How unpredictable is research impact?
Evidence from the UK's Research Excellence Framework

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Abstract:

Although *ex post* evaluation of impact is increasingly common, the extent to which research impacts emerge largely as anticipated by researchers, or as the result of serendipitous and unpredictable processes, is not well understood. In this paper we explore whether predictions of impact made at the funding stage align with realised impact, using data from the UK's Research Excellence Framework. We exploit REF impact cases traced back to research funding applications, as a dataset of 2,194 case-grant pairs, to compare impact topics with funder remits. For 209 of those pairs, we directly compare their descriptions of ex-ante and ex-post impact.

We find that impact claims in these case-grant pairs are often congruent with each other, with 76% showing alignment between anticipated impact at funding stage and the eventual claimed impact in the REF. Co-production of research, often perceived as a model for impactful research, was a feature of just over half of our cases. Our results show that, contrary to other preliminary studies of the REF, impact appears to be broadly predictable, although unpredictability remains important. We suggest that co-production is a reasonably good mechanism for addressing the balance of predictable and unpredictable impact outcomes.

Keywords:

Research impact; Broader impacts; Research assessment; Research evaluation; REF impact; Research funding

1. Introduction

Concern is growing about the wider impact of research beyond the ivory tower. Promising, demonstrating and documenting impact outside academia is now a major part of the research policy infrastructure (Collini 2012; Penfield et al 2014; Greenhalgh et al 2016). The 'impact agenda' (Martin 2011; Watermeyer 2016) has spread across research systems, featuring in countries such as the USA, Netherlands, Italy, Sweden, Australia, New Zealand, and many others.

The growth of the 'impact agenda' has taken at least three forms: (i) the introduction of impact as an implicit, and sometimes explicit, selection criterion for research funding (Bozeman and Boardman 2009; Bozeman and Youtie 2017; Chubb and Watermeyer 2017); (ii) direct funding support for non-academic engagement and knowledge exchange activity (Ulrichsen 2015; Johnson 2020; Durrant and MacKillop 2022) and; (iii) the introduction of impact as an assessment criterion for allocating public funding to a university (Smith et al 2011; Hicks 2012). The expansion of academic researchers' roles to include planning and delivery of impact affects multiple stages of the research process (Collini 2012; Watermeyer 2016; Power 2018).

In the UK, the setting for this study, research impact was introduced as an explicit part of the UK's research evaluation exercise, the Research Excellence Framework (REF) (Smith et al 2011). As a result, institutions were required to submit exemplary case studies of impact produced by university researchers. Likewise, research councils introduced a requirement for 'Pathways to impact' and 'Impact summary' sections in all applications for funding, describing potential or planned impacts on non-academic communities before the work is funded.

Following these changes, universities needed to report *ex post* impacts, and researchers needed to propose *ex ante* impacts (Chubb and Watermeyer 2017; Ma et al 2021). This allows us to consider whether the *ex post* reported impact resembles the *ex ante* proposed impact. Does research impact tend to emerge largely as planned, or are eventual impacts unrecognisable from initial plans? This question speaks to a broader science policy question about whether the outcomes of scientific research are predictable, whether researchers are able to foresee the nature of the impacts of their funded research, and if so to what extent.

In this study, we trace impact case studies, via their underpinning references, back to their funding sources and descriptions of their 'imagined impact' (Smith et al 2011; Terama et al 2016; Watermeyer and Hedgecoe 2018; Murphy 2017; Bonaccorsi et al 2020). Specifically, we consider the extent to which the beneficiary stakeholders identified in the *ex post* impact case are identified in the *ex ante* 'pathways to impact' statement, as well as whether the topics identified as being useful to stakeholders in eventual impact cases prove to be the same as those identified in the research funding process.

The study offers an assessment of the unexpectedness of research impact. It is the first study to our knowledge to compare *ex ante* and *ex post* statements of research impact from the same projects to ascertain whether the anticipated 'pathways' to impact did, in fact, materialise in the way anticipated by the researchers. Our findings suggest that research impact is non-random and that there is scope for policy intervention. As it remains unclear what the 'optimal' mix of predictable and unpredictable outcomes might be, we suggest that ensuring a mix of outcomes seems preferable to wholly pursuing one or the other.

2. Literature review

Academic 'impact' has been, and remains, a contested concept (see reviews of models of impact in Penfield et al 2014, Greenhalgh et al 2016, Boswell and Smith 2018, Muhonen et al 2020; Razmgir et al 2021; and of measurement of impact in Reed et al 2021, all of which highlight the complexity of the impact process). Since the emergence of impact as an extension of research evaluation movement of the 1980s (Martin and Irvine 1983, Irvine and Martin 1983), the policy implications of what impact is, how beneficial it is as a concept, and how to measure it, have often remained unclear. We consider here two ways in which impact has been incorporated into research systems: firstly as a part of the research funding evaluation process, and secondly as a criterion for evaluation in performance-based research systems. We discuss these two perspectives in more detail below.

2.1 Predicting Impact: *Ex ante* pathways to impact

Efforts to encourage greater research impact include the introduction of impact as an explicit consideration in research funding. The introduction of impact as an evaluation criterion for funding proposals emerged in the 1990s (Mervis 1997; Holbrook 2005). The US National Science Foundation (NSF) introduced its 'Broader Impacts' criteria alongside more traditional assessment of academic merit (Bozeman and Broadman 2009). In the UK, from 2006 to 2020 'pathways to impact' statements were required for applications to research councils, identifying the impact of proposed research and how it would be delivered. Similarly, the Australian Research Council introduced a requirement for impact statements to form part of grant applications in 2014. These statements, which in principle are meant to show the social value of the proposed research, have been considered problematic for a variety of reasons discussed below.

Any ex-ante prediction of outcomes requires some degree of imagination. In their study of the attitudes of senior academics in the UK and Australia about impact statements, Chubb and Watermeyer (2017) find that researchers' concerns often centred on the inability to foresee research impacts *a priori*: "It is impossible to predict the outcome of a scientific piece of work and, no matter what framework it is that you want to apply, it will be artificial and come out with the wrong answer - because if you try to predict things, you are on a hiding to nothing." (UK Professor, quoted in Chubb and Watermeyer 2017 p2366).

Others referred to 'pathways to impact' statements as "virtually meaningless", "made up stories", "worse than useless" and "a whole load of nonsense" (Chubb and Watermeyer 2017; Wilsdon 2020). The general tenor of these sentiments echoes long standing concerns about the unpredictability of research (Polanyi 1962), the serendipitous paths it may take (Merton and Barber 2004; Yaqub 2018), and uncertainty about the myriad ways in which users might exploit research (Freeman and Soete 1997; Andriani and Kaminksa 2021).

Applicants for research funding may also feel pressure to "sensationalise and embellish" (Chubb and Watermeyer 2017 p. 2365) impact claims as a normalised part of the research funding structure, particularly if ex-ante projections of impact are used to bear strongly upon competitive project selection. Cynicism that promises of impact would in fact later transpire as described were often expressed in terms of researchers' own lack of clairvoyance. Scientific impacts tended to still be widely discussed even though the impact statements in question were meant to target economic and social impact, suggesting many applicants either misunderstood or disregarded guidance to

articulate pathways to impact (Ma et al 2021). Conditions are ripe for "imaginations of impact" (ibid p. 2368) that might not correspond to what in fact later emerges.[1]

There is also scepticism about the value of *ex ante* statements of research impact among reviewers and program officers. Surveys showed that reviewers "ignored" criteria and NSF staff wanted "clarification" of the criteria (Rothenberg 2010 p 193). In their study of reviewers' comments on impact statements from an Irish grants programme, Ma et al (2021) found that reviewers harboured reservations about claims relating to social impacts or public policy impacts, though direct, tangible and commercial impacts seem less prone to such scepticism (see also de Jong et al 2016 for similar survey evidence). Moreover, ability to deliver, much less predict, social impact seems dependent on a variety of factors, and hence limited to a few researchers in "high-performing" contexts (Joly et al 2015; de Jong and Muhonen 2020).

If research impact emerges in complex and unpredictable ways, and if reviewers ignore sensationalised claims, then accounts of eventual impact should bear only weak resemblance to *ex ante* claims. If some of these concerns are overstated, we would expect to see similarity between *ex post* and *ex ante* claims.

2.2 Reporting impact: *Ex post* assessment of impact by REF

The challenges of assessing impact after it has happened is not necessarily any easier. Social impact is difficult to assess and measure, particularly compared to economic impact, where there are more established methodologies (Bozeman and Boardman 2009, Bozeman and Youtie 2017). Martin (2011) argues that while social and economic impact of research can be assessed after the fact, the methodologies that produce robust results are often time- and labour-intensive and unsuited to operation at the scale that would facilitate the evaluation of an entire national research system. In countries with performance-based research funding systems (Hicks 2012), this introduces a substantial methodological dilemma.

A range of approaches are possible to document the impact of research – for instance, econometric analysis, surveys, or quantitative metrics (Salter and Martin 2001; Wilsdon et al 2015; Bozeman and Youtie 2017). But qualitative approaches to capturing impact – including narratives and case studies – allow more complex and nonlinear evidence of impact to be presented, and consequently have been adopted in research systems including in Australia, the UK, the Netherlands, Sweden, Italy, Spain, Norway, Poland, Finland, Hong Kong and New Zealand. (Reed et al 2021).

Our interest in this paper is in the study of those exemplary cases put forward by their institutions as evidence of impact. These give us an interesting lens to explore how reported impact presented in *ex post* in narrative form compares with *ex ante* 'imaginations of impact' (as per Waterhouse and Chubb 2017). In particular, we seek to understand whether the 'pathways' identified in pathways statements (in terms of beneficiaries and topic) appear in subsequent impact cases.

A key characteristic of a qualitative, case-study based approach to impact evaluation is that there may be some element of selection regarding which cases are put forward. Institutions or academics are incentivised to put forward their 'best' impact cases. Whilst the design of a research evaluation exercise can exert a selective pressure on the kinds of impact that are eventually included, and this

[1] The limited usefulness of these statements for making funding decisions, as well as the time involved to write them, were cited as reasons behind the dropping of 'pathways to impact' statements from UK research council grant applications in 2020, as part of a broader review of research bureaucracy (Wilsdon 2020).

might mean that some impacts go unnoticed, a focus on REF impact cases seems warranted because the distribution of impact is likely to be highly skewed (cf. Joly et al. 2015) .

A distinct but related challenge comes from the nature of impact as being cumulative as well as skewed (Joly et al 2015). This means that the accumulation of impact is the result of a bundle of activities and projects. –Ross et al (2020) argue that the underlying logic of impact cases seeks 'chains' of impact (an antecedent, perhaps, of the linear models discussed above) rather than 'nets' in which multiplicities of actors interact to effect change. This places considerable emphasis on attribution of impact to a single principal claimant.[2] Since impact cases are "designed for immodesty" (Power 2018), important complementary and allied contributions from unexpected sources could be overlooked. Their omission would mean that indirect impacts are potentially undervalued by the by these evaluation frameworks, despite efforts to draw on a qualitative case study approach.

Moreover, studies focusing on REF cases overall (Terama et al 2016) and discipline-specific approaches to impact (e.g. Smith and Stewart 2016 for social policy; Meagher and Martin 2017 for mathematics, and Ross et al 2020 for human relations) have highlighted the immense complexity of research impact, and the wide array of possible pathways through which it may materialise, further suggests that reports of impact may bear little resemblance to impact predictions. The complexity and diversity of impact may mean that few impact cases resemble *ex ante* impact claims. However, if case selection strongly favours direct and predictable impact, we would expect to find greater similarity between *ex post* and *ex ante* claims.

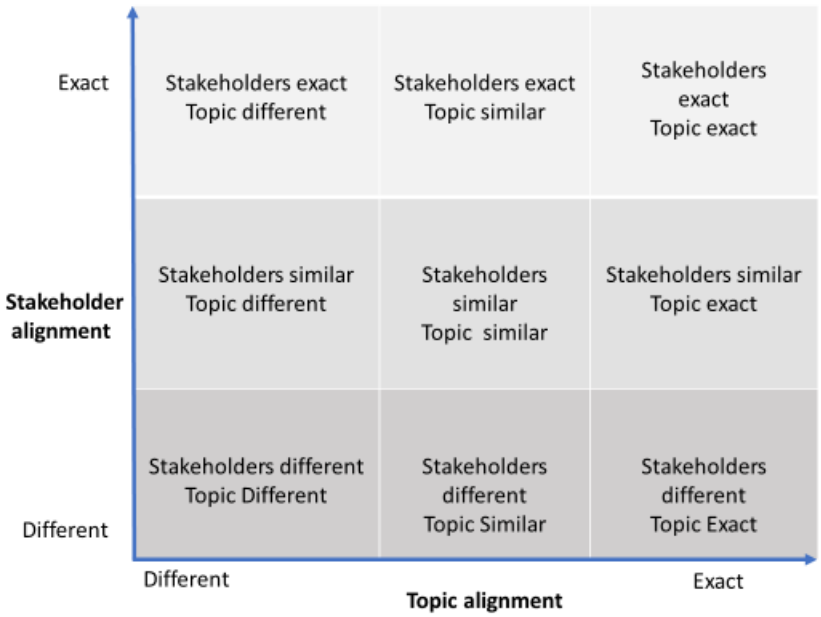
2.3 Alignment of *ex post* and *ex ante* impact claims: Topic, beneficiaries and co-production

By comparing *ex post* claims with *ex ante* claims, we can consider not only how often they align, but also the extent to which they align to varying degrees of specificity (exact-match; match; no-match).

[2] For example, potential cases were deemed "not cooked enough" to be submitted, in terms of establishing a direct line of causality back to the underpinning research (Watermeyer and Hedgecoe 2016).

We can then also consider whether degrees of topic-alignment might interact with degrees of stakeholder alignment (see Figure 1).

Figure 1: Stakeholder alignment and topic alignment



Alignment is based on the extent to which the stakeholder or topics identified *ex ante* correspond to those that are listed in the impact case. On one extreme, the topic or stakeholder in the impact case would be exactly what was predicted in the funding bid. The converse would be to observe impact claims that are unrecognisable and bear little resemblance with each other. The following sections set out how these claims might emerge in the data. Table 1 provides fictional examples of what these examples of alignment might look like, for purposes of clarification; redacted examples from actual REF cases are provided in Table A2 in the Annex.

2.3.1 Topic alignment: Can researchers anticipate what topic the research will impact?

Given the planning that goes into the preparation of a research proposal, we may not be surprised to see the proposed impact as set out in the 'pathways to impact' statement match with what is eventually described in the REF impact case. But this may not always be the case. As noted above, the contexts into which research diffuses may be too varied and complex for researchers to be able to foresee in this way.

Exact topic identification occurs when the same technology or research output is predicted in the funding application and subsequently appears in the impact case. This is perhaps more in line with traditional, more linear models of impact. It is certainly part of the underlying logic behind the introduction of 'pathways to impact' statements (Ma et al 2021) in that it is expected that assessing projects on potential impact will lead to funding research that presents a more convincing case for generating impact (Chubb and Watermeyer 2017).

General topic identification might occur if topics are broadly similar but the precise topic, or technology, identified in the impact case is not specifically mentioned in the original funding application.

No general topic identification would be expected in the most radical cases of serendipity (Yaqub 2018). Targeted search (of sufficient quality to get funded after a competitive peer review process) might yield an impact on a topic completely unrelated to that previously identified.

2.3.2 Stakeholder alignment: Can researchers anticipate who will benefit from impactful research?

It has been suggested that the impact agenda may enhance stakeholder engagement (Hill 2016). There is a large and established literature on the engagement activities of academics (see reviews in Perkmann et al 2011, Perkmann et al 2021). While this body of literature captures more concrete interactions (e.g. consultancy project, patents etc), this is rather different to knowing the end-users and potential beneficiaries of a piece of research, particularly when a researcher is making an initial funding proposal. From this perspective, we consider the extent to which the *ex post* beneficiaries identified in a REF impact case were the stakeholders explicitly identified in a Pathways statement.

Exact identification of stakeholders may be presumed to be associated with 'productive interactions' (Spaapen and van Drooge 2011) between researchers and stakeholders, wherein the relationship between the two parties means that there is sufficient understanding of the topic such that a researcher can identify a specific end-user or organisation before the research is funded. Such relationships can be based on social capital and ongoing relationships (Arza and Carattoli 2017).

General identification of stakeholders takes place when a researcher in their Pathways statement identifies a broad general target (e.g. 'government' or 'businesses') which proves to match with the eventual location of the impact case. One may reasonably infer that researcher would in this context be able to identify the broad class of stakeholders who might find research useful, even if there is not a clearly identified specific target.

No general identification[3] *of stakeholders* takes place if the intended recipient identified in the application is in a completely different sphere than those who eventually were identified in the impact case. Cases in which this happens would be in line with the serendipitous pathways of impact suggested by respondents in Chubb and Watermeyer (2017).

[3] We note here that that Pathways statements mean that beneficiaries must be identified in some way, so research that does not mention any potential beneficiaries is unlikely to be funded. Indeed, we see no such cases in our data.

Table 1: Hypothetical examples of forms of topic and stakeholder identification

Level of *ex ante* identification	Example of Pathways Statement	Example of Impact Case study
Exact topic identification	"This research will improve our algorithm regarding pain processing"	"The research on pain process in Prof X's group led to the following impacts…"
General topic identification	"This research will develop new wave amplifiers using XYZ technology"	"The wave amplification technology developed at ABC university had the following commercial impact.
No general topic identification	"This research will build knowledge on ageing and well-being"	"Prof X's work on prenatal exposure to stress has been influential…"
Exact stakeholder identification	"We will collaborate with XYZ Ltd to commercialise this research" "This research will be particularly relevant to the Scottish prison system"	"This research was used by XYZ Ltd as a part of their new model, which helped the company to increase sales by 30%. "This research was used in Scottish prisons"
General stakeholder identification	"This mathematical modelling has application in commercial settings"	"Through engagement with XYZ Ltd the mathematical models had the following impact…"
No general stakeholders identification	"This research will provide commercial benefits by local businesses in Essex"	"This research was part of a museum exhibition in the USA"

2.3.3 Co-production: Mechanism for impact?

In addition to outcome-oriented impacts, as discussed above in terms of topic and beneficiaries, process-oriented impacts via *co-production* of knowledge seems a distinguishable form of impact. (See Muhonen et al 2020 for a more variegated framework impact types, including co-production among others, in the case of social sciences and humanities). Co-produced research can be explicitly acknowledged by statements of collaboration, secondments, internships, people exchange, co-funding or provision of materials and equipment between the research group and identified stakeholders. Active co-production of knowledge with an end-user is not only a pathway to impact, but also one that may drive alignment between researchers and stakeholders.

The increasingly co-evolutionary nature of knowledge production, as a distinct mode (Gibbons et al 1994) or as a broader part of the relationship between science and society (cf. Jasanoff 2004), means that the co-production of knowledge, wherein end-users inform, shape, or actively participate in the research process, is becoming increasingly important to science policy (Nutley et al 2010; Hickey et al 2018). Co-production of knowledge can be a particularly effective means of ensuring academic-industry (academic-stakeholder) collaborations (Gibbons et al 1994; Nutley et al 2007; Bammer 2008, Orr and Bennett 2012; Cherney 2013).

Given the perceived benefits, these collaborations have been actively encouraged (in the UK for instance by the Lambert Review 2003). Indeed, in Armstrong and Alsop (2010), written by the head of knowledge exchange and head of research at the Economics and Social Science Research Council (ESRC) at the time, co-production was explicitly advocated as a crucial mechanism for generating impact.

Because co-production directly involves end-users (Hickey et al 2018) the resulting work is more likely to have the desired value and/or outcome for those end-users once research is completed. For this reason, co-production has been touted as a model for driving academic impact (Armstrong and Alsop 2010). Despite this, co-production is also inherently risky, time-consuming and challenging to academic norms (Flinders et al 2016). To this end, incentivising co-production through impact (both through funding priorities and through research evaluation such as the REF) is a way of encouraging academics to engage. In a co-production mode, we therefore expect researchers to explicitly identify research outputs as being co-produced with stakeholders, either identified in the bidding stage or the impact case. This would be an indication that the intended recipients of the research were also the end-users and source of the impact.

3. Research Approach and Methodology

Our aim in this paper is to compare *ex post* claims of impact with their *ex ante* predictions of impact and assess the extent to which research impact is predictable. In order to make this comparison, we use evidence from one of the largest and most-studied *ex post* assessment exercises in the world: the UK Research Excellence Framework, or REF.

3.1 The UK Research Excellence Framework

The REF was announced in 2011, following from the UK's Research Assessment Exercise, which ran from 1986-2007. The REF serves to allocate quality related (QR) research funding to institutions worth just over £1.5bn. This institutional block funding is considerably less than the £8bn in research council funding, but it remains a sizable award for many universities and is also likely to confer status advantages.[4]

The impact component of the REF is intended to direct some of this QR funding towards rewarding institutions for research impact, post hoc.[5] The number of impact case studies each institution is expected to submit is related to the number of research-active staff members. On this basis, institutions are incentivised to identify the most promising impact cases and to invest in presenting these as clearly and convincingly as possible.[6]

Working within these restrictions, a university must identify and submit its strongest impact cases for each of the 36 disciplinary panels in the REF. The impact cases are reviewed by the senior academics who form the REF panel, and who award cases a rating, from 1* ("recognised but

[4] The award could also serve as 'pump-priming' and help to secure further funding from other sources.
[5] The two other components of an institution's REF submission consist of: a selection of its publication outputs, and a statement on its research environment, which are reviewed by REF panel members. Overall, the 2014 REF award is weighted with 65% towards publication outputs, 15% on environment, and 20% for impact.
[6] There is evidence indicating that universities have invested considerable resources into generating these impact cases (Manville et al 2015; Watermeyer and Hedgecoe 2016; Power 2018). These range from identification of impact case candidates, to selecting which to develop and submit, as well as finding corroborating evidence trails for the impact. Impact case studies therefore represent the culmination of a very substantial data collection effort.

modest") to 4* ("outstanding"). The higher the rating of a department's research, the more public research funding the department will receive. The 2014 REF exercise saw 6,679 impact cases submitted to the 2014 REF were and assessed by disciplinary evaluation panels. Notably, following conclusion of the exercise all submitted impact cases were published. The impact cases submitted to the 2014 REF not only showcased exemplars of research impact, but also systematically accounted for around one case for every nine faculty members across UK institutions

3.2 Methodological approach

We began by collecting information on REF impact case studies and linked UKRI grants.[7] This was done in two steps: algorithmic extraction of DOIs of the 'underpinning references' contained in REF impact Case Studies,[8] and then a search of Gateway to Research using these DOIs for UKRI grants.

Our dataset comprised 2,194 case-grant pairs. For these we collected the panel and sub-panel unit to which the case was submitted, and the impact type of the case, and the research council awarding the grant linked to the case. Of these, 209 pairs have potential/planned impact statements available in their grant descriptions.[9] We used all of these 209 pairs as a subsample, for more detailed analysis and comparison with REF impact statements[10]. , Examples of matched impact cases and REF impact statements are provided in Appendix 4.

In the initial analysis, we compared the topic-focus of the research impact with the topic-focus of its funding council. On the impact case side of the pair, we are able to explore the topic-focus of the research impact by observing which of the four REF panels (or 36 sub-panels) the Cases were submitted to, and we can also observe which of the eight Impact Type labels were assigned to the Cases as reported in the REF2014 website.[11] On the grant side of the pair, we are able to explore the topic focus at the outset of projects by observing which research councils funded them. However, since Research Councils have broad and overlapping remits (see Appendix 1), this remains a rough proxy for topic-focus.

So, in our second set of analyses, we manually reviewed a subsample of case-grant pairs in more detail. This allowed us to assess the topic-focus of grants beyond identifying the funding council that funded the impact to a greater degree of specificity. Additionally, by reviewing these manually, we were also able to assess stakeholder-focus of the cases and their grants, and identify special cases where there seemed to be co-production from the outset.

We reviewed each case-grant pair in our sub-sample and categorised the following:

- *Type of stakeholder* identified in the Pathways statement and in the impact case. These were coded as public sector (e.g. government, schools or hospitals); private sector (e.g businesses or industry associations); third sector (e.g. NGOs, charities, museums or cultural

[7] We are comparing GtR data with REF Case data:
https://gtr.ukri.org/resources/data.html
https://gtr.ukri.org/resources/GtRDataDictionary.pdf
https://impact.ref.ac.uk/casestudies/APIhelp.aspx

[8] The extraction of DOIs was undertaken by Digital Science for Research England, UKRI. We thank Steven Hill for helping us with this data.

[9] *Ex ante* pathway statements were only introduced in 2007, so we do not have *ex ante* statements for research funded before this time. The cases in our survey therefore capture where impact cases cited funding received in the four years prior to the REF 2011 census date.

[10] To summarise, 90% of grants in our subsample were research grants (compared to 10% being fellowships), with the median grant duration being three years and median grant value being £490,106.

[11] See 'What is Summary Impact Type?' available at https://impact.ref.ac.uk/casestudies/FAQ.aspx

organisations, etc); or international government or agency (e.g. World Bank, OECD, UN, NATO etc). Multiple categories could be used. We coded any academic user (for instance referring to the academic impact of a piece of research) as null for the purposes of this paper.

- *Co-production* between the academics and the end-user. If the Pathways statement made explicit reference to producing a piece of research directly with a specific stakeholder who was then mentioned in the eventual impact case, this was coded as a *Yes*.
- *Topic alignment* between the Pathways statement and impact case. Comparing the Pathways statement and impact case, this captured whether the topics covered in the two texts were at least roughly within the same research domain. This was a binary variable; if the topics were deemed to be distant, they were to be coded as *No*.
- *Specific matches of stakeholders or topics.* Building on the stakeholder and topic categories above, we coded for two binary variables: exact stakeholder match or exact topic or technology match. These were coded as Yes if the exact same stakeholder or topic was mentioned in the Pathways statement and impact case.

To categorise the sub-sample, we prepared a categorisation manual (see Appendix 2). To assess reliability of categorisation with this manual, 10% of the sub-sample was randomly selected and reviewed by three independent reviewers with backgrounds from across the physical sciences, social sciences and humanities[12]. Inter-rater reliability was calculated using Krippendorf's alpha, with scores exceeding 0.7 across all categories, indicating substantial agreement, beyond chance (Llandis and Koch 1977, Fleiss 2003; Hayes and Krippendorf 2007).

For clarity, we did not attempt here to address how research impact could be "increased", and questions regarding the possible characteristics of research that lead to REF-impact versus non-REF-impact. For this, we would ideally have statements of intended impact on record for all instances of impact and non-impact. This is not possible on multiple counts. [13] Instead, we examined sources of impact, conditional on REF-inclusion. We looked back in time to see the extent to which impact claims were explicitly anticipated.

[12] While our inter-rater reliability scores and multidisciplinary background of raters give us confidence that our coding scheme minimised disciplinary biases, the existence of such biases does remain a possibility.

[13] Firstly, Pathway statements were only introduced in 2007, so we do not have *ex ante* statements before then. Secondly, Pathways statements were only required for UK researchers seeking funding from UK research councils, so researchers with other funding sources (such as European funding, or funding from other foundations, or researchers whose research does not require outside funding) do not complete Pathways statements.

4. Results

As highlighted above, this paper is based on a dataset of REF impact cases that have been traced back to UK research council-funded projects. These were analysed as case-grant pairs, the results of which are presented below.

4.1 Impact topic and funder remit show alignment

In the first instance, we begin by considering the overall sample frame of 2,194 case-grant pairs.

Table 2 below sets these pairs out across the four large REF panels (Medicine and Health, Engineering and Environment, Law and Policy, and Arts and Culture), and shows what share can be traced to funders with different remits.

The Panel remit, to which impact cases have been submitted, broadly align with the remits of the Research Council funding the impact. Some case-grant pairs seem to be linked to funders with differing remits, though these rarely rise above third-place funder. Table 3 shows that each REF Impact Panel has a Research Council with which it is most closely associated (for instance, Medicine and Health panel has 70% of its cases linked back to Medical Research Council-funded projects). However, it also shows that Impact Panels draw on other funding sources. There is a dominant funder, but it does not act alone; there are allied funding sources too.

Table 2: Share of Impact Cases, by REF Panel, linked to funding, by UK Research Council

REF Impact Panel	Number of case-grant pairs	Share of Impact Cases linked to funders (Top 3, by %)
A – Medicine and Health	784	MRC (70); BBSRC (11); ESRC (9)
B – Engineering and Environment	800	EPSRC (49); NERC (23); STFC (15)
C – Law and Policy	459	ESRC (57); NERC (14); EPSRC (14)
D – Arts and Culture	151	AHRC (64); ESRC (20); EPSRC (14)

(n.b.: AHRC: Arts & Humanities Research Council; BBSRC: Biotechnology and Biological Sciences Research Council; EPSRC: Engineering and Physical Sciences Research Council; ESRC: Economic and Social Sciences Research Council; MRC: Medical Research Council; NERC: National Environment Research Council; STFC: Science and Technology Facilities Council)

Table A3.1 in the appendix breaks these cases down by panel and sub-panel. Across the 36 sub-panels, the median share of cases linked to the top funder is 76%. This also shows that impactful research is not exclusively funded by the dominant funder.

Looking at sub-panels in particular it is possible to imagine the cases in which different funders' research might result in variation in impact case submissions. For instance, Panel D32, Philosophy, has a majority of impact cases arising from the Arts & Humanities Research Council funding (79%) but also has impact cases emerging from the Economic and Social Research Council (14%) and the

Medical Research Council (7%), both of which have funding interests (for instance, issues around ethics) that could be captured by philosophy as a discipline.

These results show that panels are generally dominated by a particular research funder. Equally, it also shows a diversity of minority funding sources contributing to impact in particular disciplines.

In addition to Panels and sub-Panels, we also explored different impact types and their funding sources (Table 3). These classifications were manually coded on behalf of Research England and are part of the publicly accessible data.[14] These offer further corroboration of our results above.

Table 3. Share of Impact Cases, by Impact type, linked to funding, by UK Research Council.

REF Impact, by impact type	Number of case-grant pairs	Share of Impact Cases linked to funders (Top 3, by %)
Technological	612	EPSRC (50); MRC (25); BBSRC (10)
Health	449	MRC (81); ESRC (9); EPSRC (5)
Societal	442	ESRC (38); EPSRC (17); STFC (17)
Environmental	300	NERC (66); ESRC (13); EPSRC (12)
Economic	85	EPSRC (39); ESRC (39); NERC (11)
Cultural	125	AHRC (59); ESRC (14); NERC (11)
Political	155	ESRC (35); MRC (34); EPSRC (14)
Legal	26	ESRC (81); AHRC (8); EPSRC (8)

(n.b.: AHRC: Arts & Humanities Research Council; BBSRC: Biotechnology and Biological Sciences Research Council; EPSRC: Engineering and Physical Sciences Research Council; ESRC: Economic and Social Sciences Research Council; MRC: Medical Research Council; NERC: National Environment Research Council; STFC: Science and Technology Facilities Council)

However, both of these approaches above rely on using the research council's remits as an initial indication of topic. As discussed, the research council may be too coarse a unit of topic-analysis since research councils have overlapping remits. Accordingly, we manually reviewed and categorised a subsample of case-grant pairs to examine their topic alignment and their stakeholder alignment. This allowed us to assess not only the frequency with which we might observe alignment, but also the degree and specificity of the alignment.

[14] See 'What is Summary Impact Type?' available at https://impact.ref.ac.uk/casestudies/FAQ.aspx

4.2 *Ex post* and *ex ante* impact claims show alignment in more detail

When we turn to the 209 case-grant pairs that were manually coded, we can begin to see in more detail the extent to which the framework set forth in Section 2 plays out within the data. This is presented below.

For stakeholders, as defined in Section 3, case-grant pairs were categorised as those where the type of stakeholder in the REF case and impact statement did not match (e.g. the impact statement in the funding proposal said the beneficiary would be government but the beneficiary in the impact case was in the private sector); where at least one type of stakeholder matched but was not specifically identified, or specific organisations did not match (e.g. the impact statement said a government ministry would benefit and the government was indeed cited in the REF case); or where the exact stakeholder was identified in the impact statement and the REF impact case. For topics, we considered them matched if the REF case and impact statement were in the same general research domain, and considered them to be exactly matched if precisely the same technology were mentioned in both instances.

In Table 4, we see that a majority of impact cases identify either the general or exact type of stakeholders (89%), and a similar majority set out either the general or exact topic of impact (83%), as was initially set out in their funding proposals. A small percentage even identified the precise topic or stakeholder in their funding bid that then subsequently appeared in the REF impact case. Conversely, it is notable that only 16% of impact cases cited research that was funded on the basis of a completely different topic; and only 12% of cases featured stakeholders not already previously identified.

Some differences emerge when we disaggregate these figures by research councils. Considering stakeholder alignment, exact stakeholders were more likely to be identified in the arts, humanities and social sciences, with 61% of Arts and Humanities Research Council-funded cases and 36% of Economic and Social Science Research Council-funded cases reflected the same exact stakeholders between funding bid and impact case. By contrast the highest percentage of cases where stakeholders were not predicted were for funding for science and technology facilities (e.g. research infrastructure), with 39% and life sciences, with 27%. This perhaps speaks to differences in funding expectations – for infrastructure the use cases are likely be more uncertain than in arts and humanities, where end users may be easier to identify. Topic alignment is a slightly different picture, with comparatively few cases completely identifying the precise topic of impact in the impact case at funding stage. For each research council a majority of topics were generally aligned, and the absence of alignment was most common with 28% with facilities investment again, and for medical research.

Table 4. Identification of stakeholders and topics mentioned in REF impact cases in original impact statements, by Research Council

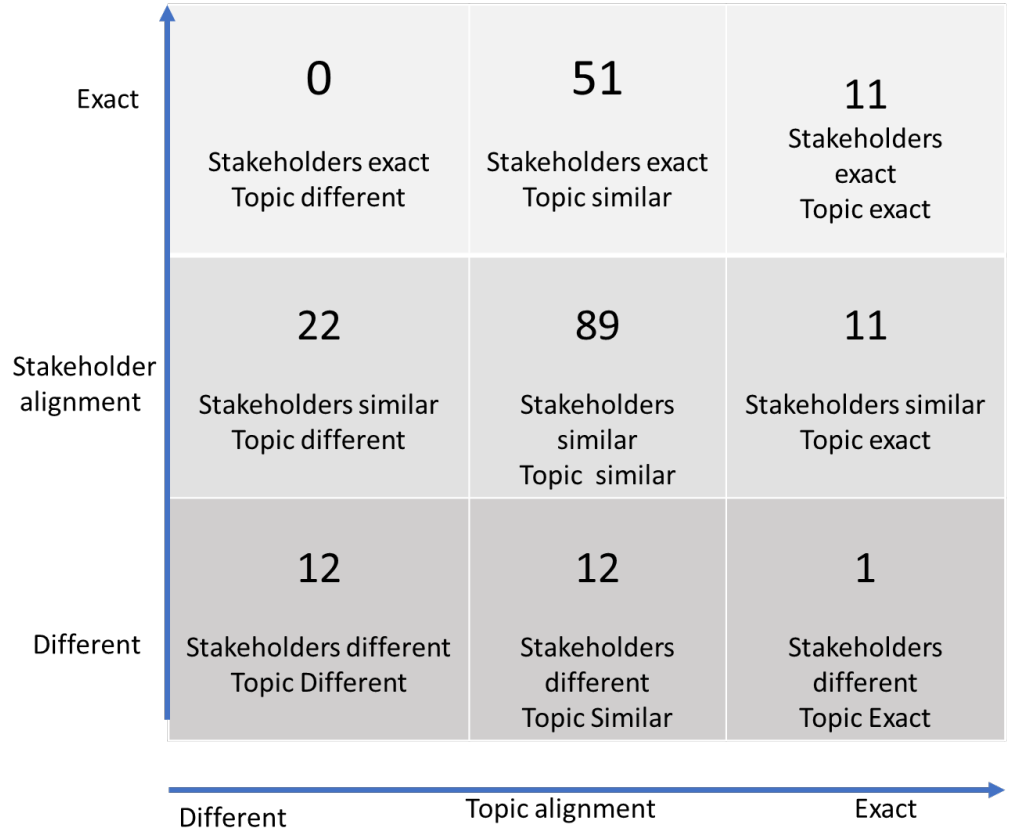
	Stakeholder class of REF case not identified in impact statement	Stakeholder class of REF case identified in impact statement	Exact stakeholder mentioned in REF case identified in impact statement		Topic of REF case not identified in impact statement	General topic of REF case identified in impact statement	Exact topic of REF case identified in impact statement
AHRC	3%	35%	61%		0%	90%	10%
BBSRC	27%	55%	18%		9%	73%	18%
EPSRC	11%	61%	28%		15%	68%	15%
ESRC	9%	55%	36%		23%	77%	0%
MRC	6%	81%	13%		28%	59%	13%
NERC	0%	75%	25%		0%	100%	0%
STFC	39%	50%	11%		28%	72%	0%
Total	**12%**	**59%**	**30%**		**16%**	**72%**	**11%**

(n.b.: AHRC: Arts & Humanities Research Council; BBSRC: Biotechnology and Biological Sciences Research Council; EPSRC: Engineering and Physical Sciences Research Council; ESRC: Economic and Social Sciences Research Council; MRC: Medical Research Council; NERC: National Environment Research Council; STFC: Science and Technology Facilities Council)

We turn to where the identification of stakeholders and topics interact. From Figure 2 below, we can see that it was very uncommon that the exact stakeholders were identified but the topic of impact was subsequently different from the impact statement, or that the topic was exactly identified but with substantially different stakeholders (1 pair). Case-grant pairs where stakeholders were similar and topics were similar, were the most common (89 pairs). This is followed by case-grant pairs where the stakeholders were exactly identified and the topics were similar (51 pairs). A relatively low number cases had prior identification of the precise stakeholders and topic of the impact (11 pairs). Likewise, relatively few had substantial differences from the stakeholders and topics that had been identified in the funding proposal (12 pairs).

Overall, the six cells on the right of figure 2, where the topic is aligned to at least some extent, make up 84% of the 209 pairs. These resonate with our findings from section 4.1 where 76% of 2194 pairs showed alignment with the dominant funder's remit. The six cells across the top of figure 2, where the stakeholders are aligned to at least some extent, make up 88% of the 209 pairs.

Figure 2: Stakeholder and topic alignment in the sample of REF impact cases (n=209)



4.3 Coproduction in funding-REF case pairs

In coding the data, we also coded for 'coproduction' – that is, an explicit mention in the pathways to impact statement of working with an end-user that was then mentioned in eventual impact case. We found that 'coproduction' was coded in 112 (54%) of our sample.

Coproduction was prevalent, and featured across research council funding sources as shown below. Table 5 shows that co-production in case-grant pairs did not vary substantially between research councils, with the exception of STFC (which invests in facilities and infrastructure, and hence could be expected to show less co-production). Notably, the funder with the highest share of its pairs coded as positive for co-production was AHRC (arts and humanities). As noted previously in Table 4, AHRC also had the highest level of exact stakeholder alignment at 61%. The next highest, EPSRC (engineering and physical sciences) was substantially lower in terms of exact stakeholder alignment (at 28% in Table 4) but still had 60% of pairs representing co-production in Table 5.

It is possible that some of this variation is influenced by the type of impact (as seen above in Table 4). These are broken down in Table 6 below. These show that co-production in REF impact cases is indeed more common in cultural impacts (as expected) but also where impacts are economic and technological (which might not be anticipated by the research council figures in Table 5). Between them these perhaps point to different modes of co-production and stakeholder engagement in the disciplines and types of impact funded by this research.

Table 5: Percentage of cases co-produced, by research council

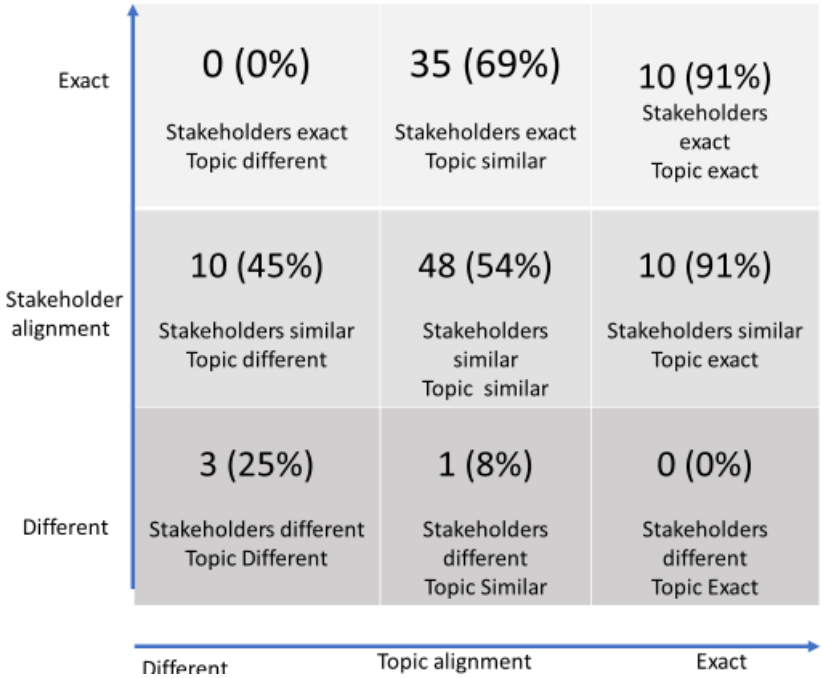
Funding Council	% Cases Co-produced	Number cases
AHRC	61%	31
BBSRC	55%	11
EPSRC	60%	91
ESRC	50%	22
MRC	47%	32
NERC	50%	4
STFC	22%	18
Total	**54%**	**209**

Table 6: Percentage of cases co-produced, by impact type

	% Cases co-produced	Number cases
Cultural	63%	24
Economic	69%	13
Environmental	53%	17
Health	40%	30
Legal	0%	1
Political	50%	10
Societal	47%	57
Technological	61%	57
Total	**54%**	**209**

Figure 3 shows the count and percentage of cases coded for co-production against our framework originally set out in Section 2. We see here that there is an association between co-production and alignment of topic and stakeholders. Co-production appears to be common where impact cases are closely aligned and less so where there is less alignment. However, the association is not exhaustive and uniform across all pairs, since some cases, where there is substantial disparity between anticipated and actual stakeholders, still proved to be the result of co-production.

Figure 3: Counts of cases reporting co-production (percentage of cases reporting co-production as share of all cases in cell in brackets)



5. Discussion

As research impact becomes an increasingly important part of the research evaluation landscape, one fundamental question about impact relates to the extent to which the nature and direction of impact activities can be foreseen by researchers. This question has substantial implications for the effectiveness of research funding in delivering social impacts, particularly with regard to the design of funding mechanisms and incentive structures for funders, universities and researchers.

This paper addresses this question by exploring whether cases of impact claimed in the UK Research Excellence Framework were anticipated at the outset of research projects. Using matched pairs of impact cases and underlying cited research projects, and a subsample of predicted impact statements, we explore the extent of alignment between *a priori* and *ex ante* evaluations of impact with respect to the stakeholders identified, the topics of research and the role of co-production as a driver of impact. Our aim in doing this is to assess the extent to which uncertainty and serendipity contribute to (*ex ante*) impact, and the implications for research funding systems (cf. Polanyi 1962; Yaqub 2018).

5.1 Alignment between ex-post and ex-ante impact claims: A reflection of multiple funding rationales and perspectives

Our findings regarding alignment of *ex post* and *ex ante* impacts appear to reflect at least two parallel funding rationales; one perspective that seeks to steer research towards specific outcomes, and another that seeks to exploit unforeseen opportunities emerging from research.

For steering research towards specific outcomes, our analysis shows that research impact can, to a measurable extent, be explicitly anticipated before research is funded, at the topic and stakeholder level. Our analysis finds that 76% of impact cases in the REF are submitted to panels within the remit of the UK research councils that funded them. Analysis of our subset of *ex ante* impact statements also shows close alignment between the topics and stakeholders in the *ex ante* and *ex post* impact statements. On this basis our findings do not support an interpretation that processes of impact are completely unpredictable on a wide scale, or represent window-dressing (in contrast to interviewees in Chubb and Watermeyer 2017). Indeed we find that *ex ante* statements of impact, while unpopular (and discontinued in the UK in 2020), provide a reasonable signal of the direction of future impact.

For taking advantage of unforeseen opportunities arising from research, our analysis conversely shows that nearly one-quarter of REF impact cases in our sample were submitted to panels outside the conventional remits of their funding bodies. These include interdisciplinary research related to research councils' core aims (for instance the Arts and Humanities Research Council funding research on the creative industries, or the Engineering and Physical Science Research Council funding research on ethics of AI). Our subsample analyses further show that there are non-negligible cases in which the impacts of a piece of funded research are not foreseen, with 17% of cases addressing a topic that differs appreciably from the original impact statement, and 12% of cases where the type of beneficiary varied from that which had originally been predicted.

The presence of parallel rationales begs a broader question of what a socially optimal level of expected or unexpected research outcomes might be. Is alignment of 76% between research councils and REF disciplinary panels high or low? Complete 100% unpredictability would not be desirable as it would undermine the value of directed funding at all. Equally, 100% success in

targeting impact in a particular field could reflect serendipitous opportunities being overlooked or perhaps even a stifling of creativity. The ratio seen in our data appears to reflect a mix of both rationales. The finding that only a small share of our cases addressed the precise topic identified at the funding stage shows that there are degrees of uncertainty in the research process, and that these vary between disciplines (e.g. the benefits of scientific infrastructure and medicine may be more unforeseeable than, perhaps, arts and humanities where 'normal impact' relations between academics and stakeholders provide an ongoing, and relatively predictable, source of impact (cf. Sivertsen and Meijer 2019)). Our findings also show that end users of research are often identifiable at the funding stage of research, highlighting the importance of building longer-term relationships between researchers and the stakeholders who have interest in their work (cf. Isett and Hicks 2020).

Perhaps more salient than the actual level of alignment is the ability to adjust it. Our findings regarding co-production as a driver of impact suggests that there is scope for policy intervention, if desired. We find co-production[15] to be common, appearing in more than half (54%) of our sample. The presence of co-production is indicative of close alignment between stakeholders and topic, but the association is not ubiquitous. While co-production has been put forward by research funders as a driver of impact (Armstrong and Alsop 2010), it is only one of many pathways by which impact can be generated (Muhonen et al 2020). On this basis we can conclude that co-production can be a mechanism for changing alignment of intended and revealed impact outcomes, but it is unlikely to be the only one.

Our paper makes a contribution to the literature by teasing out the underlying tensions between *ex ante* and *ex post* descriptions of impact, and relating them to the issue of desirability of predictable impact. In doing so, we show that there are meaningful levels of alignment between anticipated and realised impact outcomes, and that coproduction is a common but not definitive channel aligning these anticipated and realised impacts.

5.2 Limitations

There are sources of possible over- and under-estimate in the degree of alignment we see in our data beyond the factors, such as selection, we have previously discussed. One source of overestimate is the use of broad categories within our dataset. A more elaborate classification scheme (for instance using more of the models of impact identified in Muhonen et al (2020) may have resulted in more cross-category movement, though this would have been more prone to yielding low inter-rater agreement.

One source of underestimate could lie in the way in which funding sources are acknowledged in research outputs (Hopkins and Siepel 2013; Grassano et al 2017). Our approach relied on the attribution of research outputs to specific research projects. Mis-attributed grants that have only a tenuous link to either the research output or the impact case could lead to underestimates, though it should be noted that we found little evidence for this.

Further factors could affect our estimates, though whether these contribute to over- or under-estimates is not obvious. These include the window of time between the ex-post and ex-ante claims; the presence of other funding sources attributed to underpinning references; and how negative impact is perceived, where academic guidance meant that a change did *not* happen (for instance, if

[15] Co-production was defined as an explicit reference to producing research directly with a specific stakeholder who was then identified in the eventual impact case (see also Appendix 3 for further details on our definition).

academic research was used as the basis *not* to adopt a proposed regulation). For each of these, it is not clear a priori how they might affect estimates though it is likely that further research would make headway on each of the respective issues.

5.3 Further implications

We have seen that researchers who are engaged with stakeholders, and who are funded by research councils, may then subsequently generate impactful research. From a research funder perspective, our work highlights the importance of developing and strengthening capacity for providing impact among researchers (for instance through building strong stakeholder relationships). In particular, awareness of the potential specific beneficiaries at the research design stage appears to be useful.

Current efforts to this end, such as the Higher Education Innovation Fund (HEIF) in the UK, which supports collaboration and dissemination activities through a block grant provided to institutions, point to ways in which capacity-building for stakeholder engagement can be funded. If there is a danger of REF lapsing into an 'audit culture' that prioritises specific linear, documentable outcomes (cf. Martin 2011, Watermeyer and Hedgecoe 2016; Power 2018), funder-level interventions like HEIF show the potential for complementary forms of funding to support institutional 'impact cultures'. Researchers are responsive to university-level changes in emphasis to impact activities (de Jong and Balaban 2022), so institutional focus on stakeholder engagement and external relationships may help to drive a broad spectrum of impacts. These may include those that are 'REF-able' but also those that are more difficult to capture.

The literature on impact has grown substantially in recent years, and this work points to numerous rich areas for further study. In particular, other ways of exploring the relationship between *ex ante* and *ex post* evaluations of impact, particularly outside of public research settings, could be very useful. The role of selection effects, both at the institutional level in the selection of cases to submit to the REF, and in the funding of research projects, is particularly interesting. The forthcoming data from the REF 2021 exercise will also provide new data for exploring and understanding these relationships. The increased weighting on the impact component of REF 2021 suggests there remains appetite to interrogate the impact agenda further.

In conclusion, this paper has aimed to explore how eventual impact, as measured in the Research Excellence Framework, compares with promises of impact before the research was funded. We have presented evidence showing that, more often than not, impact results from research funding that had anticipated the focal impact.

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Appendix 1: **Research Council Remits, as described by keywords from their websites, covering both areas of research and their areas of anticipated research impact.** [16]

Arts and Humanities Research Council (AHRC)
Archaeology; contemporary challenges; cultural assets; creative economy; design; discovering ourselves; history; impact of artificial intelligence; languages; philosophy.
Biotechnology and Biological Sciences Research Council (BBSRC)
agricultural production; animals (including humans); animal health and welfare; antimicrobial resistance; bioenergy; data-driven biology; food, nutrition and health; healthy ageing; industrial biotechnology; microbes and microbiome research; plants; reducing waste in the food chain; replacement, refinement and reduction (3Rs) in research using animals; synthetic biology; systems approaches to the biosciences; tools and technology underpinning biological research
Economic and Social Research Council (ESRC)
area and development studies; climate change and sustainability; data and analysis for decision making; demography; economic and social history; economics and the economy; education; environmental planning; health, wellbeing and social care; human geography; international relations; linguistics; management and business studies; politics; population and society; psychology; public services; science and technology studies; social anthropology; social policy; social statistics, methods and computing; social work; socio legal studies; sociology.
Engineering and Physical Sciences Research Council (EPSRC)
advanced materials; artificial intelligence and robotics; chemistry; circular economy; digital economy; energy and decarbonisation; engineering; healthcare technologies; information and communication technologies (ICT); manufacturing; materials; mathematical sciences and physics; quantum technologies; research infrastructure.
Medical Research Council (MRC)
antimicrobial resistance; experimental medicine; global health research; health and biomedical data science; infections and immunity; methodology development; molecular and cellular medicine; neurosciences and mental health; obesity; population and systems medicine; public health; regenerative medicine and stem cells; translational research.
Natural Environment Research Council (NERC)
atmospheric physics and chemistry; biodiversity and systematics; clean air; climate and climate change; digital environment; ecology; geosciences; greenhouse gas removal; marine environments; polar sciences; science-based archaeology; regional impact from science of the environment; sustainable management of UK marine resources; sustainable packaging; terrestrial and freshwater environments; UK climate resilience; Understanding the effectiveness of natural flood management.
Science and Technology Facilities Council (STFC)
astronomy, solar and planetary science; particle physics; particle astrophysics; nuclear physics; accelerator science; computational science.

[16] Sources: keywords, as listed on UKRI website, www.ukri.org accessed 8th March 2022.

Appendix 2: Coding Manual

Categorisation Manual for REF/GtR Subsample

1) Who are the stakeholders?

List the beneficiaries of the research identified in *gtr_potential_impact* text; and, list the beneficiaries of the research identified in *ref_impact_details/ref_impact_summary* text. The following beneficiary categories should be used for this exercise:

- [GVT] Public Sector (government, schools, hospitals)
- [PVT] Private Sector (businesses, industry associations, etc)
- [NGO] Third Sector (NGOs, charities, lobby groups, museums and cultural organisations, etc)
- [IGO] International Government (World Bank, OECD, UN, NATO, etc)

Multiple categories can be used, if appropriate.

Please enter the labels in square brackets, with semi colon separation. For example, “GVT; NGO”

In most cases, the stakeholders should be mentioned explicitly as *direct* beneficiaries in the texts. However, if that is not the case, the categories can also be deduced from other background information, but this should be done with caution.

If the text mentions academia as beneficiaries of the research, this should be ignored and no code should be assigned for these beneficiaries. Academia includes research and teaching undertaken at universities.

2) Can the impacted stakeholders be identified as co-producers in the GtR text?

Based on *gtr_potential_impact* and *ref_impact_details/ref_impact_summary* as a pair*,* a *Yes/No* binary variable should be assigned to each observation.

Co-produced research can be explicitly acknowledged by statements of collaboration, secondments, internships, people exchange, co-funding or provision of materials and equipment between the research group and identified stakeholders. If no such explicit information is provided, then the observation should be coded as *No*.

3) Are the research topics aligned?

Based on *gtr_potential_impact* and *ref_impact_details/ref_impact_summary* as a pair*,* a *Yes/No* binary variable should be assigned to each observation.

When the topics described by GtR and REF texts fall within the same research domain, this should be coded as *Yes.* When two very distant research domains emerge from the texts, then the observation should be coded as *No.*

4) Are there any highly specific or exact matches across the pair?

Based on *gtr_potential_impact* and *ref_impact_details/ref_impact_summary* as a pair*,* a *Yes/No* binary variable should be assigned to each observation.

If Yes, list whether:

- [STK] specific stakeholders are named explicitly in both texts
- [TEC] specific topics or technologies are named explicitly in both texts

Multiple categories can be used, if appropriate.

Appendix 3: Full-sub-panel results

Table A3.1. Share of Impact Cases, by REF Panel and Sub-Panel[17] UoAs, linked to funding, by UK Research Council.

REF Panel and Sub-Panel	Total Number of Impact Cases	Share of Impact Cases linked to funders (Top 3, by %)
Panel A (Medicine and Health)	**784**	**MRC (70); BBSRC (11); ESRC (9)**
A – 1 (Clinical Medicine)	220	MRC (90); BBSRC (6); EPSRC (3)
A – 2 (Public Health, Health Services and Primary Care)	109	MRC (85); ESRC (14); EPSRC (1)
A – 3 (Allied Health Professions, Dentistry, Nursing and Pharmacy)	70	MRC (61); ESRC (20); EPSRC (13)
A – 4 (Psychology, Psychiatry and Neuroscience)	178	MRC (74); ESRC (21); BBSRC (2)
A – 5 (Biological Sciences)	157	MRC (45); BBSRC (26); NERC (22)
A – 6 (Agriculture, Veterinary and Food Science)	50	BBSRC (54); NERC (24); MRC (20)
Panel B (Engineering and Environment)	**800**	**EPSRC (49); NERC (23); STFC (15)**
B – 7 (Earth Systems and Environmental Sciences)	152	NERC (84); EPSRC (7); ESRC (7)
B – 8 (Chemistry)	69	EPSRC (59); NERC (25); MRC (9)
B – 9 (Physics)	183	STFC (60); EPSRC (31); NERC (5)
B – 10 (Mathematical Sciences)	93	EPSRC (45); MRC (20); NERC (14)
B – 11 (Computer Sciences and Informatics)	112	EPSRC (77); MRC (6); BBSRC (5)
B – 12 (Aeronautical, Mechanical, Chemical and Manufacturing Engineering)	48	EPSRC (85); NERC (10); MRC (2)
B – 13 (Electrical and Electronic Engineering, Metallurgy and Materials)	50	EPSRC (92); ESRC (2); MRC (2)
B – 14 (Civil and Construction Engineering)	25	EPSRC (64); NERC (36)
B – 15 (General Engineering)	68	EPSRC (81); MRC (9); NERC (6)
Panel C – Law and Policy	**459**	**ESRC (57); NERC (14); EPSRC (14)**
C – 16 (Architecture, Built Environment and Planning)	46	EPSRC (61); ESRC (28); NERC (7)
C – 17 (Geography, Environmental Studies and Archaeology)	111	NERC (52); ESRC (27); AHRC (12)
C – 18 (Economics and Econometrics)	42	ESRC (81); MRC (19)
C – 19 (Business and Management Studies)	70	ESRC (66); EPSRC (29); MRC (6)
C – 20 (Law)	18	ESRC (56); AHRC (33); MRC (11)
C – 21 (Politics and International Studies)	30	ESRC (90); AHRC (10)
C – 22 (Social Work and Social Policy)	28	ESRC (82); MRC (14); AHRC (4)
C – 23 (Sociology)	37	ESRC (81); EPSRC (8); AHRC (5)
C – 24 (Anthropology and Development Studies)	23	ESRC (65); AHRC (9); EPSRC (9)
C – 25 (Education)	32	ESRC (84); AHRC (9); EPSRC (3)

[17] We note that the 2014 REF included 36 sub-panels but the subsequent 2021 REF will have 34, consolidating Engineering into one panel and introducing a panel for Archaeology.

REF Panel and Sub-Panel	Total Number of Impact Cases	Share of Impact Cases linked to funders (Top 3, by %)
C – 26 (Sport and Exercise Sciences, Leisure and Tourism)	22	MRC (59); ESRC (32); EPSRC (9)
Panel D – Arts and Culture	**151**	**AHRC (64); ESRC (20); EPSRC (14)**
D – 27 (Area Studies)	8	ESRC (88); AHRC (12)
D – 28 (Modern Languages and Linguistics)	19	AHRC (79); ESRC (16); EPSRC (5)
D – 29 (English Language and Literature)	11	AHRC (91); ESRC (9)
D – 30 (History)	27	AHRC (63); ESRC (37)
D – 31 (Classics)	1	AHRC (100)
D – 32 (Philosophy)	14	AHRC (79); ESRC (14); MRC (7)
D – 33 (Theology and Religious Studies)	4	AHRC (100)
D – 34 (Art and Design: History, Practice and Theory)	25	EPSRC (44); AHRC (40); ESRC (8)
D – 35 (Music, Drama, Dance and Performing Arts)	24	AHRC (71); EPSRC (25); MRC (4)
D – 36 (Communication, Cultural and Media Studies, Library and Information Management)	18	AHRC (56); ESRC (28); EPSRC (17)

Appendix 4: Examples taken from the dataset

Table A4.1: Examples of forms of topic and stakeholder identification

Level of ex ante identification	Example of Pathways Statement	Example of Impact Case study
Exact topic identification Development of facial scanning technology impacting upon cancer and stroke patients –as anticipated.	"Using facial scans to measure a radiation-induced damage [could] open a completely new way of non-invasive monitoring of radiotherapy for head and neck patients. Furthermore, it would be of benefit to other patients, such as stroke patients, enabling early detection of symptoms and better patient care.	"By pioneering dynamic 3D facial scan as new medical diagnosis tools, the research contributes directly to improving the efficacy of assessing and monitoring the condition and treatment of cancer and stroke."
Research on bioluminescence yielding a technology for measuring responses to drug treatment –as anticipated.	Bioluminescent biosensor assay technology could be used to predict response to chemotherapy in a range of [cancers and drug treatment for other diseases such as HIV].	Bioluminescent biosensor technology has allowed rapid testing of bioactive compounds and formulations. The outcome of the research with bioluminescent biosensors is to allow, for the first time, the direct effects of physical and/or chemical challenge on a living cell to be visualized and quantified in situ and in real time.
General topic identification Research on infectious diseases impacting on disease outbreak policy – broadly as intended.	"The ultimate aim for impact from my research is to reduce the burden of infectious disease on the human population"	"…[The research] has provided detailed mathematical/modelling advice to the DoH, [and] SPI-M with real-time modelling updates on control and containment of pandemic influenza [and] has provided analysis that "has been essential in determining UK pandemic policy"".
No general topic identification	[This research funds] equipment only, agreed in relation to the network infrastructure for robust and resilient computing and storage services"	"Research in particle physics at XX has impacted on the public understanding and appreciation of science around the world by underpinning the hugely successful media impact of Professor XX, which in turn has had a strong influence on societal views of science."

		"The search for and discovery of the Higgs boson using the ATLAS detector have had a significant impact upon the public's interest and engagement in physics. This has been achieved through a variety of public engagement activities."
		"The impact arises through an outreach programme [that] portrays the development and achievements of modern particle physics with illustration through music."
Exact stakeholder identification Impact on a specific organisation, ICE, within a broad stakeholder group – exactly as intended.	"This research is relevant to the major engineering institutions and industry bodies, including the Institution of Civil Engineers (ICE)."	"Our health and safety research has made a very important contribution to the [Institution of Civil Engineers] ICE in their development of guidance on best practice in health and safety management, which is now available as a manual."
General stakeholder identification Impact on a group of stakeholders in the private sector, broadly as intended in the medical sector.	"… developing and delivering innovation from fundamental research in regenerative therapies and devices and in broader aspects of medical technologies."	"The creation of a new business was set up as a University spin-out company in 2005 to directly exploit the research… and develop nonwoven materials that were found to have major applications in industrial, healthcare and consumer markets.
No general stakeholders identification Ambitions for university-industry engagement, however the impacts that transpired were oriented to the general public in a very broad sense.	A research student was directly involved in an industrially led system definition study, feeding into a future mission science-led proposal (EXP Characterisation Observatory - ECHO). This yields many tangible commercial benefits, including a competitive advantage for any future missions & a strengthened national commitment if there is a strong UK science component."	The university's Observatory is engages with the public via six Open Evenings and approximately 50 group visits a year, offering access to a wide range of facilities. Many of the 4,000 visitors annually report that they develop a first or renewed `enthusiasm for astronomy', or become `inspired to learn more' about what they have seen or heard from our researchers; some young people enthuse about `now wanting to be a scientist'. Science teachers taking an

		RCUK `cutting-edge' CPD astrophysics course also say that they have gained an `increased understanding of the subject', and `increased confidence in its delivery to pupils'.
Stakeholders left largely unspecified in the pathways to impact statement, and the resulting impact is described broadly in terms of public engagement.	"The results obtained in this project will be highly relevant for quantum networking in general, as they will also be applicable to a large variety of other quantum technologies."	"Over a four-year period, teachers and around 16,000 pupils from all over the UK have benefited from engagement with physics research. Outcomes include enhanced science teaching in schools, an increased interest of school children in science and scientists' work, and a greater ability of school children to understand and reflect on science, leading to better-informed study choices. The UG physics population across the South-East has roughly doubled over the REF period (based on numbers at the SEPnet partners), which is an important contribution to alleviating the problem of a scarcity of STEM graduates."