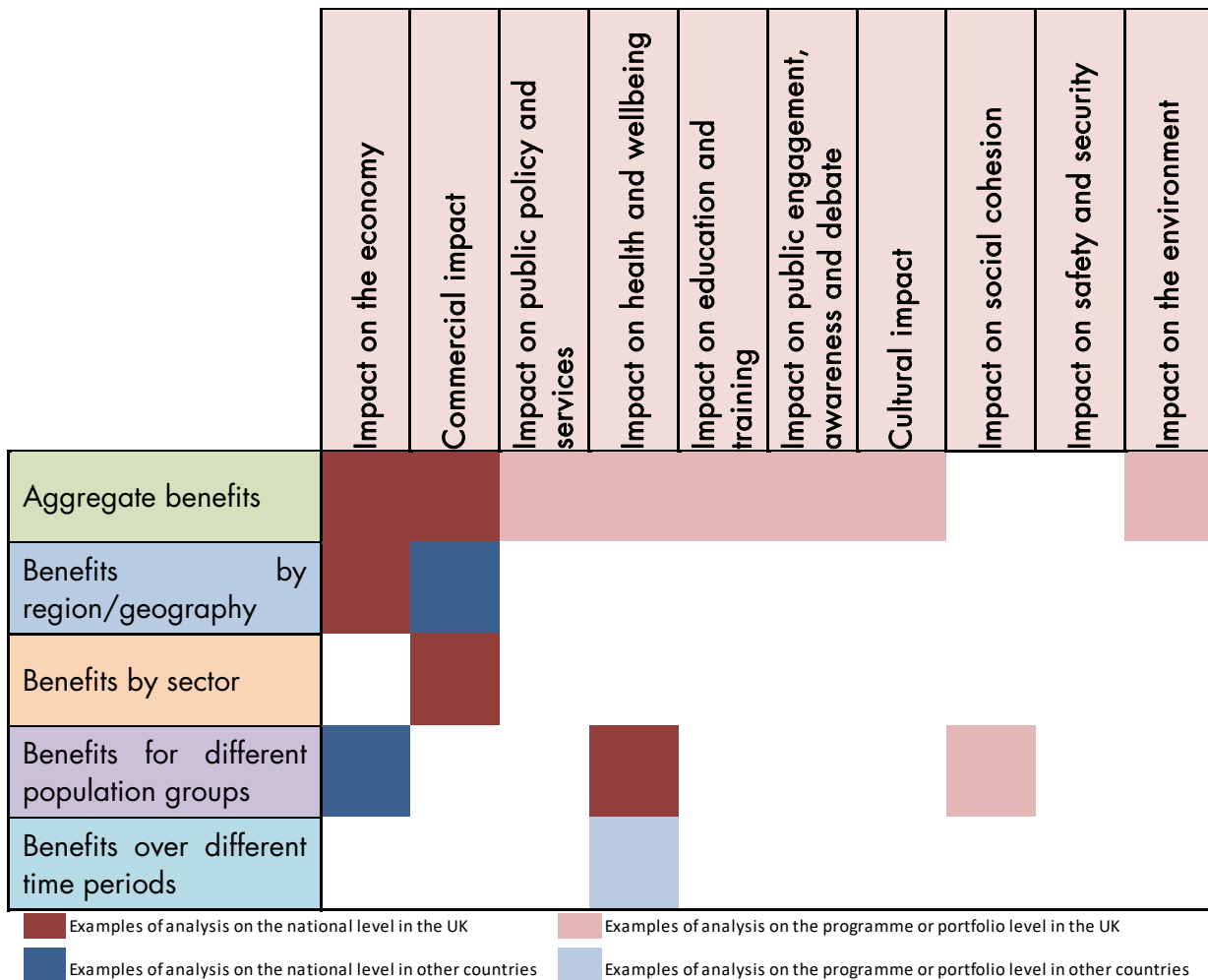


Figure 4 Mapping the existing evidence onto the impact index

There are some overlaps between categories, as noted above in section 2.2.2. For example, there are many studies which characterise the economic benefits from research based not only on overall GDP numbers, but through attempting to monetise other types of benefits (e.g. health or environmental benefits). In addition, many studies which focus on another type of benefit (e.g. many of the studies on cultural benefits) also attempt to link this to the economic impact that this could potentially have. There is an overlap between commercial and other benefits. For example, benefits to the creative industries could be considered as one component of the commercial impact, or captured under creative benefits of R&I.

There are also overlaps in terms of methods. Core to the collection of information on the benefits of research and innovation are three key elements: surveys, case studies and interviews. Each of these is widely used to capture perspectives on portfolios of research, and they typically draw on a mix of informants covering both researchers and users of the research. This mix may differ depending on the portfolio of research in question. These approaches can be extremely effective in understanding the benefits from a programme of R&I work in its own context and terms. This type of work draws on realist

foundations, whereby the underpinning assumption is that it is most valuable to analyse the impacts of a portfolio of work on its own terms and in its own context. However, it is typically less effective in terms of giving a wider perspective on the overall benefits from R&I across portfolios, since these data may not be readily compared.

In sections 3.2–3.11 we set out how the benefits of R&I can be conceptualised, the ways in which they are measured, and the limitations and strengths of those approaches, for each column of the impact index. In addition, in section 3.12, we detail a number of cross-cutting datasets and approaches which span the different categories.

3.2. Impact on the economy

Summary

- Economic analyses are useful because they are easy to communicate and can be comparable with other policy options.
- Most economic analyses are based on one core methodology which has some important underpinning assumptions and considerations.
- A key limitation of the approach is that it is a ‘black box’ approach which provides little information on the routes through which impacts occur.
- There is a risk that the focus on economic analyses limits the picture of benefits from research to those that can be readily quantified in this way.
- There are other microeconomic approaches to assessing research benefits but these are less widespread and developed.
- Some economic analyses have attempted to characterise benefits by region or population group and these approaches could be further explored across different contexts.

3.2.1. What constitutes economic impact?

Many studies seek to characterise the impact of research in terms of its economic benefits. This is typically expressed in terms of GDP gains or return on investment. However, economic impact of research could be conceptualised more broadly, capturing wider benefits such as attracting capital investment or improving the resilience of the economy. Research and innovation leads to economic benefit in a number of ways and there is significant overlap between the economic returns from research investment and many other benefit categories, since funders often attempt to quantify and monetise what are effectively benefits to, for example, health or the environment. In this section we focus primarily on the economic analyses conducted at a national level, though we also touch on these quantification approaches.

At a more conceptual level, we can consider several ways in which research and innovation can support economic growth and stability. Firstly, new innovations can drive improvements and efficiency, produce new products and open up new markets, as described in the previous section, across multiple sectors of the economy. This can then lead to aggregate-level growth and economic benefits. Secondly, research can lead to savings in both the public and private sectors – through efficiencies, or by stopping or reducing ineffective practices. This can have significant implications economically. Publicly funded research can act to address market failures or overcome barriers that would not be addressed by privately funded research.

Furthermore, as noted above, research and innovation can lead to benefits, for example to health, that can be said to offer economic benefits by enabling people to continue to work or by reducing costs of care provision over the longer term. The benefits in terms of individuals' quality of life can also be monetised, as noted previously. The Frontier Economics (2014) study on rates of return in science and innovation conceptualises this in terms of private and social returns. Private returns accrue to those making the investments, while social returns are benefits to others, including both benefits for firms who can capitalise on innovations made by others, and wider benefits to society which can be monetised.

3.2.2. Examples of available evidence on economic impacts

High-level analyses of the economic impact of investment in R&D at the national level have been conducted and typically demonstrate positive outcomes. Guellec and Van Pottelsberghe de la Potterie (2002), in a study of 16 OECD countries, show that science and technology are important to productivity growth and economic growth, emphasising in particular public investments in the higher education sector. Furthermore, Sena et al. (n.d.) show that public investment in innovation can spur economic growth through the creation of an environment conducive to knowledge exchange. Coccia (2009) notes that there might be an optimal level of investment in R&D to optimise outputs, and sets it at between 2.3% and 2.6% of GDP. However, it is important to note that these studies typically focus on R&D rather than R&I more widely.

Focusing on the UK context, work by Haskel et al. (2014) suggests that there is an annual return of 20% from investment in R&D at the aggregate level, based on the increases in private sector R&D output through raising the level of the UK knowledge base, and that this may be higher if public sector investment could be shown to crowd in private sector investment. Other studies also suggest that this might be an underestimate, pointing to the range of contributions made by R&D that are not readily quantifiable in terms of their overall contribution to the UK economy (Frontier, 2014). Indeed, Nesta's (2009) analysis of the contributions of investment in innovation to the UK economy suggests that innovation was responsible for two-thirds of the UK's private-sector labour productivity growth between 2000 and 2007, increasing productivity by an average of 1.8 percentage points per year. The study takes a broad definition of innovation to encompass elements such as design, skills and organisational structures, as well as R&D-based innovation. Studies do acknowledge that estimates for the UK are high relative to international analyses, but it is suggested by one paper that this may be 'consistent with the high international ranking of UK university science' (Haskel and Wallis, 2013).

Some studies have also looked at the extent to which public expenditure on R&I stimulates private sector investment. Sussex et al. (2016), for example, find that every additional £1 of public research investment in R&D (in biomedical and health research specifically) is associated with an additional £0.83–1.07 of private sector R&D spending in the UK. In addition, the model showed that 44% of that additional private sector expenditure occurs within one year. This can be converted to an annual rate of return on public sector investment in biomedical and health research of 15–18%.

More micro-level economic analyses have also been conducted, particularly in work related to the impact of R&I on economic elements of development. For example, work by Sanglestsawai, Rejesus and Yorobe (2014) focused on distribution of benefits from R&I across income groups. Unsurprisingly, agricultural

workers on the least productive farms are poorer and benefit disproportionately from genetically modified crops, demonstrating the distributional effects of R&I.

Time lags are also important in terms of calculating the economic returns on investment, since benefits which take longer to emerge are of less value due to discounting of future benefits against present gains (in most models). These differ between the public and private sectors, likely reflecting the differences in the type of the work conducted and the fact that a larger proportion of public R&D is supporting basic research which is not intended to serve a specific commercial (or other) application (Frontier Economics, 2014). Time lags between private R&D investments and commercialisation, and the resulting economic benefits, are typically relatively short at around 1 to 4 years (Rouvinen, 2002; Pakes and Schankerman, 1984). Time lags between public R&D and commercial returns or other wider benefits (e.g. benefits to health) are significantly longer, typically in the range of 15–20 years (Adams, 1990; Morris et al. 2011). However, time lags between innovation and returns are less well explored.

3.2.3. Methods used to determine economic impacts

Macro-level analyses based on the production function approach

Core to the analysis of the benefits of R&D has been the production function approach developed by Griliches (1979). This is a macroeconomic approach in which inputs – including knowledge – are linked to outputs such as productivity through a production function in order to directly measure returns on R&I investment. This approach, and variations on it, have been widely used and form the basis of most economic analyses of returns from research. The approach is described in some detail in a report by Frontier Economics (2014), but in brief the approach consists of creating a ‘production function’ in which measures of output (e.g. productivity) are linked to input measures covering labour, physical capital and knowledge capital. This is then analysed to look at either the elasticity of the output in question in relation to knowledge capital or the rate of return on investment in R&D. In general, such studies show positive impacts of public investments in R&D, but Salter and Martin (2001) note many are limited by methodological problems.

There are a number of potential limitations and methodological challenges in this approach. These are explored in detail in Frontier Economics (2014, Appendix A). A brief summary of some key issues is provided here. Firstly, there are a number of definitional issues around the variables used in the model. The output variable is often by nature limited in the extent to which it captures the benefits of research and can be defined in many different ways. Defining knowledge capital is also a challenge, and is usually based on measures of R&D activity. This has a number of associated issues, for example double counting, since this will also include labour and capital costs, and estimating the extent to which knowledge capital can be said to depreciate over time. It is also important to note that time lags play an important role in these models. Output benefits typically take time to occur, but capturing this requires time series data which may not be available or consistent, and the appropriate lag structure is not clear from the literature and therefore is often determined empirically (Abdih and Joutz, 2006). There are also issues related to the interaction between variables. The production function implies that knowledge stock is separable from the other factors of production, whereas in reality it is likely that there may be significant interplay between them. Finally, there may be biases resulting from other omitted variables that influence outputs. There are

other methodological challenges around data quality that may also impact on the quality of these estimates.

Nonetheless, this approach has been widely used and is extremely valuable in terms of providing an aggregated, macro-level analysis across the overall benefits of R&D in a quantified way. It is also possible to construct the model based on available datasets at a national or firm/sector level. Linked to this, however, is an important limitation of the approach, which is that it does not give any information on the routes through which the returns are realised, only the extent to which they are achieved.

Application at the sub-national level

As noted above, although this production function methodology can be applied at the national level, it can also be applied at the firm or sector level and has been used in regional and population group analyses. For example, it has formed a critical element in the assessment of agricultural research programmes (Everson, 2001; Alston et al. 2000; Andersen, 2015). One important way that this type of analysis has been applied is in the assessment of spillovers – that is, the link between private and public sector investment in research.

This is an important component of a series of studies looking at the economic returns on public and charitable investment in biomedical and health research in the UK (HERG, 2008; Glover et al. 2014; Glover et al. 2018). These studies bring together an estimate of the spillovers from research in the sector, with a bottom-up estimate of the return on investment in terms of the monetised health gain. The first component, the spillovers, are estimated by fitting an economic model to time series data on biomedical and health R&D expenditure in the UK for ten disease areas,¹³ to see how far public investment in research stimulates private sector spending on R&D, or whether it in fact replaces it (Sussex et al. 2016). The health gain method takes a more instrumental approach, bringing together four key components as described in section 3.5. This second part of the analysis is interesting from an economic analysis perspective as it provides an example of a more microeconomic approach that goes beyond the ‘black box’ production function to attempt to understand in more detail the mechanisms through which economic outcomes are achieved.

Micro-level approaches

Another example of microeconomic-level analysis is the work of the STAR METRICS project in the United States, which looks at the direct and indirect economic impact of research and innovation spending at universities in terms of employment (both within the university and more widely). There is also the Industry and Academic Engagement project at Imperial College, London (Fini, 2013), which aims to create a large database to link individual researchers and the outcomes of their work to economic impacts at a more granular level.

¹³ Technically, the approach used is a vector error correction model, which analyses the relationship between the different funding sources (public, private, charitable) by modelling them as a combination of short-term movements and longer-term equilibrium trends.

Similar to the STAR METRICS approach, several studies analysing the regional and national economic benefits of large-scale infrastructure investments use an approach based on standard Office for National Statistics (ONS) multipliers to estimate indirect and induced impacts of R&D spending (standard rates are 0.44 for induced impact and 0.23 for indirect impact, as a multiplier of direct spending). This means that, based on the standard multipliers, £1 of spending on such R&D infrastructure projects yields £0.67 in additional economic activity through indirect and induced impacts. An example of this is the analysis by STFC (2010) of the benefits from the second generation multi-user X-ray synchrotron facility. The analysis estimates that spending on the construction, operation and decommissioning of the facility over its 33 year lifetime was £594m, implying induced and indirect impact of £398m. They also note that of the direct spending, £534m was in the local area, which in this case was North West England. This local and regional spend data is often available in terms of the direct spending. However, it is less clear whether the indirect and induced benefits are similarly local in nature. Similar analysis has been conducted for the UK space industry, looking at both overall economic impact and jobs generated (Oxford Economics, 2009). Again, direct impacts are broken down by region, but multiplier effects are provided on an aggregate basis.

Micro-level approaches can also enable analyses of benefits to particular population groups, or to particular regions or in terms of reducing inequality (Rich et al. 2014; Mathenge et al. 2014). For example, novel macro-level approaches have been used in the analysis of the distributional benefits of agricultural research for development. As noted above, the standard methodological framework for analysis of the economic benefits of R&I described above (Griliches, 1958) focuses specifically on how the total monetary benefits compare to the initial investment. However, in the development field, this is not necessarily a helpful outcome as the key aims are around addressing poverty and inequality, so it is perhaps not surprising that development-focused research, particularly in the case of agriculture, is one area where approaches to looking at the distribution of the benefits of R&I have been explored. This is covered in a recent 'special section' in *Food Policy* which includes a number of studies intended to improve 'rigor and accuracy in the measurement of differential size and dimensions of the effect size parameter associated with a multitude of adoption domains defined by geographical, agro-climatic or socio-economic boundaries' (Mywish et al. 2014). A number of papers in the issue cover relevant applications of novel microeconomic models to explore the impact of R&I on different groups and populations (Mathenge et al. 2014; Shiferaw et al. 2014; Sanglestsawai et al. 2014). For example, work by Sanglestsawai, Rejesus and Yorobe (2014) focused on distribution of benefits from R&I across income groups. They analysed farm-level survey data from the Philippines, building on a novel technique for estimation (instrumental variable quantile regression) that allows them both to assess the variable outcomes from adoption of a particular genetically modified crop and also to address selection bias, which is a common issue in these types of studies. The evidence suggests that this is a useful and novel analytical method that allows this type of distributional analysis to be conducted on survey data despite its limitations in terms of response bias and the wide variation in outcomes on an individual level. This could be applied to wider survey analyses on the outcomes of research and innovation for different population groups both inside and outside the agricultural sector.

Summary

Overall, economic analysis approaches add value as they provide a simple message, often in terms of a rate of return that is particularly appealing to some audiences, and which enables comparison of R&D (though typically not, as yet, R&I) investments with other, unrelated investment routes. This can be particularly useful when making the case for investment in research over, for example, wider infrastructure projects. In some senses, economic benefits can capture a wide range of benefits that could also be considered to fall within other categories and provide a useful way to aggregate and compare outcomes across domains. However, this needs to be treated with some caution, for two main reasons. Firstly, many of the benefits of R&I, particularly those which fall within the wider societal benefits, may not be easily quantifiable or monetisable, so there is a risk that only those outputs that can be captured in this way are measured and thus valued. Secondly, the approaches tend only to offer information on the outcomes, not the route through which these outcomes are achieved, which limits the utility of these approaches to develop and refine the research and innovation process in the future. Therefore, although economic analysis provides a powerful and useful part of the R&I evaluation toolkit, it should not be applied to the exclusion of other approaches.

3.3. Commercial impact

Summary

- There is a reasonably large evidence base on commercial impacts of research.
- The evidence focuses primarily on patent analysis and econometric approaches, which provide a fairly limited picture of the ways in which R&I can impact on companies.
- Evidence suggests that R&I does have significant impact on the private sector and there is some evidence showing regional-level effects from universities.
- One of the strongest pieces of evidence on the impact of R&I on the private sector overall is the emerging literature on spillovers, which shows that not only does public sector investment bring benefits for the private sector, but it also leverages ('crowds in') additional R&I investment from the private sector.

3.3.1. What constitutes commercial impact?

The commercial impact of research and innovation is one of the traditional evaluation areas as it is often closely associated with much sought-after economic impacts. Most approaches in this area focus on intellectual property and revenue generation. However, the most widely used metrics for commercial impact are narrowly focused on a linear model of science and technology research feeding intellectual property into manufacturing industries. Research and innovation can have a greater impact than this on the commercial sector, through improving processes, opening up new markets, and other spillover effects (NESTA 2009).

3.3.2. Examples of available evidence on commercial impacts

Econometric approaches provide detailed insight into the financially quantifiable impacts of research and innovation. Methods using intellectual property analysis are often employed to capture the link between research output and commercialisation – though this has limitations since much intellectual property is

not actively commercialised. Also, to fully capture the commercial impact of research and innovation, the remit must be broadened to include the many other paths to commercial impact. Recent works have recognised the breadth of potential benefits, and have incorporated new approaches to capture them. Lendel (2010) developed a framework of the interaction of ‘university products’, which are channels through which universities can affect regional economies. This framework aims to take a long-term view of the effect of university R&D expenditure over several phases of the business cycle, and considers seven elements of a technology-based economy as identified previously by Berglund and Clarke (2000). These elements include intellectual infrastructure, knowledge spillovers, physical infrastructure, and entrepreneurial culture. The entrepreneurial culture that arises in R&I-heavy areas is identified as particularly difficult to assess. As an approximation, the author used the number of new start-ups in the area, normalised by population, and found that regional economies with relatively high numbers of new businesses were healthier and more entrepreneurial (Lendel, 2010). Another challenge is that the strong interrelation between university products (such as new knowledge, new products and industries, trained labour) can make it more challenging to disaggregate and analyse outcome variables. An example given is the participation of students in contracted research, which contributes to both their education and wider knowledge creation – separate outcomes but which benefit from the same process.

NESTA’s innovation index was developed to ‘provide a basis for better policymaking about innovation by developing and deploying significantly improved measures of innovation in the UK’ (NESTA, 2009). To meet this goal, NESTA aimed to measure innovation beyond R&D and patent citations by examining the effect of innovation investment on economic growth and productivity (NESTA, 2009). This econometric approach was supplemented by a survey of 1,500 businesses across ten industries to drill down to the sector and firm level. The economic work considered innovation as the sum of two parts: ‘private benefit’ (the benefit captured by the business making the investment) and total factor productivity (TFP) (which measures growth not accounted for by factor inputs such as R&D spillover benefits). The study found that R&D contributed only a small amount to productivity growth (0.04%); however, the authors note that the spillover benefits yielded wider benefits that were captured in the TFP (1.27%). Innovation was found to be strongly linked to business growth in the software and IT sector, with 13% average annual revenue growth for innovative firms¹⁴ and no growth for non-innovative firms. The business survey revealed that measuring R&D investment did not effectively capture innovation in most sectors. Even low-R&D sectors were found to demonstrate significant innovation in the form of organisational, design or marketing innovation. These benefits would not be captured through most existing metrics for commercial impact. Additionally, the results showed that innovative firms outperformed non-innovative firms in all sectors studied, including the energy, accountancy, construction, software and legal sectors. In the legal sector, the least innovative firms were disproportionately the smallest and had decreasing sales, and the most innovative firms were disproportionately the largest with the highest sales growth.

¹⁴ Innovative firms are defined as those reporting a new or significantly improved product or service in the last three years.

The digital economy has become so intertwined with the mainstream economy that it can no longer be considered a subset or separate part (European Commission, 2014). Estimates of the digital economy size are complex and varied but are consistently large; for example, Boston Consulting Group estimated a size of \$4.2 trillion in 2012 (Dean et al. 2012). The importance of this area is not lost on research and innovation funding bodies, which have created initiatives such as Research Councils UK's (RCUK) Digital Economy Theme, which supports research to 'rapidly realise the transformational impact of digital technologies on aspects of community life, cultural experiences, future society, and the economy'. As seen from the NESTA study discussed above, there is a distinct gap in growth between innovative and non-innovative software and IT firms, and investment in innovation has been accelerating in this space. Measuring the impact of such investment is perhaps particularly challenging due to the primary involvement of private firms with relatively small public input. Knowledge spillover effects from public institutions may be received by private firms, but the firms may not generate spillovers from their own investments. At a recent workshop (Innovation Policy Platform, 2017) an entrepreneurial mindset was deemed to be as important as excellence for businesses to partner with universities, due to a switch from contract research to business incubation and acceleration.

3.3.3. Methods used to determine commercial impact

Several commonly used metrics for commercial impact centre around intellectual property. Quantitative studies often employ figures on patent filings, grants and citations as metrics for commercial impact (Le Bas and Sierra, 2002; Thomson, 2013; Almeida, 1996; Jaffe et al. 1993). As the filing or holding of a patent does not necessarily imply commercial impact, income from intellectual property or formation of spin-out companies is often also considered. Hughes et al. (2013) showed that research grant holders were over three times more likely to have taken out a patent, licensed research outputs, formed a spin-out, or started a consultancy than non-grant holders. The report also finds that technology transfer is a broader process and acquiring intellectual property is just one way in which businesses connect with research. Additionally, Haskel (2014) charts intellectual property protection and spin-off formation along with income from licensing and the sale of shares.

Intellectual property metrics are not only used in an academic context. The Canadian Academy for Health Sciences, a policy research organisation, employs licensing returns, product sales revenues, spin-out valuations and economic rent as preferred metrics for evaluation of commercialisation (CAHS, 2009), and the UK's Research Excellence Framework records patent applications and grants as outputs. The rich data contained in a patent, including the country of the inventor and the applicant, have enabled studies to explore the geographic distribution of innovation benefits. For example, Le Bas and Sierra (2002) used patent analysis to investigate the effect of national innovation systems on the location of multinational firms, and found that the system of academic research was important to strengthen the advantages of local firms and enable them to succeed abroad (Le Bas and Sierra, 2002). A key limitation of patent analysis is that many disciplines do not produce outcomes that generate intellectual property. However, these disciplines may still have significant commercial impact, for instance in the creative or digital economies. Appreciation of the relevance of intellectual property to specific fields is important if evaluators are to appropriately assess and compare commercial impact.

Econometric approaches have also been applied to measuring commercial impact. The insights gained through such methods are often appealing to evaluators, as they seemingly enable direct comparison between investing in research and participating in other investment opportunities. Building on two previous US-centric studies (Toole, 2007; Ward, 1995), Sussex et al. (2016) developed an econometric model to estimate the effect of government and charity research expenditure on subsequent pharmaceutical sector R&D expenditure in the UK across ten disease areas. The model found that public research investments ‘crowd in’ further private sector R&D investments. For every £1 of additional public research expenditure, there was an associated £0.87–1.07 of private sector R&D in the UK. The study noted that 44% of this additional expenditure occurred within one year, defying the time lag commonly associated with research and innovation impacts (see section on economic impacts for more details). Figures such as these offer strong support to organisations required to justify their investment. Econometric analyses can also provide a high level of granularity, provided that the relevant data exists. In this study, there is disaggregation beyond the level of health to individual disease sectors. A study conducted by the UMETRICS initiative, using data collected through STAR METRICS, explored expenditures on people and purchases from vendors in a disaggregated manner (Weinberg, 2014). Further dis-aggregation to gain deeper geographical or population insights may become feasible with the increasingly data-driven and connected economy.

Geographic proximity has been used as a measure of the impact of research and innovation on the commercial sector, with researchers examining the role of linkages with research centres and knowledge spillover in where businesses choose to locate. An array of approaches have been taken in the literature, including surveys (Kuemmerle, 1999; Gassmann and Boutellier, 2004), looking at quantitative data on R&D investment and intellectual property (Le Bas and Sierra, 2002; Thomson, 2013), and econometric approaches (Abramovsky et al. 2007; Abramovsky and Simpson, 2011). By combining datasets from the ONS and the UK Research Assessment Exercise (RAE) with survey data from the Community Innovation Survey, Abramovsky and Simpson (2011) explored the co-location of businesses and universities. They found that pharmaceutical firms are more likely to be located within ten kilometres of a chemistry department, and chemical-related R&D is more likely to occur near materials science departments. However, their analysis only found significant evidence for increased linkages between businesses and universities for the chemicals sector, although there are weaker relationships in other industries such as machinery and communications equipment. There is also international evidence to suggest that academic strength and wider research capacity and excellence is a predictor of foreign R&D investment in a region (e.g. Siedschlag et al. 2013; Demirbag and Glaister, 2010).

Overall, the commercial impact of research and innovation is a well-studied field of significant importance to the economy. Beyond the economic aspect of commercial impact, it is often through commercialisation of research outputs that other impacts can be achieved on a wider scale. Process-produced data such as patent filings, grants and citations are readily available for analysis and give an insight into commercial impact. However, taken alone such established indicators only provide a narrow snapshot of a large and dynamic system (Gault, 2005). To fully measure the commercial impact it will be important to consider the full range of pathways through which it can occur. Important aspects, such as an entrepreneurial culture and other spillover benefits, should not be omitted purely because they are challenging to measure.

3.4. Impact on public policy and services

Summary

- Impact on government policy is one of the most commonly reported ways in which research has a societal impact. This may be because policy changes are easier to capture than other types of impact, such as behaviour change.
- Research could have an impact on policies, laws, regulations and public services through improving the quality of evidence underpinning decision making and stimulating public discourse.
- Impact in these areas is usually measured via case studies (using document review, surveys and interviews with researchers and key stakeholders), as well as self-reports, such as the REF.

3.4.1. What constitutes an impact on public policy and services?

Research can play an important role in underpinning developments in public policy and changes in the availability and delivery of public services in the context of evidence-based policymaking. Often this is thought of in terms of informing changes in national-level legislation, but it can be conceptualised more broadly to take in a range of impacts. These include: informing policy debate within the general public, in a government body or at a non-governmental organisation; increasing public engagement with the policy process; improving efficiency of or access to public services; or improving the equity of public service provision. Indeed, policymaking does not take place only at the national level, and research can inform local-level or organisational policy decisions as well as going beyond national borders to inform policy on the international stage (e.g. the European Union, the United Nations) or at a national, regional or local level in other countries. Impacts on policy and services may not only be at the level of policy change. They may also include innovations in the ways in which policies are implemented or interpreted, generating regulations and monitoring adherence to them, and improving the availability of services to different groups.

3.4.2. Examples of available evidence on policy impacts

Influencing public policy and public services is one of the most commonly reported ways that research can have a wider impact. For example, among the 2014 REF case studies, of the 60 impact clusters identified, ‘informing government policy’ was the largest (King’s College London and Digital Science, 2015). Influence on policy has also been reported in studies of specific programmes and portfolios of research – in an analysis of projects funded through the NIHR’s Health Technology Assessment programme, 64% of projects reported an impact on policy and practice, based on a survey of the lead researchers (Hanney et al. 2007).

While not aiming to be comprehensive, this section presents a subset of examples of how research can provide high-quality evidence to inform decision making and stimulate public discourse. For example, the Air Pollution Information System, a partially NERC-funded project provides upper limits of air pollution for different types of habitats and pollutants. This allowed regulators to make more informed decisions when granting environmental permits (Monitor Deloitte, 2015). ESRC-funded research developed good practice procedures for the regulation of the erotic dancing industry, which have been adopted by a number of local authorities (Hardill et al. 2012). The ABRO Pharming project aimed to commercialise

the production of human proteins in farm animal milk. While the project did not achieve production of commercial quantities of human proteins, the research generated extensive media coverage and a national debate around cloning, which then led to regulatory and policy changes (BBSRC, 2017).

There are several models that can facilitate use of evidence for improved policies, laws, regulations and services (White, 2016). In an analysis of 6,679 REF 2014 case studies, the pathways to impact on UK parliamentary committees were explored (Kings College London and Digital Science, 2015). The most common pathway was giving oral evidence at the committees, followed by third parties using academic research to support their arguments, and researchers providing written submissions. There also exist institutional arrangements to facilitate research impact on public policy. In Denmark, Norway and Sweden, national governments fund dedicated institutions to produce systematic reviews of evidence on topics selected in collaboration with government agencies, and these reviews can inform policy discussions and guidelines. In the UK, the What Works Network of seven independent Centres and two affiliate members,¹⁵ initially established in 2013, collect and promote evidence in public services and policy in a range of areas (What Works Network, 2018). Each operates slightly differently, but broadly their remit covers bringing together the evidence on topics to inform policy, filling gaps in that evidence, translating the evidence into actionable guidance for policymakers, and helping policymakers to engage with and act on the evidence. This involves a range of activities from capacity building to the development of policy toolkits. The five-year review of the Centres points to a number of practical examples of their impact, including a number of policy changes and changes in government investment (What Works Network, 2018). However, there is as yet no formal evaluation across the Centres of their effectiveness and impact.

Transfer of research findings to public services and policies has a long tradition in some policy areas. In healthcare, evidence-based guidelines offer recommendations based on research evidence. In the UK, this is done by NICE, and internationally by WHO. Increasingly, use of evidence is also impacting on policies and services in other areas, such as criminal justice, traffic policy and drug policy (Oliver et al. 2014). For instance, ESRC-funded research on the neural processes underpinning human visual processing played a key role in informing a national campaign to lower urban speed limits to 20mph in residential areas (Johnson and Fletcher, 2015).

However, research is often one of many factors influencing policy decisions, and can be disregarded or emphasised to serve a particular agenda (Peterosino et al. 2003). To increase transparency in how knowledge is used, a non-profit organisation, Sense about Science, has been conducting spot checks of transparency around what information informed UK government policy proposals since 2016 (Brown et al. 2018). It is also important to point out that research findings themselves can also be misleading, for instance due to conflicts of interest among researchers (Gorman, 2016) and questionable research practices (John et al. 2012).

3.4.3. Methods used to determine impacts on public policy and services

The key approaches that have been used for measuring the impact of research on public policies and services are surveys of researchers, case studies (usually based on interviews with researchers and other

¹⁵ A third affiliate, covering children's social care, is being established.

stakeholders and document reviews), and researcher self-assessment (such as in REF impact case studies). Another more recent approach to tracking the policy impact of research is through ‘altmetrics’, or alternative metrics, which collect information from the social web, and can also be used to track references in policy documents.

There are important limitations accompanying each of these methods. Interviews and surveys with researchers have limited response rates. Survey response rate was reported to be 50–75% in one review of research impact studies (Hanney and Carroll, 2017). Strengths and weaknesses of case study approaches are described elsewhere (see section 3.12.5). It is often not clear how case studies are selected or what methods are used during the process, although it can be assumed that it is probably a combination of desk research and interviews. Case studies have limited generalisability as they are usually selected for highest impact – as our interviews suggest, they can help make a case for advocacy. Document review can make it possible to access information from more projects than can be accessed through interviews, but offers limited information on actual impacts (Hanney et al. 2007). Altmetrics are a new and promising approach for tracking policy impact, but currently a large share of references in policy documents are not correctly attributed to their author (see section 3.12.3) (Hanney and Carroll, 2017).

Overall, research can provide high-quality evidence to improve decision making and stimulate public discourse. One path towards research impact on policy is through policy evaluations where researchers assess ‘what works’ in different areas and explore the underlying mechanisms for policy effects (Dhaliwal and Tulloch, 2012). This type of research can improve efficiency of public services or equity of access to these services. However, policymaking is a notoriously complex process, and therefore researchers need to consider policymaking process carefully and make focused efforts on translation and research policy partnerships to have an impact. In addition to working with local and national governmental or non-governmental policymakers, researchers can also help inform policy debate within the general public by providing empirical evidence on certain policies and/or presenting different theoretical approaches to public policy topics. Academic researchers are well positioned to draw attention to and provide information on various policy issues affecting the public, ranging from the impact of AI to economic inequality.

3.5. Impact on health and wellbeing

Summary

- Impact on health and wellbeing is well understood as an important benefit from R&I across disciplines.
- Measurement within the biomedical and health sphere takes three main forms: (i) quantification as part of an economic analysis, typically at the national level; (ii) case studies; and (iii) mixed methods analyses focusing on a programme or portfolio of research, typically comprising some combination of surveys, interviews and case studies.
- Economic analysis-based approaches to quantifying health benefits have been conducted both bottom-up and top-down, and in both cases there are significant assumptions underpinning the work and, particularly for top-down analyses, important data gaps.
- The Payback Framework is widely used as an underpinning for both portfolio analyses and national-level frameworks for the impact of biomedical and health research on health and wellbeing.
- Analyses of health and wellbeing benefits from other fields of research tend to be limited to case study examples.

3.5.1. What constitutes impact on health and wellbeing?

A significant body of the literature on the benefits of R&I, particularly literature originating from the UK, focuses on the benefits to health and healthcare systems. However, this is often narrowly defined in terms of specific outcomes relating to the programme or condition in question, though there are some exceptions, such as economic returns studies described in 3.5.2. More broadly, R&I can have a wide range of impacts on health and wellbeing, not limited to improvements in healthcare practice and health outcomes, but also spanning improved health equity and increased access to services, increased patient or user choice and satisfaction, and improved health and wellbeing in society through public and population health interventions and improvements. With respect to this last category of benefit, it is clear that benefits to health and wellbeing can result from fields outside of traditional health and biomedical research. For example, research and innovation in the spatial and built environment may have significant impacts on people's ability to be physically active or to enjoy a pleasant environment, which could lead to significant health and wellbeing outcomes. Similarly, improvements in transport infrastructure, reductions in pollution and changes to educational practice could all have outcomes for the health and wellbeing of individuals. This breadth of types of R&I that can contribute to health and wellbeing is understood and discussed in much of the literature, though not always effectively measured.¹⁶

3.5.2. Examples of available evidence on health and wellbeing impacts

Broadly, the evidence suggests that investments in R&I have led to significant benefits in terms of health and wellbeing. The series of studies on economic returns suggest that the health benefits from research investment in the UK from public and charitable sources across a number of fields are equivalent to returns of around 7–10p per year, forever, for every £1 invested (not accounting for spillovers to the

¹⁶ For example, benefits to health and wellbeing are referred to in the annual impact reporting for most of the UK Research Councils, across disciplines, but measurement is typically limited to case study examples.

private sector, which are discussed in section 3.8). However, it should be noted that this analysis is for R&D investment rather than R&I. Evaluations at the programme level typically identify a range of changes in policy and practice, though often the availability of hard evidence of implementation and health benefits is limited by the time horizon used. Estimates suggest that the time lag between research being conducted in the biomedical and health fields and it having an impact on practice is on average of the order of 17 years (Morris et al. 2011). Conducting evaluations is therefore challenging due to the necessary trade-off between relevance and recall. If conducted too early, the full benefits from R&I investments will likely not yet have emerged. If conducted too late, the challenges of recall, data collection and tracing the pathway from investment to outcomes become increasingly significant.

Charitable funders are important in this sector, supporting 45% of publicly supported medical research in the UK (AMRC, 2017). In an analysis of Researchfish data across 40 medical research charities, impacts identified included 166 citations in policy documents and 314 examples of influence on the training of health professionals or other researchers.¹⁷ Researchfish is an online survey that gathers outputs, outcomes and impacts arising from research, and is used by all researchers who have been awarded Research Council funding, as well as many other research funders. The economic returns studies described above also cover charitably as well as publicly funded research.

Evidence on the impact of wider fields of research on health and wellbeing also exists, though it is more diffuse. For example, as part of its annual impact reporting, NERC (2017) characterises its impacts in terms of both prosperity and wellbeing. The reporting presents examples of ways in which NERC contributes to wellbeing, such as through its work with the Met Office on improving hazard protection and planning. Although an overall measure or collective assessment of this type of impact is not provided in the report, wellbeing clearly forms part of the way in which the benefits stemming from the research are conceptualised. Health impacts are also captured in annual impact reporting by EPSRC (2017), though again primarily in a case study format.

The impact of arts and humanities research is explicitly explored in a 2008 report from AHRC, providing a range of examples of the ways in which research in those fields can promote mental and physical health in a range of groups and individuals, such as through better design, changes to the environment, and participation in cultural and creative activities. This is also explored by Crossick and Kaszynska (2016) in terms of the role of art and culture in supporting health and wellbeing. They point to examples such as the role of art in helping to develop caring attitudes and perspectives amongst medical practitioners and build their empathy, as well as the role of art in mental health and wellbeing. The Royal Society for Public Health also conducted a major survey which shows that cultural engagement is beneficial to health across a breadth of areas, but also noted that methods and measures used in different contexts were very diverse, making synthesis challenging (RSPH, 2013). There are a large number of reviews exploring the benefits of arts for health (e.g. Daykin and Byrne, 2006; Hacking et al. 2007; Daykin and Orme, 2008; Beard, 2012; CPA, 2011), but these do not take the next step to link this back to relevant investment in R&I.

¹⁷ <https://www.researchmedia.com/amrc/making-a-difference-impact-report-2017/>

3.5.3. Methods used to determine impacts on health and wellbeing

A key underpinning to many of the studies looking at health outcomes from research is the Payback Framework developed by Buxton and Hanney (1996). The Payback Framework has two main components. The first is a set of payback categories for classifying impacts. The five standard payback categories are knowledge production, research targeting and capacity building, policy and product development, health and health sector benefits, and broader economic benefits. The second component is a logic model for the research and translation process, as shown in Figure 5.

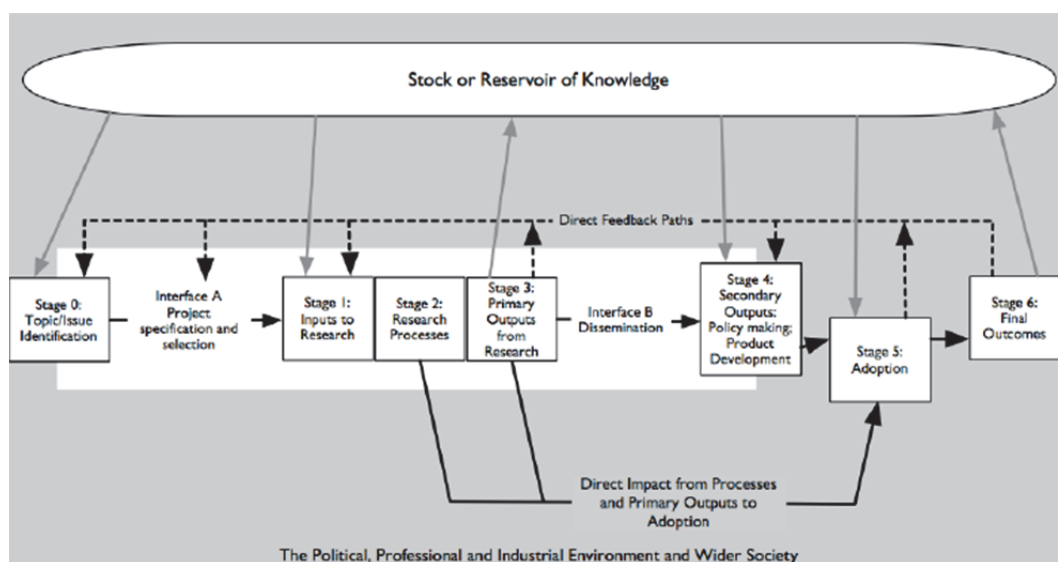


Figure 5 Payback Logic Model

Source: Buxton and Hanney (1996)

This framework is not a measurement approach in itself; rather, it provides the logical underpinnings for many other analyses (and indeed for many other frameworks adapted for use in specific contexts (CAHS, 2009; Banzi et al. 2011; Engel-Cox et al. 2008)). It has also been extended for applications outside of health (Klautzer et al. 2011). It is most commonly used as a structure for case studies, but it can also form the framing for wider studies taking in a range of evidence-gathering approaches (e.g. Oortwijn et al. 2008; McClure et al. 2012; Scott et al. 2011; Wooding et al. 2009). An example of this is the two studies evaluating the NIHR's Health Technology Assessment (HTA) programme, which drew on methods including bibliometric analysis, interviews, surveys and case studies to characterise the outcomes of the research funded through the programme, from the initial production of knowledge to ultimate impacts on health and wellbeing (Guthrie et al. 2015; Hanney et al. 2007). This type of mixed-methods approach is fairly typical in evaluations of programmes of health and biomedical research, in that it attempts to capture evidence along the pathway from knowledge production to changes in policy and practice, and to ultimate health benefits, drawing on a combination of methods and metrics. However, it risks being a rather linear approach and does not, unless carefully conducted, always capture the range and complexity of ways in which research and innovation can impact on health and wellbeing for individuals.

There have also been a number of studies which attempt to quantify and often monetise the health benefits stemming from research, building on the ready availability of health economic evidence and techniques, notably the ability to convert health benefits to economic benefits through QALYs. It is

important to note here that the consensus view on the value of a QALY, based on NICE figures, is relatively unique to the UK. In other countries this is not always so clearly defined, and can often draw on survey data, which often gives very high values for each QALY, thus sometimes rendering comparisons with end figures across countries inappropriate. One commonly proposed QALY threshold is three times GDP per capita (WHO, 2001), but this would be significantly higher than the NICE valuation. This is not an argument against using QALYs, which can be a powerful tool, but rather a warning that these differences need to be taken into account when comparing analyses between countries.

In any case, arriving at the value in terms of the health gain itself already presents some challenges. The first thing to note is that there a number of ways in which R&I can contribute to health economic benefits for the health system. This can be through providing new or improved interventions that result in improved health outcomes (typically, though not always, with higher costs for delivering those interventions). It could also be through providing the same or similar outcomes through an intervention which costs less to deliver. Finally, it could be through stopping ineffective practice (with potential benefits for health and/or delivery costs) or through demonstrating that a potential new intervention is not cost-effective and/or clinically effective and hence should not be pursued. The first two, though challenging to measure in some cases, are relatively straightforward, at least from a conceptual perspective, and tend to form the basis for most analyses of this type. The latter two are more difficult conceptually to integrate into measurement approaches and as such are often neglected. In these cases, the benefits from R&I are best characterised in terms of a value of information approach, but this is challenging to quantify and integrate into wider analysis.

One example is a series of studies that have attempted to assess the impact on health of research-led changes in practice at a national level in the UK, and then convert that into an economic benefit (HERG, 2008; Glover, 2014; Glover, 2018). This is then combined with spillover effects as described in section 3.9. However, the core of the work is to characterise and measure the extent of the health benefits from evidence-based changes in practice in a number of fields – cardiovascular, cancer, mental health and musculoskeletal research. The studies measure four components, which are combined to calculate an overall return to the UK on public and charitable investment in R&I. These are:

- Health gain: Areas where key health gains have been achieved were identified through analysis of mortality and morbidity data, then key contributing interventions were identified through expert consultation and analysis of clinical guidelines. The health gain, cost of delivery and population benefiting were then estimated for each intervention by analysis of existing studies and health datasets.
- Time lag: The typical time between research being conducted and changes in practice being achieved is characterised through an analysis of relevant clinical guidelines in the field in question.
- Attribution: Also based on an analysis of the research cited in guidelines, estimates are made of the proportion of the benefits in terms of health gain that can be attributed to research conducted in the UK.
- Funding invested: The studies produce a time series of the investment in research in that field across all major UK public and charitable funders.

This approach has a number of limitations and caveats which are set out clearly by the authors. For example, the net monetary benefit of interventions not analysed is assumed to be zero, significant assumptions are made about the role of clinical guidelines in practice changes, and various other estimations and approximations are required to account for the limitations in availability of data. However, this bottom-up approach does have some significant advantages over many other studies which have attempted to characterise health benefits from research at a system level from a top-down perspective. These studies characterise the overall level of improvement in health outcomes, then attempt to apportion a part of this to R&I, however, estimates of this proportion are limited and not based on robust analysis. The proportion of improvement attributed to R&I ranges from 20–30% in some cases (Muskin, 1979; Ballinger, 2000) to 50% in others (Access Economics, 2003, Access Economics, 2008; Access Economics, 2011).

3.6. Impact on education and training

Summary

- Academic research can contribute to improving education for children and young people, as well as training for professionals, in a wide variety of ways.
- In some countries, such as the UK and US, research on education practices is disseminated to education policymakers and school staff.
- Studies in other fields (particularly health) often capture contributions to training of relevant professionals in that sector as part of case studies or other analyses.
- Overall, there is relatively limited evidence in the area of impact on education and training, with case studies and REF data being the main sources of evidence.

3.6.1. What constitutes impact on education and training?

Impacts of research on education and training can include contributions to formal curriculum development and educational practices, but might also span wider contributions including outreach activities, producing training materials, contributing to textbooks, or increasing access to education. A key overall metric for this area of benefit would be improving educational outcomes. It is also worth noting that education and training in this context is not limited to schools, colleges and universities. Much of R&I contributes to education in the form of professional development and training of practitioners in a range of sectors reflecting the specialist nature of much R&I and its relevance to specific contexts. It is notoriously challenging to keep up with the growing global scientific output (Van Noorden, 2014), so researchers can have an impact on education and training by providing direct training to professionals and by communicating accessible research summaries to curriculum committees and professional organisations (Van Noorden, 2014). Overall, this means that this category of benefit is broad, spanning from educational videos, resources and open days for young children, to professional training and development for experienced practitioners, encompassing both the changes in teaching and educational practices, and their outcomes in terms of access, effectiveness and level of knowledge and skills gained.

3.6.2. Examples of available evidence on education and training impacts

Research findings are often used to improve training and educational materials. This is perhaps most common and well documented in clinical training. Research assessing the impact of the UK Prospective Diabetes Study looked at the share of slide decks mentioning the study and its results among the slide decks hosted online by two professional education websites (Home, 2008). Case studies drawing on interviews with researchers also report research results being included in textbooks and incorporated in clinical training (Guthrie et al. 2015). Researchers also report on Researchfish if they have influenced training of practitioners or researchers (Guthrie et al. 2015) – for example, the AMRC (2017) note 314 examples of influence on the training of health professionals or other researchers across research supported by 40 medical research charities. Researchers and research centres also conduct outreach events, such as talks for young people, to communicate their research and the research in the area more generally (TNS BMRB, 2015). This type of outreach may help increase young people's aspirations to pursue further study or research careers.

Furthermore, research evaluating practices in early years and school education can impact education practices by providing empirical evidence of programme effects. Similarly, in higher education, research can provide insights into improving student enrolment and retention (Bettinger et al. 2012), boosting student outcomes, and defining and measuring quality of teaching (Strang et al. 2016).

As mentioned above, there are a growing number of organisations that facilitate the translation of research to policymakers and practitioners. Research on education is collated and shared by organisations such as the What Works Clearinghouse in the US and the Education Endowment Foundation in the UK. In 2015, a study by the National Audit Office found that 64% of school leaders were using the Teaching and Learning Toolkit produced by the Education Endowment Foundation to inform decisions about Pupil Premium funding, up from 36% who used any research in 2012 (National Audit Office, 2015). The Toolkit is based on synthesis of studies in education, selected based on criteria such as research design and relevance. While a lot of the research efforts have focused on early years, primary and secondary education, in the US the Bill and Melinda Gates Foundation has also sponsored extensive research and implementation in higher education, including online learning (Young, 2012).

3.6.3. Methods used to determine impacts on education and training

As outlined above, there is fairly limited evidence on the impact of research on training and education. The methods by which information on this type of impact has been collected are researcher self-report through tools such as Researchfish, case studies (based on interviews), and document review. The limitations of these approaches have been discussed elsewhere in this report (see for example section 3.11.3).

3.7. Impact on public engagement, awareness and debate

Summary

- Public engagement involves sharing the activity and benefits of higher education and research with the public. The public includes citizens, but also policymakers, professionals or businesses.
- Public engagement involves dissemination of research outputs, but also the effective use of that research by stakeholders (e.g. to inform policy) and active involvement of the public in the research process through citizen science.
- Case studies are the most commonly used method to measure impact in this area. Case studies are often used to demonstrate the different types of engagement activities or the extent of these activities. They are sometimes used to demonstrate the impact of a particular project or area of research on the level of engagement, awareness or debate.
- Case studies have been used to examine the impact of citizen science on public engagement.
- Surveys are also frequently used to track either the extent of public engagement (e.g. Researchfish) or public attitudes to science (e.g. the Public Attitudes to Science survey, the Wellcome Trust monitor). These could be useful in tracking the impact of research in a given area on public engagement over time.
- The Payback Framework is a framework that is often used in health services research, and considers dissemination as an important route to impact.

3.7.1. What constitutes impact on public engagement, awareness and debate?

Public engagement refers to the various ways of engaging members of the public with a specific topic or discipline. The National Coordinating Centre for Public Engagement (NCCPE) defines it as:

‘...the myriad of ways in which the activity and benefits of higher education and research can be shared with the public. Engagement is by definition a two-way process, involving interaction and listening, with the goal of generating mutual benefit’ (NCCPE, 2018).

Public engagement has undergone a change in the last few decades, with science no longer simply ‘broadcast’ to the public by experts, but increasingly offered up for meaningful public debate. The ‘public’ can include citizens, policymakers, professionals or businesses. Public engagement creates opportunities for people to exchange ideas and information, and learn from each other. Engagement activities include presentations and discussions, festivals and exhibitions, outreach activities, and social media. Public engagement often involves, but is not limited to, dissemination of research to a public that is framed as an audience of research findings, and this paradigm is often used to increase awareness and understanding of issues (Duncan and Manners, 2017).

Recent years have seen the growth of the open science movement, where members of the public are perceived as experts in their own right and are even active participants in the process, as seen in the increasing use of citizen science initiatives. Impact in this area can include shaping the nature of public debate, improving the use of science in policy and practice, increasing public engagement with research findings, improving public attitudes to science (e.g. increasing people’s trust in science and scientists), increasing public awareness, and creating publicly available tools or resources. More broadly, active research engagement can have a wider legacy of increased confidence and empowerment of individuals and communities, and the creation of networks and relationships (Facer and Enright, 2016).

3.7.2. Examples of available evidence on impacts on public engagement, awareness and debate

The UK Research Councils and UK funding bodies have made public engagement a condition of grants that they award. Most impact reports by the UK Research Councils report on their public engagement activities, and public engagement is also considered a route to impact within the REF. A report by the NCCPE found that public engagement featured heavily in the REF 2014, with 3,108 of the 6,640 case studies (47%) making some reference to engaging with the public (NCCPE, 2017). The report found that researchers often see public engagement as dissemination of their research rather than engaging the public in the research process. Moreover, the evidence provided on impact on public understanding and awareness was generally found to be weak, with most researchers limiting their evidence to a list of the outlets they have used and the numbers of people engaged.

There is some evidence to suggest that research contributes to improved public engagement, awareness and debate. Usually this is in the form of evidence which suggests that people attended museums, galleries and free public lectures. For example, almost 1.5 million people attended free public lectures at Russell Group universities last year and more than 5.5 million people attend exhibitions at museums and galleries located within Russell Group universities every year (Russell Group, n.d.). A report by The Russell Group, which draws on evidence made available through the REF 2014, found that 47% of case studies submitted by Russell Group universities had ‘societal impact’, which includes categories such as informing public debate and stimulating public interest, amongst others (Russell Group, 2015).

Within this type of impact, social sciences research has helped to engage the public with global challenges such as climate change. For example, one case study demonstrated that research into the development and transfer of methods for climate readiness and resilience by University College London has engaged both citizens and policymakers to improve their understanding of climate change issues. Research at the University of Oxford, spanning historical studies, political science and sociology, focusing on how consumerism developed in China, has enabled both Western policymakers and business leaders, and a wider international public, to better understand Chinese consumerism and its consequences. Biomedical sciences research has also led to increased public debate: the first demonstration of cloning from an adult mammalian somatic cell by University of Edinburgh researchers has stimulated religious, ethical, cultural, political and scientific debate, with Dolly the sheep becoming a scientific icon and entering the public and educational lexicons in addition to scientific ones. However, many impacts on public awareness, understanding and debate are included in other categories of impact, including health and environment, and therefore it is difficult to gather a comprehensive understanding of the extent of impact of research in these areas (Russell Group, 2015).

Beyond dissemination, however, there is some evidence that citizen science, a form of public engagement which actively involves the general public in the research process, has increased public engagement. A case study demonstrates that the University of Oxford’s online platform Zooniverse has led to increased public understanding of science and research methods. The platform was originally developed from underpinning physics and astrophysics research and now supports nearly 40 citizen science projects, in which volunteers help professional researchers analyse information more quickly and accurately. The projects have engaged 1.4 million members of the public from 100 countries with astronomy and other

areas of research, such as biomedical sciences. 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 3 months (Russell Group, 2015).

Active engagement in research is also evaluated in a review of the Connected Communities programme, which aimed to support participatory, engaged research between universities and communities (Facer and Enright, 2016). This study aimed not just to illustrate and evaluate the work of the programme, but also to look at the distribution of engagement and resulting benefits. The study found that enabling equitable opportunities for participation remains a challenge with most work that gets funded building on pre-existing collaborations. Moreover, the demographic, ethnic and cultural make-up of university staff is a factor in limiting the diversity of representation in participants and perspectives in the collaborative research supported. The study also notes that those with caring responsibilities and disabilities face particular challenges in becoming involved in research activities.

3.7.3. Methods used to determine impacts on public engagement, awareness and debate

Case studies are typically used by UK Research Councils to showcase their public engagement activities (see for example NERC, 2017; MRC, 2017; BBSRC, 2017). For example, a case study from the MRC impact report for 2017 highlights how festival organisers for the MRC Festival of Medical Research felt that festival goers had increased their awareness and understanding of the benefits of medical research (MRC, 2017). Another case study from BBSRC research found that the ABRO (Roslin Institute) pharming project stimulated extensive media coverage and a national debate around cloning (BBSRC, 2017).

Aside from case studies, there also exist a variety of tools and methods that cover impacts on public engagement as a category, usually in the form of 'dissemination'. For example:

- As part of Researchfish, researchers are required to complete and report on a number of outputs, including 'dissemination'. The engagement activities indicator helps demonstrate the extent to which researchers are engaging with audiences outside academia; however, it does not necessarily indicate whether the research has an impact on the level, engagement or awareness of audiences (See box 4).
- The Payback Framework was originally developed to examine the impact, or 'payback', of health services research (Buxton and Hanney, 1996; Donovan and Hanney, 2011). The framework has two elements. The first is a multidimensional categorisation of the potential benefits from health services research into five main types of benefits. The second is a model for assessing the benefits from research. The model includes 'dissemination' as an interface between the research process and impact on society (for more detail see section 3.5).
- There are a number of surveys in the UK that aim to gauge the UK public's attitudes to a variety of disciplines. The Public Attitudes to Science survey is a large annual UK survey run by Ipsos MORI for the former Department for Business Innovation and Skills (now Department for Business, Energy and Industrial Strategy). Five of these surveys have been conducted and the most recent such survey, conducted in 2014, found that public interest in

science was high and rising (Castell et al. 2014). The Wellcome Trust Monitor is a regular survey, run by Ipsos MORI for the Wellcome Trust, which captures public views on science and biomedical research. The most recent version, published in 2016, demonstrates that the public express high levels of interest in medical research (Huskinson et al. 2016). The Wellcome Trust is also currently undertaking a global survey of 140,000 people from 140 countries to gauge global attitudes to science and health challenges; the results are expected in 2019 (Wellcome Trust, 2018). In 2015, The Royal Society of Chemistry commissioned the social research company TNS BMRB (now Kantar Public) to research public attitudes, awareness, interest and engagement toward chemistry in the UK (TNS BMRB, 2015). The survey found that the UK public has a positive view of chemistry and chemists, and are interested in finding out more about chemistry, in particular how it can address social challenges (e.g. developing clean water technologies or renewable energy technologies).

The most common methods used to demonstrate impact on public engagement are case studies and surveys. However, there are few instances in which these methods are used to show a direct link between a particular area of research and its impact on public engagement, although a series of surveys focusing on a particular area of research administered over time could potentially be used for this purpose. The case study approach is typically used to showcase different types of public engagement activities and the extent to which researchers interact with the public. Case studies are also used to demonstrate the number of people that attended an event or exhibition, watched a television programme, or listened to a radio show. Surveys, such as Researchfish, are used to measure the extent to which academics carry out public engagement. There are also a variety of surveys that measure the level of public engagement in and attitudes to science, and some of these also track this over time, thus potentially capturing any changes in this measure.

A report by Wellcome Trust (2015) summarises some of the challenges involved in evaluating public engagement activities. They note the challenges in soliciting feedback and understanding its meaning. For example, if people are asked whether they enjoyed an event, they are likely to say yes, but this information is not necessarily meaningful. The study points to three novel approaches that could add value in this area: realist evaluation, outcome mapping and Most Significant Change methodology. Realist evaluation is explored in Appendix B. Outcome mapping is an approach where desired changes or outcomes with key engaged groups or communities are established and targeted at the outset and then monitoring is designed to measure those changes. Most Significant Change is an approach in which metrics are not used, and analysis is instead based on stories collected from stakeholders across common 'domains' (e.g. community empowerment). Through multi-stakeholder discussion, those stories are compared and analysed systematically to provide insights into what the key outcomes of the programme are and how they come about.

3.8. Cultural impact

Summary

- Cultural impact often comes from arts and humanities research, but there are also numerous examples of research in disciplines outside of the arts and humanities, such as the social sciences and even biomedical sciences, delivering cultural and creative impact.
- Cultural impact is often described as important to the economy, but rarely mentioned as an impact area of value in its own right.
- Case studies and interviews are the dominant methods for demonstrating cultural impact.

3.8.1. What constitutes cultural impact?

Research and innovation can shape the way we see, understand, and participate in cultural events and experiences. Researchers who study cultural history and disseminate their findings to the public can help create a critical mass that ensures the preservation of cultural heritage. This preservation could take the form of a new archive, capturing oral history, or improving the accuracy or accessibility of museum exhibitions. Research into unknown or misunderstood cultural and artistic methods or activities can increase the accessibility to the public of traditional works and improve the underlying quality of evidence explaining the evolution of such activities or the materials used. However, cultural impact need not only revitalise historical traditions; any creation of a new cultural event – or revitalising an old one – or improving attendance at cultural events would also be considered cultural impact. The concept of culture itself can be difficult to define, which adds complexity to the way in which the cultural value and impact of R&I is understood and conceptualised, as noted by Crossick and Kaszynska (2016). This study suggests that benefits from cultural engagement can include:

'an improved understanding of oneself, an ability to reflect on different aspects of one's own life, an enhanced sense of empathy which need not mean sympathy for others, but an empathetic appreciation of their difference, and a sense of the diversity of human experience and cultures...a reinvigorated sense of civic and civil engagement, and perhaps to a more acute sense of the public realm and of social justice' (p42).

Although the concept of innovations in the context of cultural impact is often focused on innovation in content, there are many other ways that innovation can take place. A study of innovation in the National Theatre and Tate found that innovation spanned artform development, audience reach, value creation and business models (Bakhshi and Throsby, 2010).

3.8.2. Examples of available evidence on cultural impacts

Cultural impact does not come only from research in arts and the humanities. Research in other disciplines, for example in biomedical and social sciences, has significant implications for understanding and preservation of cultural heritage or expanding and enrichment of cultural experiences (Russell Group, 2015; King's College London and Digital Science, 2015). For example, citizen science projects have engaged members of the public with astronomy, while Dolly the sheep (the first demonstration of cloning of an adult mammalian cell) has stimulated ongoing religious, ethical, cultural, political and scientific debates. Equally, new tools and techniques could facilitate restoration or new understandings and presentations of concepts, materials, artworks or artefacts. Museums and exhibitions also relate to wider scientific and social science-focused concepts and materials. Some case studies discussed in the literature

reviewed include engaging local people in archaeological digs, developing documentary films, and improving underpinning research at the British Museum (AHRC, 2016). These are only some limited examples of a diverse range of impacts.

3.8.3. Methods used to determine cultural impact

The literature points to a number of different methods that are used to assess the impact of research on culture. Case studies and interviews were used in three reports (Krapels et al. 2015; AHRC, 2016; Universities UK, 2010), and Krapels et al. (2015) uses bibliometrics, surveys and a workshop to identify case studies. Funder reports such as those used for AHRC can also be useful for identifying case studies, while secondary data analysis and literature review can be useful for establishing the extent to which cultural impacts are reported across sources (Lendel, 2010; Greenhalgh et al. 2016; Universities UK, 2010)

As described below (Section 3.11.3), case studies help create memorable stories to clearly articulate for policymakers, funders and the public how academic research can have an impact on culture. Since cultural impacts can require significant background context to understand, case studies are in many cases an appropriate method for communicating these kinds of impacts. However, the main text of funder reports, such as that from AHRC, ultimately emphasises how research has an impact on the ‘creative economy’, which is a critical part of the UK’s national economy. While this may be true, it only captures part of the value delivered by cultural contributions from research, and fails to highlight the intrinsic value of cultural benefits. Moreover, the connection between research outside the arts and humanities and cultural impact is not very evident in the literature.

Datasets are available that could support further analysis of cultural impacts, though they are not widely used in the evaluation of R&I investments. For example, the Department for Culture, Media and Sport in England runs an annual survey called ‘Taking Part’, which captures data, including (since 2012/13) some longitudinal data through repeat inclusion of the same sub-set of individuals, on engagement with arts, sports and heritage activities. Several studies have used the data to look at the impact of engagement (e.g. Fujiwara, 2014) or value placed on engagement in cultural activities (Miles and Sullivan, 2010), but the dataset also offers the potential to be used in other ways to analyse the role of R&I in cultural engagement and its subsequent outcomes. Eurobarometer surveys and Understanding Scotland’s Creativity are other examples of surveys on participation in cultural activities (Crossick and Kaszynska, 2016).

Another potential source of evidence for the analysis of cultural impact would be information captured by relevant organisations (e.g. museums, theatres, galleries) on the feedback from those attending events and exhibitions. However, as noted by Crossick and Kaszynska (2016), such evidence needs to ‘capture the audience experience in ways that go beyond the simple test of enjoyment’ (p128). An example of one attempt to do this is the Manchester Metrics Pilot, which proposed a standardised system to assess the quality of artistic productions by asking the public, artists and peers to assess them against a set of metrics both before and after the event, using a simple survey delivered through an app. The core criteria include presentation, distinctiveness, rigour, relevance, challenge, captivation, meaning, enthusiasm and local impact, with others relating to the relative quality on an international scale being included for artists and peers. The approach was found to be broad enough to apply across a range of cultural experiences

spanning plays, art exhibitions and opera (Bunting and Knell, 2014). Having such a comparable, integrated dataset would be extremely useful for the development of insights into the role R&I plays in cultural engagement and its benefits, as well as in developing insights for the sector, as noted by Davis and Heath (2013).

As highlighted by Kaszynska (2015), understanding the way in which cultural impacts occur for individuals and groups is not straightforward, and would need to draw on wider techniques from the social sciences, such as ethnography and anthropology, to explore the way in which cultural experiences occur. This type of work is starting to emerge in terms of assessing the cultural experiences which occur (e.g. Born, 2005; DeNora, 2000; Paterson, 2009; Pink, 2009), but this has yet to be linked back to the role R&I plays in forming these cultural experiences.

3.9. Impact on social cohesion

Summary

- Social cohesion, in its broadest sense, explores the sense of community that exists in a society, and includes aspects such as equality and social capital.
- Case studies are the main method that has been used to assess the impact of research on social cohesion.
- There exist a variety of tools to measure social cohesion that could be used to determine the impact of research on social cohesion in a more quantitative way.

3.9.1. What constitutes impact on social cohesion?

Social cohesion, in its broadest sense, explores the sense of community that exists in a society (Dragolov et al. 2013). The term covers concepts such as equality (promoting equal opportunities and reducing disparities and divisions within society, for example in relation to poverty, labour, market access, health, equitable education or intergenerational justice), and social capital (i.e. strengthening social relations and interactions) (Berger-Schmitt, 2002). Social cohesion is generally thought to reflect social harmony, although this should not necessarily be seen as a homogenising concept, and is regarded as an important resource for economic success, quality of life and wellbeing (Eurofound, 2014). The Bertelsmann Stiftung Foundation considers a cohesive society to be characterised by resilient social relations, a positive emotional connectedness between its members and the community, and a pronounced focus on the common good. In the Bertelsmann Foundation's conceptualisation, social relations are the horizontal network that exists between individuals and groups within society, while connectedness refers to the positive ties between individuals and their country and its institutions, and a focus on the common good is reflected in the actions and attitudes of the members of society that demonstrate responsibility for others and for the community as a whole.

This area of impact therefore seeks to measure how complex social developments, such as social structure, conditions and attitudes, interact with each other. The EU and the OECD both see social cohesion as an important concept to strive towards in society (Jenson, 2010). The economic and social cohesion of Europe is a central policy goal of the EU, as confirmed in the Maastricht Treaty of 1992.

3.9.2. Examples of available evidence on impact on social cohesion

There is some evidence that social science research can contribute to improved social cohesion, but also to a better understanding of human behaviour and the wellbeing of citizens, which are important elements of social cohesion (ESRC n.d.). The Economic and Social Research Council (ESRC) funds research into social cohesion and has demonstrated impact from its research on social cohesion. For instance, research by the ESRC-funded Centre for Learning and Life Chances in Knowledge Economies and Societies (LLAKES) investigates the role of lifelong learning in promoting economic competitiveness and social cohesion. This research has shown that skills inequality is one of the drivers of income inequality, which reduces growth and undermines social cohesion (Cingano, 2014). Another ESRC-funded project investigated emerging forms of urban agriculture in the UK and their impact on social cohesion and environmental justice (Tornaghi, 2014). A project funded by the ESRC Centre for Business Relationships, Accountability, Sustainability and Society (BRASS) led to improvements in fire service working practices and community cohesion in the South Wales valleys (ESRC, n.d.). Another example is the ongoing NORFACE (New Opportunities for Research Funding Agency Cooperation in Europe) research programme on ‘Dynamics of Inequality Across the Life-course: structures and processes’, of which the ESRC is a member, which seeks to understand the dynamics of inequalities over the life course, causal processes in relation to these inequalities, and the impact on social cohesion (NORFACE, n.d.).

The role of cultural engagement and related arts and humanities research in social cohesion has also been demonstrated. For example, through a project on disability representation in museums and galleries, nine partner museums developed new approaches to the way in which they presented disabled people’s lives in their exhibitions. The evaluation of the programme, based on interviews, focus groups and ethnographic observation, demonstrated that the work had changed attitudes towards people with disabilities in multiple complex and diverse ways (Dodd et al. 2008).

3.9.3. Methods used to determine impact on social cohesion

The main method that has been used to assess the impact of research on social cohesion, as identified through our literature review, is case studies. For instance, there are over 60 case studies considering ‘social cohesion’ in the REF Impact Case Studies database. A 2012 report published by The Russell Group looked at the impact of Russell Group research on social cohesion and social infrastructure, and presented a case study demonstrating how research at the School of Education at Queen’s University Belfast contributed to early years education in Northern Ireland and to the way it has been used to counter sectarian thinking among young children (Russell Group, 2012). A more recent Russell Group report presents a number of case studies demonstrating that Russell Group research has an impact on culture, which they suggest indirectly supports social cohesion (Russell Group, 2015).

Social cohesion is difficult to measure because it is a broad concept that consists of a variety of dimensions. However, there exist several tools that attempt to measure aspects of social cohesion. For example:

- The OECD Better Life Index (Better Life Index, n.d.) compares wellbeing across 38 countries, looking at certain aspects of social cohesion under the headings of ‘community’ and ‘civic engagement’. Specifically, the Index captures the quality of people’s social support network and

people's trust in government, including voter turnout and public engagement in decision making.

- The OECD publishes another study (OECD, 2016) that sheds light on five indicators of social cohesion similar to those in the present study; however, data are reported only for 2011.
- The Legatum Prosperity Index (Legatum Institute, 2017) measures prosperity through eight dimensions of material and non-material wealth. Social cohesion is included under the dimensions of social capital.
- The Bertelsmann Stiftung Foundation in Germany developed the Social Cohesion Radar, a quantitative conceptual framework and tool to measure the state of social cohesion at various different points in time. The framework organises social cohesion into three key domains: connectedness, social relations and focus on the common good. Each domain contains three constituent parts, which results in nine dimensions of social cohesion. The framework draws on 12 datasets. Using the Social Cohesion Radar, Dragolov et al. (2016) looked at the level and trend of social cohesion in 34 countries, across four survey periods covering a 25-year timespan. The results of this study are perhaps the most comprehensive empirical measurement of social cohesion. The study constitutes a secondary data analysis as it was based on existing data that were collected for a wide variety of research purposes. Social cohesion was found to be strongest in the Nordic countries, specifically Denmark, followed by Norway, Finland and Sweden. It is not clear whether the Social Cohesion Radar has been used to measure the impacts of research into social cohesion.
- The European Social Survey is a cross-national academic survey, established in 2001, that is conducted across Europe every two years. The survey measures the attitudes, beliefs and behaviour patterns of diverse populations in more than 30 countries. The questionnaire covers a range of topics, including: trust in justice; welfare attitudes; economic crisis, quality of work and social integration; understanding and evaluation of democracy; personal and social wellbeing, social inequalities in health and their determinants; and attitudes towards immigration.

The case study approach has often focused on demonstrating the impact of research on aspects such as cultural benefits, which are assumed to support social cohesion. The strength of a qualitative, case study-based approach is that indirect impacts, which are often complex and subtle, are captured. A key limitation of this approach is that case studies are often not generalisable and only provide a snapshot of the impact of a given area of research. Our review has failed to identify studies or evaluations that have directly measured the impact of research on social cohesion per se using existing quantitative tools, such as surveys, which capture more robust measures of social cohesion. The lack of a quantitative approach also means it is hard to compare the impacts of research into social cohesion across different research programmes, regions or countries. There are a number of surveys and questionnaires that measure aspects of social cohesion, which could be incorporated into evaluations of research to provide more robust evidence of impacts on social cohesion. However, it should be noted that surveys tend to provide broad rather than deep information, and methods that rely on secondary data, such as the Bertelsmann Stiftung Foundation's Social Cohesion Radar, have some disadvantages in that the data are typically generated from datasets that do not necessarily precisely measure social cohesion since they were designed for a different purpose (Dragolov et al. 2013).

3.10. Impact on safety and security

Summary

- R&I can impact on safety and security in many ways, for example by improving policing practices, developing new tools for military purposes, or through improved infrastructure resilience.
- Given the significant investment in defence research, alongside the wider contributions from other fields, the impact of R&I on safety and security is likely significant.
- However, there is very limited evidence focusing on these benefits, perhaps due in part to measurement challenges and the sensitive nature of some activities in this field.
- Evidence that is available, for example around research into policing methods, is traditionally evaluated using population-level metrics such as reduced crime, which are hard to link to specific R&I.
- Recently more studies are emerging which use more nuanced, mixed-methods approaches and frameworks.

3.10.1. What constitutes an impact on safety and security?

Safety and security is a wide-reaching classification that has important consequences for citizens worldwide. R&I can have impacts on safety and security through improved policing practices, development of new tools for the police and military, improved infrastructure resilience, and increased regional and national security. Due to the sensitive nature of some activities in this field and the complex interplay with external factors, there are some additional hurdles to measuring the impact of R&I. However, given the significant spend on research within the remit of safety and security, and the significant effects on the public, this is an important domain to evaluate. Furthermore, a safe and secure society is better placed to produce impacts from R&I in other areas.

3.10.2. Examples of available evidence on safety and security impacts

One clear theme in the wider literature is that there has been limited effort to measure the impact of R&I on safety and security. This is evidenced by a lack of available literature and narrative from stakeholders within the domain. Officials from the US Department of Defense (DoD) have noted that evaluation of impact is difficult, and stakeholders and staff from DoD-funded Regional Centres say they cannot measure the extent to which the Centres meet their goals of empowering security practitioners and resolving security challenges (Hanauer et al. 2014). Military innovation has been behind significant technological advances such as radar, nuclear technology and satellite navigation. However, beyond such impact narratives there has been little work on measuring the impact of either military or civilian research on safety and security. This lack of effort to measure the impact of research on defence is surprising given that some of the largest research funders are in the military domain. For example, the UK Ministry of Defence spends around £1.7bn on R&D each year, with a significant proportion going to academia and industry (Ministry of Defence, 2017), and the US DoD is the largest federal sponsor of R&D with a budget of \$66bn in 2014 (Office of Management and Budget, 2016).

Cyber resilience is another area of growing importance for governments and businesses. A key feature of cyber resilience is cyber security, which is also of importance to the general public. The cost to the UK of cyber-crime is estimated at billions of pounds per annum, and is rapidly increasing (National Crime Agency, 2016). As a result, there is an arms race between malicious and benign actors to create and

overcome ever more sophisticated defences and threats (McAlaney et al. 2018). To support this arms race, extensive research is performed in academia and industry. For example, the EPSRC has 14 Academic Centres of Excellence in Cyber Security Research (ACE-CSR) to protect and promote the UK in a digital world. This is an area where the impact of research may be more easily quantified, as fixing an exploit or neutralising a threat has a measurable economic benefit through reduction of fraud, theft or business downtime.

3.10.3. Methods used to determine impact on safety and security

In the UK the REF captures qualitative data on impact in this domain through case studies. However, even here the security impacts often seem to be cursorily explored, with researchers preferring to detail revenue gained from technology spin-outs (Khazragui and Hudson, 2014). This may be due to a perception amongst respondents that an impact on security will not be valued as highly as revenue figures. A case study example includes research into semiconductor crystals for imaging purposes at Durham University, which led to a spin-out company producing security systems for screening liquids and gels at airports. The company won a \$400,000 prize at the Global Security Challenge and holds a \$4m contract to provide material to the US Defense Threat Reduction Agency. Success stories taken from case studies like this can be valuable for organisations needing to justify funding support. However, case studies are not able to effectively evaluate the total aggregate benefit of a research programme for a domain such as safety and security, and certainly do not give sufficient detail to explore disaggregated benefits.

Currently, quantitative impact in this domain is largely measured through general metrics such as population-level data. For example, research addressing a safety and security concern may aim to reduce a certain incidence of crime, for instance through the development of smart CCTV cameras to target shoplifting. High-level trends such as the incidence of prosecutions for shoplifting could be used as a metric to assess the impact of the research. These high-level metrics are appropriate when focusing on innovations directly addressing a safety or security issue, and well understood by a broad audience, but are unlikely to capture the indirect benefits of research and innovation in other fields. As an example, Durham Police Department achieved a 20% budget cut by introducing innovative practices, such as taking remote statements with digital signatures and introducing civilian ‘mental health navigators’ to support reform of shoplifters (Financial Times, 2018).

Increasing trends towards evidence-driven funding and policy, combined with a difficult economic climate, are leading the policing sector to use more comprehensive evaluation approaches. Lum, Koper and Telep (2011) have developed a three-dimensional framework called the Evidence-based Policing Matrix to visually categorise experimental research on police and crime reduction into intersections across the three dimensions of crime prevention: the nature of the target, the nature of the strategy, and the specificity of the strategy. Using this matrix indicated that proactive, place-based policing approaches were the most successful (Lum, Koper and Telep, 2010). Official policing bodies, such as the Mayor’s Office for Policing and Crime (MOPAC), which is funded by the Home Office, have also employed more comprehensive evaluation approaches. In an evaluation of the Police Now initiative, an innovative two-year programme training graduates on the front line, MOPAC employed a longitudinal mixed-methods approach. Quantitative and qualitative approaches were used to analyse data from surveys, interviews and crime datasets. Although there were positive findings and learning around the training process, the

programme was not found to have produced a statistically significant effect on public confidence in the police.

Overall, the impact of research on safety and security is not well measured. This is true across a number of fields of research, including those directly focused on safety or security. As safety and security impacts overlap to some extent with economic and health impacts, it may be possible to adapt existing evaluation methodologies from those more extensively studied areas to the domain of safety and security. Ideally, a set of metrics against which impact can be judged should be developed for this area.

3.11. Impact on the environment

Summary

- Impacts on the environment span a range of issues from conservation and reduction in pollution to local environments and resilience to environmental challenges, which can be indirect as well as direct and as such can result from many disciplines of R&I.
- Despite the quantitative nature of many of these kinds of impacts, environmental impact is mostly assessed using qualitative methods.
- Measurement within the environmental sphere typically takes two main forms: Case studies and -mixed methods analyses, which focus on a programme or portfolio of research, typically comprising some combination of surveys, interviews and case studies.

3.11.1. What constitutes environmental impact?

Having an impact on the environment could take a number of forms. Some environmental conditions could be improved by preserving habitats, species or resources, which could even include local green spaces in urban areas. Improving how we manage waste (for example through increased recycling) is another way to improve environmental conditions. Other environmental indicators have a positive effect on society when they are diminished, for example through the reduction or removal of pollutants such as greenhouse gasses. This can happen indirectly through research that, for example, identifies ways to make cars weigh less and thereby use less fuel (Peretz et al. 2009). Because the way we consume food and energy has effects on natural resources, environments and the global climate, environmental impacts could come through improving energy efficiency, increasing the accessibility and/or use of renewable energy sources, or adopting more sustainable agricultural practices. With climate change on the rise, creating mechanisms to build resilience in the wake of natural disasters such as tropical storms, floods and droughts can help preserve and protect other fragile environments. In some cases, environmental activities are not undertaken because of political sensitivities, so increasing public engagement, awareness or action for environmental goals could also be deemed to have environmental impact.

3.11.2. Examples of available evidence on environmental impacts

Some environmental impacts that have been measured in the literature reviewed are negative. These include impacts such as increasing demands on agricultural activities (Rodrigues et al. 2010). Other studies such as Deloitte (2016 and 2015) reported on research with positive environmental impacts, such as informing the ban on harmful pollutants and increasing sustainable energy generation. Case studies were a frequently used method to describe environmental impacts of research (Morgan Jones et al. 2013;

Kings College London and Digital Science, 2015; Peretz, 2009; NERC, 2017), though studies on the impact of NERC research used information described in the funder reports. An analysis on agricultural research used interviews to determine its wider impacts (Rodrigues et al. 2010). Surveys (Daoud et al. 2016; Rodrigues et al. 2010; Peretz, 2009) were also conducted alongside literature reviews (Daoud et al. 2016; Deloitte, 2016) to gather more wide-ranging impacts. Deloitte (2016) used cost-benefit ratio analysis to determine the impacts of research on the environment. Research also pointed to the impact of a broader range of disciplines on the environment as more broadly conceptualised. For example, Crossick and Kaszynska (2016) describe the impact of art and culture in the urban environment in terms of regeneration, revitalisation and development of urban spaces and neighbourhoods.

3.11.3. Methods used to determine environmental impact

Although a variety of qualitative and quantitative methods have been used to determine environmental impacts from research, qualitative methods such as case studies are the most dominant despite the fact that many of the indicators of environmental impact are of a more quantitative nature. Although case studies have the ability to clearly demonstrate a nuanced narrative in a way that is memorable for readers, it can be difficult to extrapolate the impacts from one case study across an entire portfolio of research funding. One possible explanation is that case studies are selected because they are the best examples of impact, and not because they are representative examples. Where researchers write their own case studies or produce end-of-grant reports for funders, there may be a tendency to over-report impacts from research given the prestige associated with having impact. On the other hand, researchers may be in the best place to understand the full range and scope of impacts as there may not be anyone else so deeply involved with the work.

The use of cost-benefit analysis is one way to demonstrate that environmental research had an impact, but this method is limited to demonstrating economic impact. Many of the reports from NERC, for example, highlight how environmental research can lead to cost savings rather than highlighting the research's benefits in terms of environmental conditions themselves. The most commonly cited benefits of environmental impact were related to cost savings, safety improvements, increased revenues, improved resilience, job creation and public engagement. Framing environmental impacts in this way can help show policymakers and members of the public that environmental research is valuable in a way that resonates with them; however, this approach risks perpetuating the conception that the main or only kinds of impact from research relate to the economy.

3.12. Cross-cutting approaches and datasets

In this section, we review five cross-cutting approaches/datasets that can capture information on benefits across multiple categories, including some which have particular relevance in the UK context. These are Research Excellence Framework data, interaction-based models, big data, Researchfish and case studies. We explain what each of these is, set out how it can be used, and discuss important challenges and limitations.

3.12.1. Research Excellence Framework

What is it?

The REF is the UK's national system for the assessing the quality of research in HEIs. The aims of the REF are to provide accountability for UK taxpayers' investment in research, to facilitate benchmarking, and to inform the allocation of core funding to UK universities. The REF was first conducted in 2014, and the second round will be in 2021. The assessment is based on three elements: outputs, environment and impact. The impact component of the REF is assessed through case studies submitted by institutions describing the non-academic impact of research. All the elements of the assessment are based on peer review through disciplinary panels (termed units of assessment) which are supplemented by research users for the purposes of the impact assessment.

In terms of a resource for assessing the benefits of R&I, the case studies from REF 2014 are now publicly available in a searchable database. This was created to make the more than 6,000 impact case studies widely available. The database includes text-mining functionalities which have been used to conduct some initial clustering of the content, for example in terms of the nature of the impact.

How can it be used?

The database provides a useful resource to find diverse examples of impact from UK research. The full text of the case studies can be queried in order to search for impact in a variety of ways, including by beneficiary, region or particular impact type. The database also allows for analysis of case studies by disciplinary area (according to the unit of assessment) or by institution. Research funders have performed some analyses based on the acknowledgements of the funding supporting the work, which are included in many (though not all) case studies (Digital Science, 2015; Kamenetzky et al. 2016; KCL, 2015). The diversity and detail means that the case studies provide a rich resource for the analysis of the nature of impacts, the pathways to those impacts, and the way in which researchers have chosen to characterise their impacts. Since the case studies include evidence for the impact, this also provides a useful collection of sources and users which support and verify the impacts of UK HEI research.

Challenges and limitations

The REF 2014 case study database is subject to certain limitations as an analytical tool. Firstly, case studies are a skewed sample, intended by institutions to capture the best examples of impact from their research by disciplinary area. The level of impact certainly could not be extrapolated to the average research project. Other elements of the assessment process, such as the need to provide corroborating evidence for impact, may also have skewed the selection of case studies for inclusion in the dataset. The case studies are also produced with a particular disciplinary review panel in mind, and as such may be tailored for that audience. They are also limited by the data-collection capabilities of institutions. For example, where researchers have moved institutions, the impacts may have been more difficult to track and collect evidence on (since case studies remain with the institution, rather than travelling with the researcher). Finally, the case studies provide a snapshot in time, rather than evidence of impacts emerging over particular timelines. Nonetheless, they provide a rich dataset, and it is likely that there are examples of impacts within the dataset spanning every element of our R&I conceptual framework.

3.12.2. Interaction-based models

What are they?

A key framework for interaction-based models has been produced by the SIAMPI project (Spaapen and Van Drooge, 2011). The project was supported by the European Commission within the Seventh Framework Programme. Interaction-based approaches focus on the process that produces impact rather than on aggregate societal impact, where the impact of specific research is difficult to attribute.

The central concept in this approach is productive interaction – the mechanism through which research activities produce socially relevant applications. Productive interactions are defined as contacts between researchers and various stakeholders that lead to efforts by stakeholders to apply research results to social goals. The main types of interaction included in the SIAMPI approach are personal interaction, indirect interaction through a medium (e.g. publication, prototype, guideline, etc.), and financial or material exchanges. To assess productive interactions, data can be collected through interviews and focus groups, as well as media information, annual reports and other documents.

How can they be used?

The idea is that instead of measuring ultimate impacts – which can be subject to lengthy time lags, are difficult to attribute, and may be dependent on many factors outside the control of researchers – analysis should focus on the useful interactions that researchers have with various stakeholders as an indication of the potential for impact and exposure of the research. The SIAMPI approach also emphasises that various indicators of impact may be relevant in each discipline, and has influenced the Netherlands' national evaluation framework, the Standard Evaluation Protocol, to allow researchers to influence the indicators used for various academic fields.

The emphasis on the process required for generating social impact has been reflected in research funding infrastructures. For instance, the EU's Horizon 2020 requires collaboration with non-academic stakeholders for some types of research funding in order to boost research impact. Similarly, other organisations have emphasised the need to focus on the factors that support impact rather than only evaluating it ex-post, through approaches such as involvement of intermediaries and knowledge brokers. Recent literature has also emphasised the need for organisational support that enables impact and knowledge mobilisation.

Challenges and limitations

This is an interesting approach that could address some of the key challenges associated with research impact assessment. However, it is not clear how far these interactions are correlated with the ultimate impact of work. That is, are these interactions true markers of the likely impact of work? There is some evidence that factors such as networks across boundaries (e.g. between research and policy or practice) can support research translation and implementation. But the strength of this link and the power of interactions as a predictor of ultimate benefits is less clear.

3.12.3. Big data

What is it?

In the context of research evaluation, big data would have the following characteristics (Klievink et al. 2016):

- The use and combination of multiple large datasets from various sources
- The use and combination of structured, semi-structured and unstructured data
- The development and application of advanced analytics to handle complex tasks
- Innovative use of existing datasets and/or sources for novel applications.

How can it be used?

Much of the potential in big data research evaluation lies in the linkage of datasets and sources. Big data approaches such as machine learning and data mining can extract data and identify patterns through means of association, classification, clustering and regression, sentiment and network analysis from large and varied datasets (Liao et al. 2012). A key advantage of these approaches in the research evaluation context is the potential for reduction of burden: if existing datasets can be harnessed effectively, this may reduce the need to collect additional data from researchers through case studies and surveys.

The field of altmetrics, which are non-traditional metrics developed to complement traditional measures such as citations, impact factors and the h-index, was an early adopter of big data approaches. The best-known company developing such metrics is Altmetric, which was founded in 2011 and is now integrated into leading journals, funding bodies and institutions. Altmetric combines a range of indicators such as attention, dissemination, and influence and impact to help explore the nuanced nature of research impact. For example, Altmetric performs text mining of policy documents from a wide range of sources including government guidelines and reports, independent policy research publications, advisory committees and international development organisations.¹⁸ In this way, a political impact can be attributed to a document, affecting its altmetric score and associating the score with a qualitative narrative.

Organisations are already taking steps towards effective use of big data. The STAR METRICS initiative in the United States is supporting research evaluation by working to match data from institutional administrative records with those on relevant outcomes such as patents, publications, and citations (Largent, 2012). Enabled by the STAR METRICS repository, the UMETRICS initiative has taken a more evidence-based approach to quantifying the impact of research (BTAA, n.d.). In one piece of work, the effect of research investment on the economy, through expenditures on people and purchases from vendors, was analysed in a geographically disaggregated fashion (Weinberg, 2014). In another study, the UMETRICS dataset was used to examine networks of researchers and, amongst other findings, identified that female graduate students are more likely to be employed on grants with female principal investigators (Lane et al. 2015).

¹⁸ <https://www.altmetric.com/>

In the UK, work by BBSRC in collaboration with the UK National Centre for Text Mining has led to a portfolio analysis tool to help analyse text data, such as grant abstracts and research objectives, to inform more detailed analysis of the research portfolio and thus better understand the nature and content of the research supported. This offers opportunities for wider applications that not only explore the content of the portfolio but link this to outputs and outcomes.

Big data tools provide the opportunity to integrate and analyse data from a wide range of sources such as patent and publication databases, government datasets, grey literature and social media. From this wealth of data, more effective metrics could be developed to better capture the opaque causal links between research and impact (Lane, 2012). Furthermore, automated collection and synthesis of data from these sources could both provide better evidence to support impact and reduce the reporting burden for researchers, for instance by avoiding duplication of effort when providing bibliometric data to multiple evaluation bodies (Lane, 2010). Taking a big data approach to research evaluation may enable more formative assessments to be carried out as data can be collected in a rapid and automated fashion, helping funding bodies support researchers to achieve maximum impact.

Challenges and limitations

Big data is not able to completely replace traditional methods of evaluation such as surveys, official statistics and case studies (Macfarlan, 2015). Different data types bring their own perspectives and biases, so information gained from different methods and sources should be viewed as complementary. Furthermore, while text mining thousands of documents offers great breadth of analysis, there is likely a trade-off with reduced depth (Raftery et al. 2016). The automated analysis of case studies is as yet unable to fully explore the detail and complex mechanisms through which impact may occur, and sentiment analysis of social media or news reports is not yet a robust way of measuring public engagement with research. When working with large datasets, evaluators must have well-defined questions and processes. If information from large datasets is interpreted without appropriate context, incorrect assumptions and spurious relationships can arise (Jackson, 2015).

Big data approaches are only as powerful as the datasets they can access. A key obstacle is the storage of data in 'silos', which are repositories under the control of different organisations that are often hard to integrate. For big data to become a key part of research evaluation, a new and more open attitude is required across institutions, funders and businesses (Wilder-James, 2016). These stakeholders will need to acknowledge that combining data from multiple sources could lead to better decisions and benefit all parties.

3.12.4. Researchfish

What is it?

Researchfish is an online platform used by many research funders (including all UK Research Councils) to assess the outputs, outcomes and impacts of the research they fund. The tool currently captures information on behalf of 79 research funders (74 registered in the UK, 5 overseas) and contains more than seven years' worth of output, outcome and impact data (Hinrichs et al. 2015). Most of the information is collected through an annual survey of researchers where they enter information on the

outputs, outcomes and impacts of their research projects against standardised fields across a range of areas. Researchers are expected to complete the survey for the lifetime of the project, and for some period of time after the project is completed (up to five years). Failure to submit a response can lead to consequences such as ineligibility for further funding; however, the completeness and accuracy of responses is more difficult to validate. Researchers are also invited to continue to add information over a longer timeframe, but there is no compulsion after the mandatory period set by the funder (this period varies – for example, it is five years for the MRC).

Researchfish is a rich data source that can support research evaluation and impact assessment initiatives. The data can be analysed in a number of ways, including by single research funders, in aggregate form or comparatively across research funders (or research institutions) (Hinrichs et al. 2015). Research funders will often extract narratives that describe impact from Researchfish data.

How can it be used?

Researchfish is a unique resource in that it provides consistent longitudinal data on the impacts from a large proportion of UK academic research. The level of coverage of the dataset could not be readily generated ex-post through surveys or other data collection mechanisms, and the comparability across funders means that the dataset offers useful opportunities for comparisons and benchmarking as well as integrated, aggregate analysis. There is also a significant amount of qualitative information in Researchfish which could offer opportunities for more detailed and nuanced analysis of the data as better text mining tools emerge over time. Researchfish is extremely useful for providing an overview of the outputs and outcomes of portfolios of research, and for gaining an overall understanding of the key routes and areas of impact. It can also be used to stratify portfolios for other analysis (for example to select researchers for interview or to identify potential case studies in specific evaluations).

Figure 6 maps the areas of our framework where the existing Researchfish question set provides some potential material and evidence for analysis. The extent and completeness of this data in each area is variable. For example, it captures quite extensive and stratified information on policy impacts, whereas cultural impacts are largely limited to specific artistic outputs produced. Based on this analysis, more use could be made of the dataset, particularly in terms of the time series data it provides and the potential to conduct analysis of the time periods over which impacts are realised. The information captured also includes whether outputs are local/regional, national or international in scale. However, this does not really facilitate regional analysis as, although the location of the institution may be provided, this does not necessarily mean that a 'local' impact is local to that institution.

Challenges and limitations

There are limitations to the Researchfish dataset. The first of these is the quality, integrity and completeness of the data, which was a recurring theme in the stakeholder interviews. This is due to data being integrated from older data-collection systems (e.g. E-Val), and also compliance rates of individual researchers. Evidence suggests that Researchfish data underreports impacts overall and, anecdotally, funders suggest that the most productive and impactful researchers may be least likely to submit complete data onto Researchfish. We are also aware that completion practices vary between institutions. For

example, in some institutions the Researchfish return is delegated to administrative staff or a PA, while at other institutions researchers complete it for themselves.

The nature of the question set and consistency between funders is valuable in terms of enabling aggregate analysis, but it was noted that this is also a challenge in that it does not effectively capture all relevant outcomes for every research programme (indeed, this would be close to impossible). In particular, it was suggested by respondents in several interviews that the question set could be updated to shift away from the initial medical focus to reflect the diversity of funders that now use the tool. The tool is already intended to cover all disciplines, but the evidence from interviews suggests that this has not been adequately addressed.

Finally, it is clear that at present some of the potential of the Researchfish dataset is not being realised. A key limitation is the lack of data sharing between research funders, both due to concerns over the sensitivity of the data and due to challenges in integration between data systems and other practical challenges. This limits the opportunity to capitalise on one of the key benefits of the dataset, namely its comparability across contexts. The formation of UKRI may offer an opportunity to overcome some of these barriers, at least for a core group of UK funders. Many funders also do not seem to be drawing effectively on the full richness of the dataset, with much of its use, at least in terms of what is made publicly available, focusing primarily on funders' annual reporting requirements. This may at least in part reflect the capacity and capability of research funders and HEIs to analyse the data in Researchfish, with limited resources available for evaluation.

	Impact on the economy	Commercial impact	Impact on public policy and services	Impact on health and wellbeing	Impact on education and training	Impact on public engagement, awareness and debate	Cultural impact	Impact on social cohesion	Impact on safety and security	Impact on the environment
Aggregate benefits	[Red shaded area]									
Benefits by region/geography										
Benefits by sector										
Benefits for different population groups										
Benefits over different time periods	[Red shaded area]									

Figure 6 Impact index showing data captured by Researchfish

3.12.5. Case studies

What are they?

The objective of a case study is to explore, explain or describe an activity. In many respects case studies are self-contained narratives that can be used to illustrate effective practice. In other contexts they can be diagnostic, in so far as they describe what works and what does not work. The topics of case studies can also be varied, and in this respect they are almost completely flexible. Case studies are a qualitative, descriptive research technique, and provide detailed information about a limited topic or context with the aim of producing a rich and detailed understanding of that particular area, rather than widely generalisable conclusions. However, groups of case studies together can say more about a broader context if they are carefully selected.

How can they be used?

Case studies are widely used in the context of research evaluation and research impact assessment. However, the detail and quality of case studies varies substantially, and in some cases they are little more than anecdotes. The nature and content of case studies vary depending on their purpose. Case studies are often used for advocacy purposes, to provide a description of excellent examples of impact to showcase the

quality and impact of a portfolio of work. This is illustrated in their widespread use in reporting by the Research Councils. They can also be used to help ‘bring to life’ examples of impact in wider portfolio reviews. ‘Stories’ or narratives are naturally appealing and can often carry more weight than statistics or data since they are more memorable and create a more personal connection. Case studies can also be extremely useful from an analytical perspective as they set out the ways in which outcomes and impacts came about, not just what they are. With careful sampling (not just selecting for the ‘best’ examples) and analysis, this can provide useful insights beyond the specific examples investigated (e.g. Wooding, 2011 and 2014). Generally speaking, case studies have a distinct advantage over other methods when a ‘how’ or ‘why’ question is asked. The case study methodology is able to access detail and context. When used correctly, case studies can provide rich and deep contextual information, building a full understanding of a particular situation. Case studies are able to deal with heterogeneous and non-routine behaviour or circumstances better than many other techniques, and provide a useful way to capture diverse impacts, including those that are not easily quantified, and can address the non-linear nature of R&I. Overall, the case study approach is flexible and wide-ranging, meaning that it can be usefully applied to diverse contexts.

Challenges and limitations

One of the key limitations of case studies is that they are very specific to the context in which they take place. This means it can be difficult to generalise any findings as they may be specific to that context. This issue can be addressed somewhat by careful selection of case studies for analytical purposes. Equally, in some situations this may not be important – for example, when trying to showcase examples of great impact. Case studies also have an element which is inherently subjective. Although they can draw on factual data, in many cases much of the most interesting output of a case study relies on personal interpretation and inferences, and it can be difficult to test the validity of findings. Finally, case studies require a relatively high level of investment per subject or topic, meaning that they are not a useful way to gain insights across the whole of a portfolio or field of research. They are more useful to provide detailed information and examples to supplement rather than replace wider portfolio analysis.

4. Discussion and conclusions

4.1. What are the benefits of R&I?

4.1.1. R&I delivers significant benefits to the UK economy and society

There are significant rates of return from investment in R&D, likely in the range of 20–30% (Haskel et al. 2014; Frontier Economics, 2014; Salter and Martin, 2001; Haskel and Wallis, 2010 and 2013), and strong evidence that public sector investment in R&D ‘crowds in’ private sector R&D investment (Guellec and de la Potterie, 2003; Falk, 2006; Sussex et al. 2016; Hughes and Martin, 2012; Aerts and Schmidt, 2008; Falk, 2006). However, comparable estimates are not available for R&I as more widely conceptualised. Evidence on marginal returns – the benefits from increases in investment rather than the investment as a whole – is more limited but it seems likely that increased investment in R&D towards the target of 2.4% of GDP will continue to yield these levels of benefit (Allas, 2014; Coccia, 2009). In fact, the true benefits to society of R&I investment are likely to exceed these economic estimates (Frontier Economics, 2014) which likely do not capture fully some of the wide-ranging benefits from research spanning a multitude of areas, including health, culture, public engagement and the environment.

4.1.2. The existing literature does not fully capture the range of benefits of R&I

A more holistic way of measuring the benefits from investment in R&I would be valuable. This would better capture and illustrate the ways in which research benefits society, and facilitate better analysis of those benefits. This, in turn, would help to ensure that investments are targeted towards achieving the full range of benefits, not just those which are most easily measured.

With this in mind, we propose a broad framework, in the form of the impact index, which aims to broadly conceptualise the range of benefits and impacts that can result from investment in research and innovation. Although the existing evidence provides a compelling case for the benefits that R&I can deliver, particularly to the economy, there are many benefits that come from investment in R&I that are not well measured or, in many cases, well understood. Case study examples exist that demonstrate the myriad ways in which R&I enriches our society, improving our quality of life through improved social cohesion, through broader and deeper cultural experiences, through improved safety and security, and through a richer and more engaging education. Though many of these benefits are acknowledged in the literature, often the evidence for the role research plays in helping to realise these has not been fully articulated and measured. We hope that the impact index can provide a starting point for wider thinking and methodological innovation around the different benefits that R&I can bring.

4.2. How are the benefits of R&I currently measured in the UK?

4.2.1. There is limited evidence of methodological innovation

One key observation from our analysis is that, with the exception of a few pockets of more innovative work, most evaluations of the benefits from R&I are dominated by a few key methods. These include economic analysis based on the total factor productivity model, case studies, and portfolio-specific evaluations based on interviews/surveys and case studies (many of which focused primarily on biomedical and health research and health outcomes). In part, this may be because those methods are useful and applicable to many contexts (for example, case studies), or because they produce powerful outcomes (for example, the total factor productivity approach). However, this also reflects the lack of resources invested in evaluation, which means scope for methodological innovation is limited. It is also worth noting that most evaluations are to serve specific purposes – either advocacy, where case studies are particularly useful, or to secure funding, in which case economic arguments might be most pertinent. This means that the scope and motivation to try novel approaches can be limited. More methodological innovation and a greater diversity of approaches could help provide a broader picture of the benefits of R&I, supporting better investment decisions.

4.2.2. Existing datasets could be better used

Reflecting the limited methodological approaches used, evaluations do not always take advantage of data and methods that are available. For example, the majority of evaluations of environmental impact in the literature appear to take a largely qualitative case study approach (e.g. Morgan Jones et al. 2013; Peretz, 2009; NERC, 2017), despite the fact that many environmental outcomes might lend themselves to quantification and wider aggregation (for example, reductions in emissions or pollution levels). We also noted that evaluations typically take place either at a high level or a very specific level. They either focus on population-level metrics and then try to extrapolate changes in those high-level metrics to R&I, or they take a case study approach focusing on a very narrow change related to one specific piece of research. There are exceptions to this, but most studies we examined focus on one or both of these approaches, perhaps since these are less resource-intensive. As we know that the majority of REF case studies were both multidisciplinary in their research inputs and multi-impactful in their benefits (King's College London and Digital Science, 2015), these narrow approaches only serve to undermine the value that a richer analytical approach could bring.

Looking at some of the main datasets available in the UK context, it is particularly notable that there is much more scope to make full use of Researchfish for such analyses. At present, the majority of the analysis of Researchfish data seems to be to feed into standardised annual reporting by the Research Councils. As a unique and relatively comprehensive longitudinal dataset, there is scope for more interesting and novel use. Linked to this, it is also worth noting that much of the work done is quite siloed and discipline-limited. For example, evaluations of health research seem very strongly focused on health gain and economic outcomes, which is appropriate, but there is also scope to take a broader perspective on potential outcomes from research. Researchfish, and other wider datasets (e.g. Gateway to Research, HESA datasets) offer opportunities for more nuanced cross-disciplinary analysis. Better use of

existing datasets could give a more comprehensive picture of the range and nature of benefits from R&I, without generating additional burden on researchers or research users through additional data collection.

4.3. What evidence exists on the distribution of impacts?

4.3.1. Evaluations rarely look at the distribution of impacts

There is very limited evidence that research evaluations have explored the distribution of impacts of R&I by region or population group. Key challenges related to this involve time lags associated with longer-term impacts, which make it hard to link long-term societal benefits to specific research, or indeed to research as whole. Several interviewees suggested that it is often difficult to link benefits to particular groups of people with a particular piece of research, or even research from a particular country.

There have been limited attempts to look at distribution in some areas. Some economic analyses have attempted to characterise benefits by region or population group, and these approaches could be further explored. For example, in the development sector, microeconomic approaches have explored the impact of R&I on different groups and populations, since the key aims are around addressing poverty and inequality (e.g. Rich et al. 2014; Mathenge et al. 2014; Mywish et al. 2014). There are also analyses of regional economic benefits of large infrastructure projects, focusing on direct spending and employment (e.g. STFC, 2010; Oxford Economics, 2009). There is also evidence on commercial benefits covering geographic distribution. Here, studies have explored the linkages between R&D investment and location of businesses and investment, based on a range of approaches including surveys (Kuemmerle, 1999; Gassmann and Boutellier, 2004), analysis of quantitative data on R&D investment and intellectual property (Le Bas and Sierra, 2002; Thomson, 2013), and econometric approaches (Abramovsky et al. 2007; Abramovsky and Simpson, 2011).

4.3.2. There is a lack of longitudinal studies looking at the distribution of impacts over time

Based on our analysis, a key gap in evaluations of R&I impacts is the lack of longitudinal analysis of impacts. There is a predominance of ‘snapshot’ evaluations, which evidence time-limited impact, rather than looking at changes in impacts over a long period of time. However, R&I impacts may be short- or long-term, and so the time window covered by data collection is critical. This means that impact evaluations may often fail to capture longer-term developments in R&I impacts, and also do not necessarily focus on understanding the process of creating research impact, including critical events and their linkages.

There are, however, several attempts at longitudinal analysis. Researchfish collects data throughout the lifetime of a research grant and after completion, allowing for long-term follow up on the way that outcomes and impacts develop. There are also a number of evaluation frameworks and approaches for studying research translation empirically through longitudinal, real-time methods. Examples of this include the SIAMPI approach developed by the Royal Netherlands Academy of Arts and Sciences (Spaapen and Van Drooge, 2011), and the Payback Framework (Buxton and Hanney, 1996; Donovan and Hanney, 2011), which is often used to measure impacts of health research. Longitudinal impact assessment approaches raise challenges of burden, since they may require input from the same researchers

multiple times, so careful thought needs to be given to the best ways to capitalise on existing data collection and draw on new and emerging data mining and data analytics approaches. Despite these challenges, longitudinal analyses can offer significant value, notably in terms of demonstrating that research and innovation investments can take a long time to come to fruition, and illustrating some of the processes through which that can happen.

4.4. How can we improve on the evidence base and build on innovative practice?

We identify a number of actions that could be considered as routes to improve the quality and scope of the evidence base on the benefits of R&I.

4.4.1. Increase openness and shared learning

There is scope for funders and evaluators across sectors and disciplines to work more closely together and share learning and good practice. This could help move thinking outside some of the disciplinary silos that currently exist and enable more methodological and conceptual creativity. This may also help foster a culture of increased openness, with, for example, more sharing of data across organisations to allow better analysis of the collective benefits offered by research and innovation as a whole, which is likely more than the sum of the single disciplinary or funder contributions. The recent launch of UKRI may provide a platform for increased integration and collaboration across disciplines, particularly given the core emphasis on evaluation as part of its strategy (UKRI, 2018). Doing this would help funders gain a better understanding of the benefits of their work, and support more strategic thinking about R&I investment.

4.4.2. Build on examples of novel and innovative practice

Building on and expanding approaches and data used in evaluation could help provide a fuller picture of the benefits of R&I. It could also help to address challenges such as burden and attribution, or capture new information, for example on the distribution of benefits across population groups.

New data mining approaches are one example of innovative practice that could offer opportunities to capture a diverse range of benefits from R&I in a new way. More broadly, there is scope to better capitalise on and fully interrogate existing datasets. There is also scope to look at the availability of wider datasets that might inform R&I analyses – for example, looking at the Taking Part survey dataset to better understand cultural engagement and how and where that can be linked to R&I (see Fujiwara, 2014 or Miles and Sullivan, 2010).

Novel approaches are not limited to new data analytics methods. For example, the SIAMPI approach (Spaapen and Van Drooge, 2011) is a framework that offers the potential to address challenges related to time lag and attribution, but which needs further investigation and application across geographic and disciplinary contexts (see section 3.12.2). We also note examples of approaches, which are limited but could be built upon, that attempt to look at distribution of impacts by region and population group. For example, there is scope to improve and expand on existing methods used to analyse the regional impact of university and/or infrastructure investment (e.g. Le Bas and Sierra, 2002; Thomson, 2013; Abramovsky et al. 2007; Abramovsky and Simpson, 2011; STFC, 2010; Oxford Economics, 2009).

4.4.3. Invest in evaluation and methodological development

To build on novel practice and create a more holistic perspective on the benefits of R&I, increased investment will likely be needed. The limited investment in evaluation was noted overall across studies, and a shortage of resources was noted as a key contributing factor in a lack of methodological innovation. Funders could consider establishing a minimum proportion of their budget that they will set aside for methodological development in the 'science of science', and application of those methods to practical, formative evaluations of their R&I activities. Working collectively would help them to maximise learning and the effectiveness of that investment. Given an increased investment in underpinning research on the science of science, some initial priorities could be to focus on establishing the principles and approaches for high-quality evaluation of the benefits of research in some of the less well studied areas (e.g. social cohesion, safety and security), better integration and analysis of data on a large scale, and work looking at the distribution of impacts across population groups and regions. For example, an early study might look at the distribution of cultural benefits across regions in the UK, aiming to move beyond case studies to start to collectively characterise and analyse these benefits in a comparable way across geographies, and drawing on both new and existing datasets.

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Annex A: Methods

Introduction

This annex provides a detailed overview of the methods used in this study.

Description of methods

Rapid evidence assessment

We conducted a rapid evidence assessment to review existing evidence on: (i) the range of benefits of research and innovation; (ii) how these benefits are currently assessed or measured in the UK; (iii) the distribution of these benefits (by geography, sector, population group); and (iv) alternative approaches developed internationally. Unlike a full systematic review (which aims to search the entire evidence base comprehensively), the scope and coverage of a rapid evidence assessment are restricted through search and screening criteria selected to focus on the most relevant literature and ensure that the amount of literature to review is manageable within the scope, resources and timeline available for the work.

We developed a search strategy with expert input from RAND Knowledge Services on devising the appropriate search strings, search constraints and capture requirements. The search was conducted using title and author-supplied keywords in the following databases: Academic Science Complete, Social Sciences Abstracts, Policy File, Scopus, and Embase (Elsevier). For all searches, the publication timeframe was restricted to 2008 onwards to capture literature from the past ten years, and only articles published in English were considered.

Table 5 shows the final search strings. We also used ‘snowballing’ to identify additional articles from reference lists of selected articles, as well as the team’s existing knowledge of some frameworks, methods and datasets.

We screened articles by title and abstract. Table 6 shows the inclusion and exclusion criteria. We included articles that focused on frameworks or methods to assess the downstream, socio-economic impacts of research. Articles that focused only on ‘upstream’ measures such as research excellence (e.g. performance of research centres, PhD studentships, etc.) were not included as, while these indirectly lead to socio-economic impacts, they were deemed out of scope for the purpose of this study. Following the screening stage, we reviewed the articles in detail and extracted key information into an MS Excel template covering the following information: framework details, methods used, type of research and benefits assessed, and strengths and weaknesses. In total, we reviewed 151 articles.

Table 5 Search strings for the rapid evidence assessment

Search strings	
1	(Research OR Research and Development OR R&D OR innovation OR R&I OR RDDI) AND (Benefit* OR impact* OR ROI) AND (Evaluation OR framework* OR logic model)
2	(Research OR Research and Development OR R&D OR innovation OR R&I OR RDDI) AND (Benefit* OR impact* OR ROI) AND (Indicator* OR measure* OR metric*)
3	(Research OR Research and Development OR R&D OR innovation OR R&I OR RDDI) AND (Benefit* OR impact* OR ROI) AND (Distribution OR equality OR equity OR inequality OR National OR regional OR municipal OR international OR local)

Table 6 Inclusion and exclusion criteria for the rapid evidence assessment

Included	Excluded
<ul style="list-style-type: none"> • Publications from 2008 onwards • Articles in English • Articles about the socio-economic impacts of research and innovation 	<ul style="list-style-type: none"> • Publications from prior to 2008 • Articles about the impact of R&D funding on research excellence or the research process

Review of grey literature

To further develop an understanding of current approaches, frameworks and methods used to measure the benefits of research and innovation, we conducted a review of the grey literature. The review focused on evaluation reports, annual reports and other relevant documentation from key research funders and evaluators, primarily in the UK but also internationally. As with the rapid evidence assessment, the scope and coverage of the grey literature search was restricted to focus on the most relevant funders and ensure that the amount of literature to review was manageable within the scope, resources and timeline available for the work.

The search was conducted using Google and manually searching within relevant funders' websites. Table 7 shows the organisations searched. We aimed to include a mixture of relevant UK, EU and international research funders, as well as novel or interesting approaches used. Our inclusion and exclusion criteria were the same as for the rapid evidence assessment, and we analysed the resulting literature together with the academic papers, extracting data into the same MS Excel spreadsheet.

Table 7 List of research funders and evaluators

Research funders and evaluators	Region/Country
1 Research Councils: STFC, MRC, EPSRC, ESRC, NERC, BBSRC, AHRC	UK
2 Higher Education Funding Council for England (HEFCE)	UK
3 Innovate UK	UK
4 Wellcome Trust	UK
5 Horizon 2020/European Research Council	EU
6 Social Impact Assessment Methods for research and funding instruments (SIAMPI)	NL
7 STAR Metrics	US

Interviews with research funders

To provide a more detailed picture of existing research evaluation approaches, we conducted ten telephone interviews with research funders and evaluators, as well as experts in the research evaluation and impact field, both in the UK and internationally. Interviewees were identified through the grey literature. The interviews were semi-structured and lasted between 30 minutes and one hour. This allowed us to ask a pre-determined set of open questions (see section 4.2.4) with the opportunity to explore particular themes or responses further. The aim of the interviews was to explore in detail the evaluation methods research funders use, the data they can access and the challenges they face. Interviews were written up against the question structure using a common template and analysed alongside the evidence from the documentary review in a cross-team workshop. The individuals interviewed are listed in Table 8.

Table 8 List of interviewees

Interviewee name	Organisational affiliation
Anke Reinhardt	Deutsche Forschungsgemeinschaft (DFG)
Dr Alex Hulkes	Economic and Social Research Council
Dr Ian Viney	Medical Research Council
Dr George Santangelo	National Institutes of Health
Dr Fiona Goff	Natural Environment Research Council
Gustav Petersson	Swedish Research Council
Dr Jack Spaapen	The Royal Netherlands Academy of Arts and Sciences
Dr Shewly Choudhury	The Royal Society
Dr Ben Bleasdale	Wellcome Trust
Dr Louise Wren	Wellcome Trust
Dr David Phipps	York University

Interview protocol

Thank you for agreeing to participate in our study. The work, commissioned by the Royal Society, the Academy of Medical Sciences, the British Academy and the Royal Academy of Engineering, is investigating the current approaches to assessing the benefits of research and innovation. The study aims to produce an overall framework for capturing the benefits of research and innovation in various dimensions.

To explore the methods used by research funders, we are conducting interviews with funding organisations in the UK and abroad.. We have reviewed the available online materials about your impact evaluation process, but would like to ask you some questions to explore them in more detail.

The project will be written up as a publicly available report which will be on the RAND website and should be completed by July 2018. Do you have any questions about the project?

With your permission I would like to record this interview, but the recordings, any notes and transcripts will be kept strictly confidential and never be made available to any third party, including the National Academies.

Any quotes included in RAND Europe's final report will not be explicitly or directly attributed to you without your permission. Should we wish to use a quote which we believe that a reader would reasonably attribute to you or your organisation, a member of the RAND Europe project team will contact you to inform you of the quote we wish to use and obtain your separate consent for doing so.

All records will be kept in line with the General Data Protection Regulation (GDPR) 2018. Further information about RAND Europe's data security practices can be provided upon request.

To keep all processes in line with the GDPR 2018, we would like to ask you to confirm a few data protection statements:

1. Do you agree that the interview can be recorded by RAND Europe and that these recordings can then be transcribed for the purpose of providing an accurate record of the interviews?
Yes No
2. Do you agree that RAND Europe can store this data securely on password-protected computers and its servers for the duration of the project?
Yes No
3. Do you agree that RAND Europe can destroy the recordings and all notes and transcripts after the project has been completed?
Yes No
4. Do you agree to us re-contacting you if we wish to use a quote which we believe that a reader would reasonably attribute to you or your organisation?
Yes No

Interview questions

1. Could you outline the key methods you use to evaluate the performance of your research (including research projects, individual researchers, or research facilities and centres)?
 - Who is involved in monitoring and evaluating the impact of research in your organization?
 - How does this differ between programmes?
 - Do you have a particular framework you use to structure the data and analysis?
2. What are the main sources of data for your monitoring and evaluation?
3. How do you use and analyse the data?
 - How does this differ by audience and purpose?
 - How much do you share publicly or with different groups (e.g. policymakers, institutions, researchers)?
4. As well as any systematic data collection, do you do any 'ad-hoc' evaluations by programme, or on specific themes?
 - If so, how do you decide what to do and when?
 - What different methods and approaches do you use?
 - What additional information do these ad-hoc activities provide?
 - What purposes do they serve?
5. How well is your evaluation work integrated with other funders you work with?
6. In any of your evaluation work, do you explore the distribution of the research benefits on different regions, sectors, or population groups?
7. Could you please describe what you think is working well in terms of your evaluation approaches?
 - What could others learn from you?
8. What challenges are you facing in your impact evaluation at the moment?
 - What are the practical challenges in implementation?
 - What criticisms do you receive, if any?
 - How do you address these?
 - What do you find difficult – to do, to collect, to analyse?
 - What are the gaps in the evidence base that you would like to see addressed?

9. Based on the evidence you collect, what are the key impacts of your research?
 - If you could highlight one or two examples of your impact, what would they be and why?
10. What are you working: on at the moment, or over the next year or so?

Critical review of methods and examples of practice

Based on the data extracted from the literature and interviews, we mapped existing evidence on benefits from research and how they are measured against the columns of the framework developed, reviewing in detail the methods used, their caveats and limitations, and their transferability, as well as any other key observations and trends. Interesting case study examples of practice were drawn out from the literature and included in the discussion of methods and findings. In addition, we identified some core cross-cutting methods which were analysed separately, namely Researchfish, the REF case study database, interaction-based approaches and big data. Key learning from each of the areas was identified and fed into a cross-team workshop as described below.

Internal cross-analysis workshop

This task consisted of an internal workshop held by the study team members to analyse the evidence from the documentary review and interviews. During the workshop, the study team brought together key observations from the analysis conducted in terms of the overall evidence base for the benefits of R&I in the UK and their measurement, including methodological weaknesses, trends, gaps, and scope for international learning. Observations were clustered and key emerging themes were identified, discussed and analysed. Drawing on this, we identified key lessons learned and possible areas for action.

Limitations of the analysis

We adopted a rapid evidence assessment approach for the literature review to ensure useful information could be gathered in a limited period of time. This means that there may be relevant studies and documents that were not identified or included in the analysis. Nonetheless, through snowballing and carrying out some targeted searches, we aimed to make the searches as broad and comprehensive as possible. There are also likely biases and limitations to our search approach – notably in terms of language. The methods, frameworks and approaches identified are not intended to be an exhaustive list. We should also note that some members of the study team are contributors to this existing literature and as such may bring pre-existing biases and conceptions about how research impact can be measured and conceptualised that may influence the analysis conducted. The final report is necessarily a summary – there will be many approaches and methods that are not included or not discussed in detail. There may be pockets of innovation or interesting practice that have not been included, or examples that could have been added. However, the report is intended to provide an overview of core approaches and key limitations within the scope of the timeframe for this work, and hopefully provides a useful sense of the scale and nature of the existing work and some direction for future work in this space.

Annex B: Review of existing frameworks for assessing the benefits of R&I

In this annex we set out an overview of existing frameworks for assessing the benefits of R&I, and how they are operationalised in different contexts.

Frameworks enable classification of R&I impacts and model the pathways through which they occur

Frameworks provide a structured format for thinking about research impact. They typically serve one or both of two main purposes:

- To provide a structure and classification system to allow the range and nature of benefits from research to be grouped and classified; and
- To provide a model of the pathways through which these benefits come about, in order to support understanding of research translation and application processes.

In the context of this work, since we are looking to characterise and map the range and nature of impacts from research, we are particularly interested in frameworks that serve the first of these two potential aims. However, understanding of pathways is also critical to policy and decision making, and the balance of frameworks across these two purposes will differ depending on the evaluation context and aims. As outlined above, research impact can be measured and assessed for a number of reasons. Evaluations aiming to provide evidence to support advocacy work will likely be more focused on classifying and exemplifying the range and nature of benefits. By contrast, work focused on the analysis of the system will draw more value from frameworks which provide information on the routes by which impact is achieved.

Several reviews have attempted to group and classify frameworks for measuring R&I impact

Several previous studies have attempted to classify and group these frameworks. One such study is the work by Raftery et al. (2016), which consists of a systematic review of models for assessing the impact of health research, building on and extending a previous systematic review conducted by the same team (Hanney et al. 2007). The typology of models described in this review comprises 20 frameworks that have been applied in health and cross-disciplinary contexts. As well as this overview of frameworks, Raftery et al. (2016) also try to move towards a broader taxonomy of approaches based on the ‘philosophical roots’ of the approaches across five groupings:

- Positivist (unenanced logic models)
- Constructivist (interpretive and interactional models)
- Realist (context-mechanism-outcome-impact models)
- Critical (participatory models)
- Performative (co-production models).

This classification approach is useful in terms of understanding some of the underpinnings and principles that feed into the development and application of frameworks for assessing the outcomes of research. However, the paper also notes in the discussion that many frameworks will draw on several elements across the five groupings, and as such it is not a strict categorisation approach.

In addition to this comprehensive review, Raftery and colleagues also produced a shorter article (Greenhalgh et al. 2016) identifying and critically reviewing six widely applied frameworks. These are:

- The Payback Framework (Buxton and Hanney, 1996)
- Research Impact Framework (Kuruville et al. 2006)
- Canadian Academy of Health Sciences (2009)
- Monetisation (e.g. Johnston et al. 2006; de Olivera, 2013; Access Economics, 2008)
- Societal impact assessment (e.g. Spaapen et al. 1994; Netherlands Academy of Arts and Sciences, 2002; Research Excellence Framework (Higher Education Funding Councils, 2015)).

Greenhalgh et al. (2016) also describe several less established approaches, including electronic databases (e.g. Researchfish), realist evaluation (Pawson, 2013), contribution mapping (Kok and Schuit, 2012), the SPIRIT action framework (Redman et al. 2015), and the participatory research impact model (Cacari-Stone et al. 2014). They note that the value of each framework differs depending on context and that there is no 'one size fits all' approach; indeed, in any given circumstance no approach is likely to be perfect, but this should not prevent a 'good' or 'good enough' approach being taken. They also point to the emergence of big data as a potential game-changer for this field in terms of providing new ways to access data that may remove the need to consult individuals (e.g. through surveys or interviews), which forms a cornerstone of much research evaluation at present. This can reduce burden, and could also facilitate new approaches such as real-time monitoring, and support evaluation over longer timescales addressing some of the challenges around time lags.

Another relatively recent review and categorisation of frameworks was conducted by Banzi et al. (2011). Their systematic review aimed to identify the most common approaches to research impact measurement, categories of impact and indicators, again from a health research perspective. They note in particular that all the frameworks they identified take a multidimensional approach (i.e. they consider a number of elements, from knowledge production through to informing policy and wider socio-economic benefits) to classifying the impacts of research across categories. They suggest that these different categorisation approaches can be broadly grouped into five thematic areas (which are closely aligned with the Payback Framework): 'advancing knowledge', 'capacity building', 'informing decision making', 'health benefits', and 'broad socio-economic benefits'. Each of these will have relevant subcategories.

A number of studies by RAND Europe (see for example Grant et al. 2010; Guthrie et al. 2013) have reviewed primarily national-level evaluation frameworks and systems and analysed their characteristics. In

particular, the work by Guthrie et al. (2013) maps the different frameworks against their intended purposes according to the ‘four A’s’ of research assessment (advocacy, accountability, analysis and allocation) and draws out common characteristics and trends. For example, it is noted that while all the frameworks reviewed in detail capture output metrics and most also include input and outcome metrics, impact metrics, which are more challenging, are less common (see Table 9).

Table 9 Stages of measurement captured by various international research evaluation frameworks

	REF	ERA	SM	CAHS	NIHR	PI
Inputs	X	X	X	X	X	
Outputs	X	X	X	X	X	X
Outcomes	X			X	X	X
Impacts	X			X		

Source: Guthrie et al. (2013)

Legend to the table:

REF = Research Excellence Framework (UK)

SM = STAR METRICS (US)

ERA = Excellence in Research for Australia (AUS)

CAHS = Canadian Academy of Health Science (CAN)

NIHR = National Institute of Health Research (UK)

PI = Productive Interactions (several European countries)

In addition, characteristics of frameworks are mapped against their purposes, noting the potential trade-offs among approaches to research evaluation and how these relate to the underlying objectives of evaluation efforts, expressed by the four A’s. For instance, if the objective of research assessment is allocation of resources, some degree of comparison is likely necessary. By extension, this means that frameworks that could be used for such a purpose will likely be more summative than formative and not very comprehensive (see Table 9).

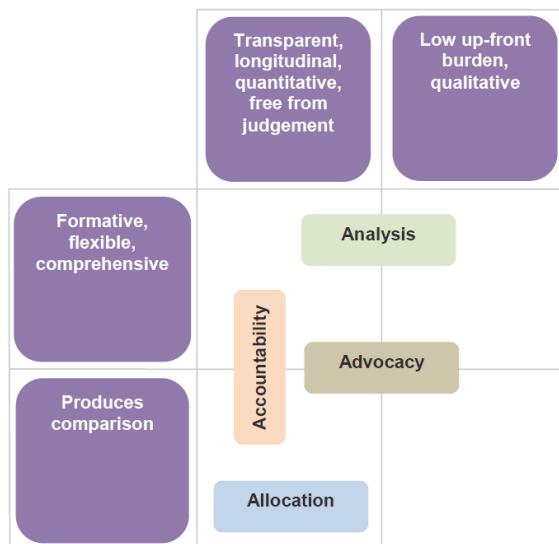


Figure 7 Typology of research evaluation frameworks

Source: Based on Guthrie et al. (2013)

Finally, a review by Marjanovic et al. (2009) takes a historical rather than comprehensive perspective, reflecting on some of the early landmark studies in research evaluation. These include the case study approaches of Project Hindsight (Sherwin and Isenson, 1967), Project Traces (Isenson, 1968), and Comroe and Dripps (1976). The review also looks at selected more recent approaches and their relative merits and challenges. The authors point to a number of studies, notably the Advanced Technology Program's *Toolkit for Evaluating Public R&D Investment* (Ruegg and Feller, 2003), which is noted as one of the most influential reference works in the field. The *Toolkit for Evaluating Public R&D Investment* characterises outputs and impacts in terms of firm or industry effects, collaboration effects, spillover effects, interfaces and comparisons with other programmes, and measures of overall programme performance.

We identify ten key groupings which characterise the existing frameworks across disciplines

The Raftery et al. (2016) study and most of the other extensive reviews identified are focused on the measurement and conceptualisation of the impacts of health research. Some of these methods could be used in other contexts, but there may be approaches in the wider literature that are not being captured by these studies. As a result, in our analysis below we build on the work of Raftery et al. (2016), but with two important differences:

1. We are taking a broader disciplinary approach bringing together literature across all research fields; and
2. We are focused on frameworks that allow us to characterise the range and nature of benefits, rather than those which only capture routes and pathways to impact.

In addition, we propose a broader classification approach focusing on key approaches and grouping together similar (if not identical) approaches. With this in mind, we map the existing literature reviewed into ten groupings as shown in Table 10.

This is a broader classification approach than those taken by other reviews, and is designed to capture together frameworks that (i) draw on largely similar theoretical and conceptual underpinnings; or (ii) have key characteristics in common that mean they naturally fall into the same grouping. We draw on the methods outlined here and this classification in our analysis of the existing evidence in chapter 3.

Table 10 Groupings of frameworks and approaches to R&I impact evaluation

Framework	Examples of studies which apply or draw on that framework	Brief summary of key principles
Payback Framework-based approaches	Canadian Academy of Health Sciences (2009) Banzi et al. (2011) Aymerich et al. (2012) Bennett et al. (2013) Bunn et al. (2014) Donovan et al. (2014) Expert Panel for Health Directorate of the European Commission's Research Innovation Directorate General (2013) Wooding et al. (2014)	Consists of two components: a logic model and taxonomy for research impact. Taxonomy comprises 5 categories of health research benefit: knowledge production; research targeting and capacity building; informing policy and product development; health and health systems benefits; broader economic benefits. It has been adapted and used in different contexts, including outside health.
Economic analyses, typically focusing on rates of return	Deloitte Access Economics (2011) Guthrie et al. (2015) Haskel et al. (2014) Sussex et al. (2016) Frontier Economics (2014)	This is a broad category which comprises different monetary approaches to assessing returns from research including return on investment, cost benefit analysis, and other wider monetisation approaches.
National-level self-assessment-led approaches	Royal Netherlands Academy of Arts and Sciences (2010) High Council for Evaluation of Research and Higher Education (France) Program Assessment Rating Tool (Gilmour, 2006)	These are national-level exercises, typically conducted every year or few years, to evaluate the research performance of institutions or programmes within the country based primarily on self-assessment and reflection, sometimes supplemented by peer or other external review. Typically there is some additional (limited) use of metrics, and the evaluation is typically against goals and objectives of the institution or programme.
Interaction-based models	Meijer (2012) Spaapen et al. (2011) Mostert et al. (2010) Meagher et al. (2008)	This covers models based on the concept of measuring interactions, relationships and flows of knowledge between researchers and stakeholders as a route to measuring impact.
Programme-specific logic model approaches	Williams et al. (2009) Sainty (2013) Evans et al. (2014) Rycroft-Malone et al. (2013) Weiss (2007)	Linked to theory of change, these are approaches which develop and tailor logic models and accompanying evaluation approaches to the specific programme or institutions in question, recognising that research may have different impacts in different settings depending on individuals and circumstances. Builds on Weiss's logic modelling work and/or realist approaches to evaluation.
Dashboard/balanced scorecard approaches	The Research Council, Oman (Krapels et al. 2015) NIHR (El Turabi et al. 2011) Wellcome Trust (2014) (Ontario) University Health Network (2008)	Measures performance and drives organisational strategy by incorporating organisational aspects together with financial performance.

Framework	Examples of studies which apply or draw on that framework	Brief summary of key principles
Regular monitoring by self-report	Drew et al. (2013) MRC (2013) Wooding et al. (2009) MRC (2018)	Ongoing monitoring through platforms such as Researchfish or other self-report-based approaches replacing or complementing typical project/programme reporting.
Peer review-based large-scale approaches	Research Excellence Framework (HEFCE, 2015) Group of Eight and Australian Technology Network of Universities, 2012 (Group of Eight, 2012) PBRF (PBRF Working Group, 2002) National Research Council (1999)	Peer review-based approaches that use panels to review the performance of research on a mix of criteria drawing on a range of materials which may include metrics, publications and case studies.
Emerging 'big data' analytical approaches	STAR METRICS (NSF, 2010) Altmetric (n.d.)	Approaches that use data and/or text mining to draw together and analyse existing datasets.
'Added value' approaches	Arnold (2012)	Approaches that aim to address the counterfactual by looking at the 'added value' or portfolio-level effect of a funding programme over and above other funding mechanisms.

Source: RAND Europe analysis

Categorising the diverse benefits of R&I

In section 2.2 of this report we develop the 'impact index', a broad classification of the range of benefits from R&I. This work builds on a previous piece of work by Pollitt et al. (2016) which is outlined here.

Previous cross-mapping of impacts across frameworks provides a model for our analysis of R&I impacts

As outlined above, frameworks characterise the diversity of benefits from research in different ways and in a variety of contexts, with differing scopes both in terms of diversity of types of outcomes and the extent to which those outcomes are downstream from the research. As part of a wider piece of work looking at relative valuation of the outcomes of biomedical and health research, Pollitt et al. (2016) conducted a review of categorisation approaches across a number of commonly used frameworks. This was not comprehensive but was an attempt to map the possible categories of impact and reconcile them across existing frameworks. Analysis of this cross-mapping of existing categorisations across a wide range of existing approaches led Pollitt and colleagues to develop a categorisation system based on the literature (shown in **Figure 8**). The categorisation system was then used, tested and refined in interviews and focus groups for the purposes of the survey tool they were developing. The review of academic funding and evaluation schemes focused on the UK but drew on international examples.¹⁹

¹⁹ The following research evaluation frameworks and systems were investigated: Snowball Metrics; Canadian Academy of Health Sciences (CAHS); Excellence in Research for Australia (ERA); National Institute for Health Research (NIHR) dashboard; Research Excellence Framework (REF); SIAMPI (Social Impact Assessment Methods for research and funding instruments through the study of Productive Interactions between science and society); Agence d'évaluation de la recherche et de l'enseignement supérieur (AERES); Research Councils UK Outcomes

In Pollitt and colleagues’ analysis of academic frameworks, three main classification approaches were also identified:

- ‘Academic focused frameworks, which concentrated on measures around volume and quality of outputs, esteem of researchers, and capacity building. Sometimes they also included one general category for wider impacts. Examples here include ERA, ROS, AERES, NIH.
- Frameworks which were focused on wider, non-academic impacts (e.g. REF, NSF)
- Logic model based approaches: Snowball Metrics, NIHR dashboard, Payback Framework and CAHS’.

Knowledge production and research targeting	Capacity building	Innovative and economic impact	Health and health sector benefit	Policy and public services (other than health)	Public engagement, dissemination, culture and creativity
<ul style="list-style-type: none"> • Volume and quality measures • Future funding 	<ul style="list-style-type: none"> • Esteem measures • Number and quality of researchers trained • Collaboration and networking • Wider participation in research 	<ul style="list-style-type: none"> • New products and process developed • New businesses (spinouts) • Benefits to companies • Job creation, workforce development and increased economic competitiveness 	<ul style="list-style-type: none"> • Impact on guidelines/policy/professional training or development in health • Impact on practice including saving NHS money • Impact on health and well being 	<ul style="list-style-type: none"> • Changes to policy outside of health • Improvements in the delivery of public services (outside of health) • Benefits to public wellbeing and society more widely resulting 	<ul style="list-style-type: none"> • Number and range of dissemination and outreach activities • Increased public understanding of and engagement with science

Figure 8 Categorisation of the benefits from research

Source: Pollitt et al. (2016)

System (ROS); Payback Framework; National Institutes of Health (NIH); National Science Foundation (NSF); Consortia Advancing Standards in Research Administration Information (CASRAI); Researchfish.