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Research impact seen from the user side

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Research impact seen from the user side

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Background

This working paper is inspired and forms part of the work of the Oslo Institute for Research on the Impact of Science (OSIRIS) in which INGENIO (CSIC-UPV) participates.[2] OSIRIS is an international research centre based at the TIK Centre at the University of Oslo that brings together different disciplines relevant for understanding research impact. The fundamental and rather original perspective of OSIRIS is to look at the process of research impact primarily from the user side: *How can we characterise the process through which research makes an impact in society?*

This working paper takes up this question from the perspective of the research evaluation literature. It takes a first step toward trying to develop methodological principles for defining and investigating the OSIRIS idea of a 'problem area' in which research users take up outputs from scientific research and seek to innovate to improve societal outcomes. OSIRIS has a particular interest in improving understandings of such impacts from the perspectives of users in the areas of health, industry, and policy making.

Motivation

The role that scientific activity plays in society is constantly being re-assessed. The public sector, which funds a substantial share of scientific research, must allocate funds across different scientific fields and approaches. These decisions are based, implicitly or explicitly, on an estimate of the value the activity generates and of how such value is generated. Such estimates and the extent to which they should drive scientific work have been a topic of debate since the early 20th Century. After the Second World War, however, a consensus emerged that science was a key contributor to social and economic

[2] The Oslo Institute for Research on the Impact of Science (OSIRIS, grant 256240) is funded by the Research Council of Norway. https://www.sv.uio.no/tik/english/research/centre/osiris/

development and that such contribution justified the investments made in it. Vannevar Bush in his much quoted report "Science – the endless frontier" (Bush 1945) laid out a model in which basic research, carried out mainly in universities and private foundations, freely explored natural phenomena without consideration of the possible economic applications of such work, while industry labs tackled immediate practical objectives. Between them government research agencies addressed practical objectives but developed long-term research of a fundamental nature: they were not circumscribed by the immediate concerns driving industrial research activity, neither did they enjoyed the "freedom of exploration" of the basic researcher. Yet, such freedom had to be defended because:

> *"As long as scientists are free to pursue the truth wherever it may lead, there will be a flow of new scientific knowledge to those who can apply it to practical problems in Government, in industry or elsewhere." (Bush 1945)*

This flow needed to be substantial and continuous but was not seen as particularly problematic: public funding of basic research should not warrant interference and the public funder should expect that, the results of the research it had supported would flow, in reasonable volume, towards application. As Mme Curie had argued almost 25 years earlier:

> *We must not forget that when radium was discovered no one knew that it would prove useful in hospitals. The work was one of pure science. And this is a proof that scientific work must not be considered from the point of view of the direct usefulness of it. It must be done for itself, for the beauty of science and then there is always the chance that a scientific discovery may become like the radium, a benefit for humanity. (Curie 1921).*

This argument is congruent, however, with a utilitarian view of science. Although authors like Polanyi criticised the utilitarian justification for spending on science (Polanyi 1962), it has dominated the rationale for public expenditure in research. The scientific freedom afforded to the basic researcher was based on the assumption that the "chance" that scientific discovery would yield a "benefit for humanity" would be turned into reality with sufficient frequency. Both Bush and Curie were accepting that the generation of applied benefits was, at least, one of the justifications to invest in basic research.

Vannevar Bush's neat sequential interpretation of how fundamental research contributed to economic and social progress and its associated research policy model, has been called

into question over the last four decades. First, analysts have shown how scientific practice had diverted from the neat distribution of tasks that Bush had put forward. Scientific practice and the utilisation of research results have been revealed as an altogether messier experience, with feedback loops between research, technological development and innovation. Many concepts and theories have been developed stressing the interactive and complex nature of the relationship between science and innovation. The chain-linked model (Kline 1985, Kline and Rosenberg 1986) drew attention to the feedback loops between design and research. The Triple Helix (Leydesdorff and Etzkowitz 1996) emphasized the fuzzy boundaries between universities, industries and government which each of these institutions being involved in tasks previously assumed to be the exclusive remit of one of the others (thus, for instance, universities will set up firms and firms carry out basic research). Notions like "technology transfer" have fallen out of favour to be replaced by more interactive concepts like "knowledge exchange" (Schmoch 1999). These and other neighbouring concepts (mode two research, transdiciplinarity, problem-orientation, productive interactions, responsible research) are framed within a more systemic view of the role of science and technology, emphasizing interactions among partners and the legal and institutional contexts within which these take place. In short, analysts and policy makers have moved their attention to the linkages between knowledge generation and application, questioning the views that saw scientific research as a world apart with its own rules and practices, that generated knowledge which had then to be transferred to other actors for their "translation" and application.

This evolving understanding of how research results are applied is increasingly informing science and innovation policy rationales but has not trickled down with similar fluidity to the evaluation of their results (Molas-Gallart and Davies 2006) and, more generally, to research impact assessment practices and methods. These continue to be dominated by approaches that take as their starting point an investment in research and the activities and outputs that it has generated. Whether one focuses on the processes of knowledge production and application by tracing forward from the research investment, or tries to estimate the economic returns it has generated, the window this perspective offers is necessarily partial. Tracing forward, for instance, will suffer from a selection bias as it focuses on those cases where traceability can be established from the researchers perspective, instead of instances where the effect has been indirect, with knowledge from

research "creeping" over time into application environments (Weiss 1980) without the researchers necessarily being aware of this process. Research and innovation policy evaluation has also favoured taking the research investment as the point of departure for the analysis. Evaluation efforts are often justified by the large investments that science increasingly requires and an unspoken but latent concern about their potential effect on social and economic welfare. When research investments in a single infrastructure run into the billions of euros,[3] it is understandable that the public institutions authorising such expenditures may not be satisfied by the knowledge that "there is always a chance" that such investment will yield social or economic returns. Yet, the ensuing political need to have evidence of such positive impact prompts evaluation approaches that, once again, have as their starting point the specific research investment. Further, they often focus on economic returns and therefore commercialisation activities and the private capture of the benefits of public research investments. Consequently, not only do research impact assessment methods focus on the results of specific investments but economic (and scientific) impact have received more methodological attention than the contribution of science to the generation of social value (Bozeman and Sarewitz 2011).

There was, however, broad awareness that the focus on economic returns could only provide a very partial account of the effects of science on society. The work of Bozeman and colleagues on the development of methodologes to identify the "research value" and "public value" of research (Bozeman , Bozeman and Kingsley 1997, Bozeman, Rogers et al. 1999, Bozeman and Sarewitz 2011) constitute one of the most important and influential research agendas in this direction. This approach emphasizes that science policy often pursues objectives other than economic growth, seeking a broader normative consensus on the principles on which public policies are constructed (Bozeman 2007). Public values emerge from this normative consensus on principles, but the way in which all public policies (including science policy) contribute to their accretion is difficult to assess, and even more difficult to measure. The interest in the broader social contributions of research is also reflected in official documents like the Ricci report on the social and environmental impact of European research (European Commission 2005), proposals from influential associations representing the views of research funding and performing organisations

[3] CERN, for instance, requires an annual investment around €900 million, and the building costs of the Large Hadron Collider exceeded €7 billion.

(Science Europe 2017) and research evaluation practice (Van Noorden 2015, Evaluation Division for Science 2017).

Broadly, the debate on the social and economic value of research and the autonomy of researchers to be guided by their own scientific curiosity continues in the 21st Century in terms similar to those of the previous hundred years. What is changing is an increasingly nuanced understanding of the relationship between knowledge generation and applications and the role that different social groups have in these processes. The conduct of scientific research is no longer seen as the reserve of those with a set of formal academic qualifications, but is opening to broader citizen communities (Bonney, Shirk et al. 2014), and, similarly, the selection of research priorities is seen as a topic where the participation of communities beyond the performers and funders of research is opening new arenas for public controversy (Wallace and Ràfols 2018). Such "democratic governance of the purposes of research" (Owen, Macnaghten et al. 2012) has gained traction in European research policy and which involves a deeper involvement of scientists in the consideration of the types of impact that their activities may lead to.

As the boundaries between research communities and the users and beneficiaries of research outside academia become blurred (Etzkowitz and Leydesdorff 1997), increasing their connections and making the relationship between knowledge generation and application more complex, the study of research impact cannot be limited to approaches that, implicitly or explicitly, take the research activity as the starting point of a process that evolves through a sequential set of stages (research, technological development, application, social and economic benefits). In fact, although the image conveyed by the notion of "research impact" is simple and follows this archetype, analysts have proposed more complex views of the processes linking research activities and their effect on society and the economy. They have stressed the multidimensional nature of these processes (Donovan 2011), and see research and their results as one of broad set of factors that contribute to, rather than cause, the generation of relevant changes in the economy and in society (Molas-Gallart, Tang et al. 1999, Mayne 2001, Colinet, Gaunant et al. 2013, Belcher, Davel et al. 2020). The image conveyed by the term "impact" suggests an origination cause (the research) yielding results as of its own momentum. Yet, this is seldom the way in which the benefits from research accrue. To contribute to economic and social changes research results need to have been used at some point, often within complex

innovation processes. We can therefore argue that "impact" is fundamentally about the **use** of research –leading to the commercialisation of new products and services, the implementation of new policy directions, the improvement of healthcare and more. Yet, research users are often missing or have limited roles in the models and narratives employed in impact assessment methodologies. The main rationale for impact assessment remains the identification and measurement of the socio-economic impacts of specific bodies of research rather than to understand how research results are used.

This paper proposes some initial steps toward placing research use and researchers users at the centre of research impact assessment. We will first complement this introduction with a review of the dominant approaches to impact assessment. As part of preparing the paper, we analysed the framing of research users in the key literature we review below and incorporated this analysis in what follows (see Table 1 below). Our first review section focuses on the shift from linear and mainly quantitative approaches toward mixed and qualitative approaches to views focusing on the complex ways in which research effects are generated. We will refer to some influential approaches that have focused on identifying the interactions and the pathways through which impact occurs and show how process-oriented methods have seldom attended to the role of the research user as a central actor in these processes. The second review section considers the challenges of focusing on the user perspective, particularly tracing back from technological developments and knowledge use as a diffusion process. We highlight the challenges that the research user perspective poses for the design and implementation of impact assessment methodologies. We then propose an initial set of elements for building an approach that can address such challenges and provide an analytical table summarising the main assessment approaches reviewed. From this preceding work we derive a set of simple principles regarding the identities, roles and positioning of research users, which configure their contributions to realising value from research. In our concluding remarks we note some potential contributions of our work to future research assessment designs and methodological innovations.

1 Antecedents: from linear to systemic/interactive models

1.1 Economic models and linearity

Efforts to quantify the returns to R&D investment have a long tradition. Quantitative analysis, mainly focusing on economic returns, has tried to estimate the returns on specific investments or, at a macro (national) level, the overall effect of R&D expenditure. These models rely on a narrow set of well-defined indicators available through existing datasets or bespoke questionnaires. R&D expenditure is taken as the main indicator of research effort, while its impact can be observed through the differential growth in GDP, or in employment, sales, patents, patent income, technological balance of payments or other economic quantitative indicators. The econometric modelling used has become increasingly sophisticated over time, helped by the constant growth of cheap processing power, and the correlated growth of large datasets. Yet, for all their complexity, such models are based on a sequential understanding of the effect of R&D, the first step of the sequence being the effort invested in research, and the impact being an attributable improvement in a measurable variable of consequence. This area of impact assessment has dedicated considerable effort to debates on the adequacy and implications of the use of different analytical techniques and of the choice of the indicators that feed them. For instance, when assessing the effects of a public investment in research, there is a need to examine its effects on private investment, in particular the extent to which the former can result in a reduction of the latter (crowding-out) (Productivity Commission 2007). Input as well as outcome additionality (Buisseret, Cameron et al. 1999) need to be determined; yet, the emphasis on additionality may focus the assessment on what is important from a current perspective while missing uncertain long-term benefits (Luukkonen 1999). Therefore, technical decisions on the way in which research impact is to be estimated (the need to consider input additionality), impinge upon assessment criteria (the consideration of long-term external benefits).

There are specific areas of research where the impact assessment question can be expressed in more simple terms. Research impact assessment, has for instance, became an active sub-field in agricultural economics. Here the knowledge generation and application process can arguably be reasonably presented in a simple linear way: the research effort invested

in the development of a new crop variety, leads to the development of new seeds, which once farmed will lead to new products being grown or increased productivity in the production of existing crops. New products or increased productivity generate benefits, which once estimated can reasonable be attributed to the new seed. This does not mean that the estimates of benefits are easy, but the problem can be expressed in such a way as to make it fully amenable to the application of statistical techniques. This type of impact assessment has led to hundreds of articles and studies. Twenty years ago, a literature survey of studies on the impact of agricultural research identified 289 studies of economic returns to agricultural research yielding 1829 different estimates of return rates (Alston, Marra et al. 2000). Since then, more have been constantly published and shared among agricultural economics communities yet seldom exposed to other academic fields, including research evaluation and the economics of innovation

Statistical analyses of research impact pay special attention to the adequacy of the estimating models, data coverage and reliability, and attempt to find reliable and robust quantitative estimates of impact. Focusing on measuring means concentrating on the impact of research and, specifically, on those aspects than can be measured. There are limits to what can be achieved with these approaches and consequently their results must be interpreted with care. Critics of the methods that tried to measure socio-economic returns to research investment have argued that these limits are insurmountable. The long chain of events linking knowledge to decision and action, and the intangible nature of knowledge and the resulting difficulty to model it, make the measures flawed (Barré 1999). Available indicators are limited and can only offer a partial window on reality (Molas-Gallart and Ràfols 2018).

The way out of the problem instead relied on new modes of research impact assessment, which would examine interactions in the system composed of research project actors and users, construct indicators that would help make visible all aspects of the research and innovation processes, and take into account the debates that the conduct of research and the application of its results would often generate among stakeholders (Barré 1999). The way in which impact estimates were obtained through statistical modelling could not offer an understanding of the processes by which such impacts occur. Impact measurements could be obtained, but without a clear grasp of how the estimated returns had come about. It had become evident that to understand how research can make a difference we needed a

grasp of long-term processes involving intricate forms of interaction among the producers and users of knowledge.

1.2 Towards complexity: loops and interactions

Identifying contributions and analysing pathways

Approaches that focus on describing the processes by which research results are applied will often emphasize the knowledge exchanges between different participants that take place throughout and provide examples of how what is learnt at some stage of the process feeds back to activities that had initially preceded it. Impact processes do not only relate to how knowledge is transferred and potentially put to use, but also to how scientific knowledge co-evolves with other forms of knowledge (Morlacchi and Nelson 2011) and it is itself influenced by knowledge gained in interactions with potential beneficiaries (Spaapen and van Drooge 2011). Such feedback loops can lead to circuitous knowledge generation and application processes and are described through systemic models that emphasize interactions between researchers and users and beneficiaries of their research results.

The "payback model" (Buxton and Hanney 1996, Donovan and Hanney 2011) has been used to assess the return to, biomedical research and its use extended to other research fields (Levitt, Celia et al. 2010). The development of new drugs and other therapies is formally structured into a clear set of different research stages, including the processes of clinical research. The payback model assesses the investments at every stage of the process, their outputs and how they feed into the next stage until yielding the medical treatments that are being pursued. This formalised, staged, view of the R&D process had led to criticisms that see the model as being linear; yet, it clearly considers feedback loops as results from later stages can feedback into previous ones (the results for clinical research can, for instance, instigate new scientific investigations into fundamental processes). Each stage of the process includes 'permeable interfaces' between researchers and potential users in the healthcare system, including "negotiations between research customers and contractors; brokerage between researchers and the policy community; the involvement of stakeholders; and effective dissemination" (Buxton and Hanney 1996: 37). The stage at which interactions between researchers and healthcare stakeholders occur shapes both the

research and its potential audience. Unburdened from the need to establish a specific estimate of the return on research investment, such process-oriented approaches can define their own focal points on which to build highly detailed descriptions of impact pathways, using research intensive methods.

Impact studies conducted for the purpose of policy or programme evaluation start from the specific project or programme under assessment. The SIAMPI approach, for example, focuses on the interactions through which research is defined, conducted, and use emerges. SIAMPI developed a conceptual framework and set of tools to assess the generation of research impact through "productive interactions" defined as "exchanges between researchers and stakeholders in which knowledge is produced and valued." (Spaapen and van Drooge 2011). When this exchange leads to an effort by the stakeholder to engage with the research a 'productive interaction' emerges and when 'productive interactions' result "in stakeholders doing new things or doing things differently" the research could be said to have an impact (Molas-Gallart and Tang 2011).

Studying "productive interactions" thus addresses processes rather than focusing on the identification of changes in markets or practices attributable to the research. For the interaction to be considered "productive", it does not need to lead to a change in practices, or to new products or services. It is enough for the stakeholders to "make an effort to engage with the research". Such departure from the traditional concentration on "impact" can be justified on the grounds that there are forms of valorisation of research results that do not lead to action; for instance, research results can confirm that a policy intervention was adequate, provide support *against* a change in policies, or may not find application because it would run against the interests of current incumbent groups, even if it would benefit the majority. Research results can also be helpful when they can help explain tragic occurrences after the fact, even when they have not been used to provide solutions to the repetition of such occurrences.

There is an important consequence of these considerations: not only does the SIAMPI approach focus on processes rather than the impacts, but assigns value to the processes themselves. This focus on processes has relevant methodological implications. The notion of "productive interactions" and the application of the approach can legitimise researchers' engagement efforts in the midst of evaluation practices that, in fact, give little weight to anything other than academic achievements. As a "formative" evaluation approach,

SIAMPI positively reinforces engagement practices (Peattie 2010). Projects typically include different types of productive interactions, among stakeholders with different interests and expectations (Spaapen and van Drooge 2011: 213-4), and fluidity may emerge in the roles of academic and stakeholder communities (Molas-Gallart and Tang 2011: 224).

Whereas SIAMPI starts out from research projects or investment to trace the interactions generated between researchers and research users, other process-oriented approaches take a specific research output as their starting point. The ASIRPA method (Joly, Gaunand et al. 2015, Matt, Gaunand et al. 2017) traces how a research output is further developed, adapted, applied through complex interactions involving different stakeholders. Initial applications of ASIRPA have assessed the impact of very specific discoveries in the agricultural area (for instance a new plant variety). Although this kind of research results has been the subject of many prior efforts to estimate their impact, the ASIRPA method shows that even in seemingly straightforward cases (the use in new crops of the new varieties and the consequent increases in productivity or sales), the impact processes are protracted, complex, involving actors from many different fields and having effects that go far beyond the economic returns generated by increased yields or the market success of new products.

ASIRPA starts from the theoretical premise that scientific knowledge as such is not useful, but is made useful through a series of transformations performed by different actors. (Joly, Gaunand et al. 2015: 441). Research value is produced by networks of actors and resources that 'translate' knowledge from use context to use context through four ideal-type impact pathways. These impact pathways also produce different configurations of outputs (value-able objects, products, methods and processes) (Matt, Gaunand et al. 2017: 216-17). ASIRPA thus consructs a theory-based approach to tracing long-term processes in systematic detail, as the basis of a comparative longitudinal case study methodology.

SIAMPI and ASIRPA are part of a broader family of methods and techniques that analyse the complexity of scientific impact processes. Originating in the healthcare sector, "contribution mapping" (Kok and Schuit 2012: 2) presumes that realising value from research requires contributions to "evolving, complex and open systems in which change is continuous, non-linear, multi-directional and difficult to control". Attempts to assess research impact in such systems is extremely challenging, with the entry point being how participants in a 'research and action pathway' conduct "alignment efforts" to enhance

their contributions (Kok and Schuit 2012: 2). Translating research into impact relies primarily on alignment efforts by 'involved' and 'linked actors' who participate in or are close to research projects or interventions. From these groups potential key users emerge to undertake translation, brokering, and dissemination activities, including ensuring research outputs can be accessed by unlinked potential users (Kok and Schuit 2012: 14). From the contribution mapping perspective then, "changes in action achieved are the result of the distributed agency of multiple actors" (Kok and Schuit 2012: 14), a conceptualisation that builds on the pioneering work of Callon (1986) in a way similar to the ASIRPA approach.

Outcome mapping (Belcher, Davel et al. 2020) develops a theory-based approach to assessing impact from transdisciplinary research that actively engages with societal actors as part of the research process. Interactions and shared activities among constellations of scientific and societal actors can shape research impact in the 'sphere of influence' surrounding the project, particularly among users of research outputs and services that are close to the project boundary (Belcher, Davel et al. 2020: 9). Broader impacts can occur when such actors contribute and provide support to 'higher level objectives' (Belcher, Davel et al. 2020: 4). The outcome mapping assessment of impact from transdisciplinary research initiatives thus also focuses attention on identifying and consulting target audiences in society that could conceivably be affected by the topic or problem driving the research.

Another approach developed in healthcare has looked at 'knowledge exchange' between researchers and practitioners and the importance of co-production opportunities (Wilkinson et al. 2012). Research-based practitioners (Nutley et al. 2009) who collaborate on designing and conducting research can move and communicate within both knowledge production and service user systems. In this way a shift from knowledge transfer to knowledge exchange can be operationalised (Wilkinson et al. 2012: 313). Practitioners and users operating as knowledge producers can add context-defined content that can counterbalance the impact of introducing 'evidence-based' knowledge to health service users. Nevertheless, while practitioner-users may consider certain impacts as providing value to the health system, health service users may find them "irrelevant and of little value" (Wilkinson et al 2012: 322). The knowledge exchange approach thus highlights the importance of understanding how user groups may define and assign value associated with

a common research impact in different ways, depending on how they are positioned in relation to the valorisation process.

Finally, in the 'public value mapping' (PVM) approach scientific and societal stakeholders are organised around particular bodies of knowledge from which they seek to realise value (Bozeman 2003). 'Knowledge value collectives' include "first order" users of knowledge, persons who either use knowledge to create additional information (including technology), who support the use and application of knowledge or who are self-conscious end users…the KVC does not include "second order" knowledge users, those who uses the knowledge or its embodiment (e.g. technology) without seeking to fundamentally add to or reshape the knowledge or create new uses" (Bozeman 2003: 27-8). Ordinary citizens can move from being second order users to also being part of the KVC when they actively seek to use or support further use of knowledge, e.g. by lobbying to change policies or practices (Bozeman 2003: 28). Unlike the tightly controlled key topics of a scientific community with its strong norms about how to advance knowledge, in the KVC relevant topics fluctuate, are multiple, and valorisation efforts can proliferate, as can the roles taken by research users in these processes.

Within valorisation processes PVM prioritises knowledge embedded in people over other forms, with scientific and technical human capital (STHC) being the sum total of all the social, cognitive, technical, political, and cultural qualities and skills individuals can deploy to generate public value from research (Bozeman and Rogers 2002). As an evaluation approach PVM starts out from either a body of research or a set of social problems that research addresses, then maps the STHC capacity within this problem domain (Bozeman 2003: 37). The valorisation within the KVC is distinctive, with value being conceived as it is actively configured through the transformation of scientific information into knowledge. The reach of a KVC can be monitored in terms of the variety of problems it engages with and the range of clients who benefit from its outputs. Its effectiveness can be assessed by comparing linked outcomes for second-order users against a variety of conceptualisations of value promoted by public stakeholders of all sorts.

For all their diversity, the approaches described in the previous two sections share the characteristic that their starting point is research activity, an investment in research, a specific research programme or project, or a specific research result. They are, therefore, well-suited to the evaluation of research investments, and can focus on a set of well-defined

and bounded actors and activities. By focusing on detailed descriptions of specific cases from different methodological standpoints the approaches provide a range of perspectives on valorisation processes starting from research or in close proximity to it. However, case-based approaches that have attempted to identify and describe in detail the ways through which research results generate value for society have also started from the entry point of the beneficiary of the research. As we will see in the following section this is an even more challenging research proposition.

2 User perspectives

2.1 Tracing back technological developments

Very often an application of new knowledge, be it through a new product or service or through the implementation of new policies and practices, will draw from different research sources. Therefore, relevant interaction networks are likely to appear more diverse and distributed when starting our research from the application area perspective. Frequently, there will be a broad set of "productive interactions" a detailed analysis of which may be made impossible by the sheer variety of direct and indirect engagements with research that the users have entered into. When this happens the analysis of impact processes from a user perspective could focus on how the user deals with researchers and research information, rather than a detailed "pathway" analysis of how an interaction has developed over time. This analysis would open up a new perspective that is very different from story narratives that have characterised much of work presented in the previous section.

In principle, taking as a starting point an application area and a set of user or beneficiary communities allows for the distant and less visible use of research results to be identified. Yet, it makes it difficult to provide the detailed studies of specific research-user interactions or of specific pathways to contribution and impact. Tracing forward from the research activity allows for a well-bounded subject; although the impact pathway will become complex overtime and involve an increasing set of actors, the community under investigation remains identifiable. In comparison starting with a problem area and a set of research users to "trace backwards" to influential research is likely to generate a much

broader set of potential lines of enquiry: users are likely to have engaged with a broad variety of research results and researchers throughout their professional life, which have a bearing on particular decisions, or the development of specific innovations. Research-users may also seek to engage with a researcher or a research group not in relation to, or through, a specific research activity, finding or outcome, but due to the recognition of their general competence and authority in relation to knowledge that is (potentially) relevant to a problem area. This further complicates attempts to trace backwards from a problem area, as the relationship between productive interactions and specific knowledge objects becomes less precise.

One way of "tracing backward" from the specific knowledge applications while keeping the set of interactions and pathways within manageable boundaries is to focus on specific products and to trace back the technologies and scientific contributions that have been required to produce them. Some of the seminal contributions taking this perspective do not fall within the area of policy evaluation but were rather developed from a history of innovation approach. The *Sources of Invention* (Jewkes, Sawers et al. 1969) analysed 59 cases of important inventions (2nd edition). The goal was not so much to trace back the knowledge components that had gone into constructing the innovations but to describe the product development stages with a view to identifying the type of organisation more conducive to the generation of beneficial innovations. They found a large variety of organisational structures in the success cases they analysed, and diverse ways of linking scientific research with technological development. The observation that there is a large variety of organisational structures (and pathways) has since become commonplace and with it the conclusion that there is no "one-size-fits-all" policy approach to support the application of new knowledge to the development of new products and services.

The first edition of *The Sources of Invention* was published in 1958. A decade later came a second key contribution to the analysis of how new technologies came about, this time from an explicit evaluation perspective and purposely tracing from products and technologies back to the research advances that had enabled them. Project Hindsight (Sherwin and Isenson 1967, Isenson 1969) was funded by the US Department of Defence. It identified 710 "events" that had enabled the development of a set of defence technologies. The advantage of adopting the research user perspective was apparent to the authors; users almost invariably knew the source of the technical information embedded in

these events, whereas that same source would rarely be aware of the ultimate user (Sherwin and Isenson 1967: 1572). More than 90% of these events were attributable to technology development projects rather than scientific research initiatives, and almost all the latter were the result of targeted scientific efforts. The effect of undirected scientific research was found to be almost negligible. Rather, impact from undirected science was more likely to occur through consolidated outputs such as "well-established, clearly expressed general theory, or in the evaluated, ordered knowledge of handbooks" (Sherwin and Isenson 1967: 1575).

Sherwin and Isenson realised that for efficient research utilization the key mechanism was 'recognized need' on the part of users. Recognized need required users to hold "have very detailed knowledge of either a class of systems or a specific system so that the critical problems can be addressed" (1967: 1575). Sherwin and Isenson also realised that those users who recognized the system need "made the researchers aware of the nature of the problems but did not dictate the nature of the solutions (1967: 1574). This very specific user-originated problematisation process could unfold over a lengthy period (5-10 years) before eventual utilization of the research could be identified.

In response to the Hindsight finding, the National Science Foundation led another study (The Illinois Institute of Technology Research Institute 1968), which reached very different conclusions. The TRACES study started from a different selection of products (a smaller number of key innovations) and took a longer temporal window. A total of 340 scientific "events" were traced, contributing to five key innovations over a period over 50 years. In contrast to Hindsight, TRACES found that 10% of the events it traced were the result of technological development, while 70% were considered to be the result of basic research.

The debate on the contribution of basic research to technological development and the solution of social and economic problems that the differing estimates from the Hindsight and TRACES projects exemplified rages on half a century later (Sarewitz 2016). From a methodological point of view, both projects deployed a set of conceptual and methodological tools that could allow for the comparative analysis of research contributions to different innovations. That these approaches have not been used very often reflects their labour intensive nature, as well as the existence of some methodological limitations. Comparisons of sue were based on the number of events that could be

classified as resulting from one type of research or another (mainly, basic research, applied research and technological development). This comparison, though, was based on the assumption that each event was of equal value and this assumption was bound to increase the weight attributed to research conducted earlier because, as we move backwards in time, the "roots of the tree" that constitute the ancestors to each innovation become wider (Marjanovic, Hanney et al. 2009). Similarly to what happened in the application of quantitative statistical techniques to the assessment of (economic) returns to investment, the techniques used were shown to be open to yielding very different estimates of impact in different contexts. While such variations could be caused by actual divergence in the role of research in generating impact, they could also be artefacts derived from the techniques used.

Another characteristic of these event-based, tracing back techniques is that they attempt to link technologies and applications to specific research outputs. Therefore, the focus is not on how users deal with research but on the identification of how different forms of research contributed to, mainly, technological developments. Although tracing back leads to the identification of a wide set of research "roots", these roots are still specific contributions to knowledge that are considered necessary to achieve the final innovation. By just identifying and counting such roots, the techniques still concentrate on the research results rather than on the ways in which they are used. They do not tell us *how* specific decisions, policies, technologies, have drawn on the results of scientific research. In this sense, additional elements for process-based methods but starting from the user perspective must be found in a different set of approaches.

2.2 Knowledge use as a diffuse process: the different functions of knowledge

In the 1980s a different strand of the literature studied how knowledge (mainly the result of scientific research) was used by practitioners. The concepts developed by Carol Weiss, in her analysis of the use of research evidence in policy decisions have remained particularly influential.

First, research could play different functions, one of which was particularly important in a policy context although difficult to pinpoint empirically: the "enlightment function" (Weiss 1977, Weiss 1986). In its original article, based on three case studies, Weiss argued

that "that the major use of social research is not the application of specific data to specific decisions. Rather, government decision makers tend to use research indirectly, as a source of ideas, information, and orientations to the world. Although the process is not easily discernible, over time it may have profound effects on policy." (Weiss 1977). Other authors later added other forms of policy use. Beyer (1997) distinguished between instrumental, conceptual, and symbolic use. "Conceptual"·was closely aligned with Weiss´ enlightment function while the use of research results to legitimate and sustain existing decisions was described as "symbolic", while "instrumental" use referred to the direct and specific application of research results. This distinction has been operationalised in quantitative empirical studies of the use of university research (Amara, Ouimet et al. 2004, Olmos-Peñuela, Castro-MartÌnez et al. 2014), user-centred qualitative analysis (Edler, Karaulova et al. 2020), and other studies have employed slightly different definitions and classifications of types of use (Molas-Gallart, Tang et al. 2000).

Second, Weiss described how the enlightment function was to come about. Instead of a direct application of specific bits of knowledge, research knowledge "crept" into policy use by a slow process of "accretion" (Weiss 1980). Consequently, it was difficult to identify and trace the indirect applications of research results to policy decisions. It would follow, in today's language, that trying to trace an "impact pathway" was a doomed mission. Instead of a piece of research generating an impact through an identifiable process of generation, co-generation, adaptation and application, results from different strands of research would intermingle and become part, often in an unintentional manner, of the policy-maker framework.[4]

Where would this knowledge "accrete" from? Different authors have used the metaphor of pools or reservoirs of knowledge that are fed from scientific research and irrigate the world of applied practice in the indirect manner described by Weiss. If this is an important or

[4] John Maynard Keynes is often quoted in this regard: "Practical men who believe themselves to be quite exempt from any intellectual influence, are usually the slaves of some defunct economist. Madmen in authority, who hear voices in the air, are distilling their frenzy from some academic scribbler of a few years back" Keynes, J. M. (1936). The General Theory of Employment, Interest and Money. London, Macmillan.

dominant form through which research results are used, then not only is it difficult to trace the links between use and the amorphous repository of (often unattributed) information but the same idea of "impact" emerges as inadequate. "Knowledge reservoirs" become "key intermediary variables in the process of realizing societal value of research from which users would draw" (Rip and van der Meulen 1995). This has implications for the target and nature of research impact assessments: the focus of the analysis should not be placed on "impacts" but on "relevance and linkages", identifying the "epistemic communities" that "carry" the reservoirs and describing their structure, growth and how they are accessed (Rip and van der Meulen 1995)

There has been little research on how this process of drawing from the pool occurs in practice, and besides the image it portrays may be misleading: with the pool standing in between the researcher and the user the image is portrayed of research activities being detached from use, with a role emerging for brokers who are knowledgeable of the pool and are able to connect the research base with users (van Langenhove 2011; Frost, Rosemary et al. 2012). This 'two communities' perspective identifies also the importance of the distinctive values and ideologies that characterise practitioner and policymaker user systems and distance them from knowledge production systems (Beyer and Trice 1982). Searching for and becoming sensitised to possible utilization allows research users to define both the potential value they see and their potential need for more direct linkages with researchers and other intermediaries. In this way, as described by the interactive processes that are at the core of approaches like SIAMPI, research uptake occurs not only through the intermediation of knowledge pools or conveyed through publications, but through connections between users and researchers. Over time, these processes can institutionalise forms of interaction between research and user systems through which research agendas are defined and knowledge, at times, co-created (Regeer and Bunders 2009). From a user perspective, therefore, an understanding of the processes by which knowledge is generated and used needs to be based on a flexible and broad understanding of how different strands of knowledge reach the context of application and contribute to new practices or relevant new understandings.

3 Understanding the impact processes from the application context: Elements of a user-focused, process-oriented approach to the analysis of research impact

The metaphors of knowledge pools and trickle down processes help portray how, in many instances, the results of research become valuable to societies. Yet, they also suggest the difficulties in assessing in some degree of detail the extent to which scientific research has contributed to a specific technology or decision, and what has been the nature and relative importance of each of the contributions made. The image of a pool conveys the notion of an undistinguished mass of knowledge; when one drinks from a pool one cannot differentiate from what specific sources different portions of water have come, neither is the drinker much interested in this question. This is, in fact, a common problem when asking users and beneficiaries about the kind of knowledge that has informed their decisions or practices. When did one come across a specific, in retrospect relevant, piece of information? How much of this information is then attributable to a specific set of research efforts? Knowledge combines and recombines before reaching an individual, older research results can be rediscovered or reinvented long after they were first discovered, or new uses can be found (reimplementation). How this happens is seldom apparent to the knowledge user and its originator. The preceding sections contain many references to case studies where this process has been disentangled, but an overview of the research to date suggests that narratives have accumulated without a shared conceptual frame of reference that could help in the analysis and comparison of impact processes. We need methodological and conceptual tools that will help us assess research impact from the users' perspective moving, whenever required, beyond a linear and instrumental understanding of impact, and enabling the identification of intangible outcomes.

Which traits of the impact processes should such frameworks take into account? The discussion of the literature above suggests some elements of our understanding of impact that need to be incorporated in user-based studies:

- *Impact*, understood as the effects of research on society, *is* better comprehended as *a process* (rather than a clearly identifiable and bounded result of a preceding process).
- This process is a *process of use that is the mechanism of value creation*: research is often defined and redefined in response to social needs and its emerging results combined and

recombined with other sources of knowledge and practice to generate constantly evolving use and valorisation processes.

- Each of the *actors* involved in this process may play several *roles*; that is, we need to move away from approaches that see scientists as doing (only) academic research, knowledge brokers transferring research results, and users applying it.
- To understand how impact occurs we need to understand interactions between actors whether as inter-organizational contacts (Spaapen and van Drooge 2011), as a "translation" or reconfiguration of networks of social and material elements (Callon 1986), or as a multidimensional array of communication between researchers and stakeholders (Bekkers and Bodas Freitas 2008, Abreu and Grinevich 2013).
- The study of impact processes needs to take into consideration the *user context* and particularly the relationships between users and the maturity of the linkages among them (Ven and Poole 1995).
- *Organisational capabilities* partly determine how research users and beneficiaries can interact with the research system and with each other.

Table 1: Researcher users and research value in impact evaluation

Evaluation approach	Identity of research users	Positioning of research users	Mechanism of value generation	Role of users	Conceptualisation of problem / value	Pathway to impact
Payback	Healthcare stakeholders	Close to and/or interested in health research	Sequence of permeable interfaces between research and healthcare systems; from problematisation to dissemination to use	Various Linked to sequence of interfaces/stages	Research/researcher led; Stakeholder adoption	Five forms of payback to research and healthcare systems and to society
SIAMPI	Stakeholders plus the general public Fluidity between researcher / stakeholder communities	In non-academic sectors of society; with close links to research/researchers	Productive interactions: direct, indirect and financial exchanges between researchers and stakeholder	Multiple Contributions to processes and uptake of knowledge or outcomes	Research/er defined; Stakeholder value-adding	Intermediary outcomes When 'productive interactions' result in stakeholders doing new things or doing things differently
ASIRPA	Heterogeneous actors in agriculture sector	As initial end-users, end-users, lead-users of agricultural research Forming networks of distributed user agency	Translation Problematisations from the wild to the lab and from the lab to the wild	Configured by network	Configured by research and adoption networks, intermediaries Changes in adoption scale, in the diversity of effects, or in learning processes	Scaling out (more initial end-users in expanded territory); scaling up (greater diversity of end-users)

Contribution analysis	Key actors in healthcare networks	As potential key users among actors linked to a research project	Contributions to interactive networks catalyzing a "going concern"	Evolving with relational network Scenario construction and development	Key user identified and mobilized	Alignment, bi-directional adaptation to integrate contributions
Outcome mapping	Societal actors using research outputs and services	As boundary partners close to research projects	Transdisciplinary contributions to objectives and actions	Boundary spanning	Transdisciplinary definition; boundary partner mobilised	Influencing diverse societal actors at the project boundary
Knowledge exchange	Health system practitioners	As part of research project team	Co-production	Designing, performing and disseminating research	Jointly defined, flexible outcomes	Practitioner research
Public value mapping	Heterogeneous first order and second order users	In knowledge value collectives connected by their relation to a body of information	Scientific and technical human capital (STHC)	Transforming or supporting the transformation of information	Plural; defined in active use of information	Knowledge value alliances; STHC mobility
Hindsight	Innovation actors	In systems design and development	Needs recognition	Identifying and communicating system problems	Ultimate user defined; system design driven	Recognised need
Two communities	Practitioners and policymakers	In user communities with distinctive values and ideologies	Accretion Direct linkages and brokering between knowledge production and user systems	Sensing, searching, diffusing	User community framed; user system defined	Institutionalisation

The preceding review of approaches to research impact has revealed two distinctive conceptualisations of research impact; impact generated through chains of knowledge focused connections between actors, and impact emerging from the 'taking up' of available and accessible knowledge. In the former, processes of interaction and collaboration with active knowledge agents generates research value, while in the latter intersection with codified outputs or artefacts is the necessary preliminary to the process of 'valorisation' of research in an application context. These are two very different models in which to attempt to define the role of the research 'user'. Based on the current state-of-the-art understandings then, there is apparent ontological divide in how research impact is understood from the 'user perspective' that we need to take account of in our thinking.

Our approach in the remainder of this section is to outline what we consider to be core elements of a conceptual approach to research impact from the user perspective. In doing this we reflect on both of our current state-of-the-art understandings of research impact and on their interrelationship. We also reflect on several key concepts that we consider to be central to shaping our understanding of research impact from the user perspective, including the concepts of research value, research impact, users, and beneficiaries.

There are a small number of simple principles that we derive from the diverse framings of research impact reviewed above. These can be simply stated:

1. the role of researcher user is actively and relationally defined
2. the role of research user is not fixed but changes over time
3. research users seek to generate or add value from research, whilst pursuing objectives relevant to their main field of operation
4. the generation and realisation of research value always exceeds its representation in reconstructions of research impact
5. end users and beneficiaries of research value can shift identities to become research users engaged in valorisation processes.

The initial principle then, which can be straightforwardly read off from the multiple approaches reviewed above, is that *the role and identity of the research user is actively and relationally defined*.

In the first understanding of research impact found in the literature, the research user is defined at any moment by the configuration of processes and actors collectively involved

in generating value from research knowledge. An actor (user) may be at one moment focused on adapting and translating basic science results into a processed form (research value), at another moment they may be providing services to other actors (users) on the customisation of an artefact or formula that relies on their prior contribution, supporting these other actors to themselves generate research value. In approaches such as SIAMPI and ASIRPA, value emerges from productive interactions among a constellation of knowledge-focused agents organised around a research or science knowledge-based question, problem, or challenge. In such contexts institutional fields overlap and organisations become more interdependent (Etzkowicz and Leydesdorff 1997). Relationships continue from one project into another, becoming more durable and multi-faceted. Researchers may become involved in the application of research results, both users and beneficiaries may contribute to the definition and conduct of research, and the intermediary role played by knowledge brokers requires active involvement in the research and application process that goes well beyond that of a connecting bridge. In the same line, applied researchers and expert consultants are not simply conveying and translating research but are involved in research themselves. In such evolving constellations of knowledge agents, different agents may be in the role of researcher 'user' at different moments, stretching their involvement and contributions across entangled processes of knowledge production, translation, communication, and utilisation.

As our review demonstrated, at one time the observation of such constellations of interacting actors tended to commence either from an arbitrary 'start-point', often a scientific discovery (that was usually purified of the prior work on which it relied), or from an observable 'end-point', often a technological artefact 'doing things' and having demonstrable effects (impact) in the world. However, increasingly this approach was modified to incorporate both 'non-linearity' and the continuously shifting and transforming terrains of knowledge-based socio-technical systems that themselves increasingly define scientific questions. From our perspective, precisely 'where' processes that generate research value start or end is an empirical question that is often not precisely answerable and will vary depending on the scope and level of an analysis – and so this is not our main concern. Rather what matters to us is that the active generation of value from research occurs in specific contexts and involves agents whose identities as knowledge producers, translators, communicators, or users are defined relationally and shift over time

as multiple, and sometimes competing, conceptions of the value that can be generated from research struggle to be realised.

In the second understanding of research impact found in the literature, the impact process is initiated by the taking up of knowledge from pools or reservoirs of research results. A research user is defined by this role of taking-up existing research outputs to valorise. There are important differences between research users defined by their relation to research outputs and users defined by their relation to other actors. Whereas the latter are involved in an active struggle to generate value from research, the former have an ambivalent relationship to the generation of value. On the one hand, the active take up of research results may be an outcome of intentional search and discovery processes. On the other hand, as we have seen, knowledge take up may be the outcome of diffuse processes of accretion and 'knowledge creep' (Weiss 1986) in which the user role may be relatively passive.

There is another important difference between a user defined by their relation to research outputs and one defined by their relations to other actors. The user defined by their relationship to research outputs encounters a set of affordances (Hellström and Jacob 2017) that are, relatively speaking, already set. The concept of value that can be designed and developed by the research user is thus relatively 'consequentialist', that is, this conception of value will flow in a considerable part from the affordances of the research output taken up. This contrasts with our first understanding, in which the possible affordances of the research are constructed – at least some of the time – through the self-same set of interactive processes through which (multiple) conceptions of value from the research are being struggled for and mutually configured.

This distinction is largely what praxis philosophies such as open science and open innovation are all about – reconfiguring the role of the user as connected and contributing to the interactions that shape the affordances and conceptions of value that are embedded in research and its outputs. From this praxis perspective, if affordances are relatively transversal, indeterminate, and values sensitive (Friedman et al. 2002; van den Hoven 2013), then possible conceptions of research value will be plural, diverse, and non-exclusionary. At the same time, related advances in knowledge infrastructures and protocols that make research data and outputs increasingly accessible and (re-)useable are

primarily designed to support the active take up of knowledge but will have a flow-on and potentially expansive effect on the relatively passive take up of knowledge as well.

Our second principle states that *the role of research user is not fixed but changes over time*. By this we simply mean that there are no *a priori* 'research users', entities that simply exist 'out there' in society waiting for a research result to drop off the end of the production line conveyer belt. There is no point, in our view, insisting on a separation between science and society or between researchers and communicators, when it comes to understanding how value is generated from research. If we understand research value as actively generated by multiple actors then precisely which actor is using research knowledge, and for what, will vary across time and as the struggle to articulate various concepts of value plays out.

In relation to the first understanding of research impact we identified, then this principle can again be quite straightforwardly derived from the extensive existing literature on 'impact pathways' and the like in which evolving sets of actors are involved and make contributions to knowledge processes. The role and identity of a particular active participant will depend both on the relationship to other actors (principle one) and on the type of knowledge process in which these actors are engaged. Activities that are devoted to knowledge production are often enjoined by actors whose primary objectives are knowledge translation focused – in such as context their relational identity is configured as a research user. When the focus of activities is knowledge translation then the same actors' roles will shift and other actors, for example those specialising in forms of science communication, such as enticing investors, informing the public, or lobbying politicians, are mobilised as active users of the research and its results.

In relation to the second understanding of research impact, an entity can be initially defined as a research user by the action of taking up research, or by the process of having their identity (or worldview) changed by the accretion of research results into their field of operation or existence. But this does not confine this agent to the role of research user, far from it, by disseminating the knowledge to other entities with interests and capabilities relevant for generating value from the research taken up the same agent immediately transforms their role to one of brokerage. Of course, in both understandings of research impact, it is also evident that actors can have multiple simultaneous roles, which is unsurprising as processes of knowledge translation and utilisation for example are often contiguous. While one role may be foregrounded at any point in time, this does not mean

other modes of contributing to knowledge processes disappear, rather they may recede during a particular phase of activities. Just as research value is potentially plural, so are the roles agents may be playing in seeking to realise this value.

These considerations about the plurality of valorisation that can be actively generated from research can be summarised in our third principle that *research users seek to generate value from research, whilst pursuing objectives relevant to their main field of operation*. As we described earlier, various methods of contribution analysis (Kok and Schuit 2012; Morton 2015) and impact process mapping (Spaapen and van Drooge 2011; Matt et al. 2017) have been particularly useful in highlighting how different types of actors make contributions, based on competences grounded in their own field of expertise, that are vital for the realisation of specific outcomes and innovations based on scientific research. What is often imagined as a relatively direct science-to-market pipeline structure, that for commercialising new pharmaceuticals, involves contributions from an array of agents, from medical instrument designers, to patent lawyers, to public health information creators, all of which are focused on the impact pathway of a new mass market drug primarily in relation to how it enables them to advance their position in their primary field of operation (advanced instrument manufacturing, law, marketing). While contribution analysis enables us to understand how the diverse contributions of different types of actors generate value that flows into a particular observable outcome, the drug itself, our third principle emphasises that it is the value that engagement in such as R&I pathway process can bring to the actor in their own main field or sector of operation that is essential to understand from the research user perspective. An innovative framework for translating research contributions outside the university into the value system of the academic field has recently emerged (Williams 2020). We would insist that to understand the full panorama of research value, the value that is generated by actively contributing institutional actors also needs to be understood in terms of how it accumulates capitals that are the stakes of the game in those actors' main fields of operation (Bourdieu 1990). From the research user perspective then, it is not necessarily the contribution to a new pharmaceutical that matters most, but the position of enhanced dominance that contributing to this outcome has allowed the actor to take in its own field of competition. We consider this principle applies equally both to research value created through

interactive chains of actors and activities and to the take up and utilisation of pre-existing research outputs and results.

Following on from this, it is evident in all the approaches we reviewed that strong limitations are placed on the extent to which the methodology used can capture the full extent of research impact. Focusing on what is more or less measurable and plausibly attributable research impact creates a pragmatic research object. These methods have made significant progress in allowing us to identify significant vectors of research value realisation and to highlight some main contributions to the various research objects these methods construct. Each of these methods build an analytic-explanatory narrative and logical structure[5] (Greenhalgh et al 2016), which inevitably comes at the expense of inconsistent or unruly elements that do not fit.[6] We would argue that the generation of value from research as it can be understood from adopting a user perspective is occluded by the institution of these analytic-explanatory narratives and the logical structure they convey. This is simply because the mapping out of the top-line vector of impact blinkers the multiple generation of research value from the user perspective (this is not a criticism, but a summary statement of a scientific approach and its limitations). Our fourth principle therefore states that from the research user perspective *the generation and realisation of research value always exceeds its representation in reconstructions of research impact*. From the user perspective, representations of research impact will (to a greater or lesser extent) occlude the multiple relatively 'sticky' localised processes, diffuse secondary institutional effects, and spontaneously or serendipitously generated new research value processes that may have emerged.

If much research value is occluded from the reconstruction of research impacts, a related problem exists in relation to the identities and roles of those for whom research value is understood to, in the end, lead to beneficial outcomes or effects. Three terms, research users, end users, and beneficiaries, are commonly used to refer to persons, organisations

[5] Classics of the genre including science push, market pull and hero innovator. These rudimentary archetypes have been supplanted by more sophisticated theory-based approaches that tend to favour systemic analytic-explanatory models (see for example Greenhalgh et al for a comparison).

[6] . 'Impact statements' of the streamlined and increasingly formulaic type favoured by national research system assessment in the UK and Norway, for example, represent a further reductionist step in which the connection to a key user or client is simply described and documented. There are sensible pragmatic reasons why such impact statements need to be tightly constructed (efficiency, comparability), but they do not provide insights into the realisation of research value in society from the user perspective (and neither are they intended to).

or other entities that are understood to benefit from the realisation of research value. There is a lack of conceptual clarity around these terms and exactly what they are meant to stand in for is rarely explicitly discussed. Beneficiaries from research do not necessarily have to be users, or end users of research – a drug consumed by a family member that stabilises their health provides benefits for the rest of the family. Consumers of knowledge-based commercially available mass produced goods are often beneficiaries of the 'black-boxing' of science and technology into a commodity – sometimes consumers engage in customisation or adaptation of such commodities shifting their identities to end users (von Hippel 2005) and sometimes they don't – the shifting contours of those who are content to be 'locked in' to the Google or Apple 'experience' and those who find workarounds and hacks is a perfect example of how research value mobilises evolving cohorts of consumers, (end) users, beneficiaries and non-participants. As our review illustrated, the function of the roles of end users and beneficiaries of research are often not clearly defined but are tacitly understood to mean those 'out there' in society that reap the rewards of investment in science and technology. From the principles of the research value from the user perspective we have already outlined it should hopefully be obvious that we consider these roles/identities to be relationally defined and actively configured in specific contexts of use. But what does that mean in concrete terms? This is one of the key questions that the OSIRIS centre is seeking to address through empirical studies. To illustrate the emerging understanding from this work in progress and the formulation of our fifth and final principle we briefly sketch three examples.

Empirical examples from the OSIRIS project

Our first example involves an economics research programme dedicated to the relationships between family life and labour market outcomes in Norway (Hardoy and Schøne 2008). This research featured strongly in policy debate across several issues over a period of around two decades. A specific research line related to the effect of parental leave following childbirth on labour market outcomes. This research was taken up in a Norwegian Official Report (NOU 2008: 6) for the Ministry of Children and Families, particularly the finding that increasing the length of paternal leave had a significant positive effect on overall family and labour market outcomes. This finding was eventually adopted in two separate changes of regulations raising paternity leave from 10 to 14 weeks and the responsibility for implementing the new rules then fell to employers. Finally, the

direct beneficiaries of the use of this research by the Ministry and by private and public sector employers, were the fathers of newborn *barnes* in Norway after 2013. However, if seems clear that all other family members were also intended beneficiaries of the policy changes.

In this example, research user roles are occupied at various moments by the Ministry of Children and Families policy formation, by the framers of new government regulations, and employers large and small. In the case of the various ministry units occupied in translating economics research into public policy the intended beneficiaries of their use of the research findings were obviously Norwegian family members. But were corporations, firms, and public sector employers also beneficiaries of the research from the perspective of the Ministry of Children and Families? If the 'benefits' of the research-driven changes was improved employee mental health, and a general smoothing of labour market inefficiencies deriving from struggles to balance family and work life at the level of families, then the answer is quite probably in the affirmative. From the perspective of employers, the changes no doubt entailed a more concrete calculation of both costs and benefits from extending paternal leave. However, if increases in paternal leave have the long-term beneficial effects on family life, if employees are more likely to return to work feeling rested, and if employees are content in the knowledge that a strong father-child attachment has been established, then it is more likely they will be working at full capacity immediately on return. Once again, it is not difficult to see the way that employers shift from being research users, to being potential beneficiaries over time.

On the face of it, employed Norwegian fathers were not in an active user role, configuring the value of the research according to their own conceptions. But is this strictly the case? Individual fathers may well have been conscripted or volunteered to participate in surveys or qualitative studies undertaken by the Human Resource department of their company or public agency about the effects of the research, or to participate in studies undertaken by the Ministry and/or academic researchers. Such ongoing use of the research configures these entities relationally as users of the contributions that Norwegian fathers (and potentially also their partners) make to the further evolution of this knowledge-based socio-economic settlement, based on their first-hand experience. Norwegian fathers shift from being passive beneficiaries to active co-producers of knowledge outputs that can then function as inputs to the next policy cycle. The shifting roles and identities of these research

users and beneficiaries are relationally defined while each of the key knowledge agents struggles to configure value from the research in terms of their main conceptualisation of value: from the perspective of the Ministry of Children and Families in terms of national welfare; from the perspective of employers in terms of productivity; and from the perspective of fathers in terms of emotional value.

Our second example is from the area of rare diseases (RD), particularly the role of patient organisations (PO) (Callon and Rabeharisoa 2007). Rare disease POs gather together RD patients and their families to participate in the co-creation of bio-medical knowledge, typically by providing and connecting natural history data and by volunteering biological samples, and in the co-production of institutional frameworks for the use of knowledge for diagnosis, treatment and care of RDs. The impact of human genome science has been particularly profound in the field of RDs, in which approximately 80 percent of identified RDs are genetic conditions or have genetic subtypes (Marshall et al. 2020). In particular, the development of next generation sequencing (NGS) technologies and their gradual distribution and integration in clinical medicine has raised hopes of reducing the time to diagnosis for individuals with undiagnosed conditions (Turro et al. 2020).

In this example, the use of NGS technology in clinical settings to do whole exome (WES) or whole genome sequencing (WGS) of patients with undiagnosed conditions basically uses the same set of techniques and media as used in basic research laboratories devoted to exploratory and discovery work. Combined with the frequent institutional overlap between hospitals, universities, and specialist centres of expertise (CoEs) for RD the proximity of basic research and clinical practice is intensified, reducing the time lag for transfer and translation of knowledge between researchers and clinical practitioners as users of the knowledge generated by the other.

On the face of it, RD patients can be conceived as beneficiaries of the integration and streamlining of NGS in clinical settings. However, this would overlook their role as the providers of biological samples and the active work done by POs to configure value from clinical research by provide complementary case history data and personal (often whole of family) sequencing information to a variety of repositories and databases. In fact, the compiling, curation and sharing of such datasets is essential to the construction of structural variant libraries of sufficient size to enable the statistical power required for bioinformatic processing (Leonelli 2016). The affordances of sequencing data outputs even allow

undiagnosed patients to share their genomic data online through different types of platforms in an effort to find a 'match' with other isolated suffers in different parts of the world (e.g. MyGene2, RD-Connect). In short, while RD patients and POs can be at times configured as the beneficiaries of research value generated elsewhere, it is more common that patients and POs occupy roles of active research users. The affordances of the sequencing data generated by researchers and clinicians have transformed the replicability, transmissibility, and re-use possibilities of research results in such a way that multiple sites of research value creation can be more easily mobilised and consolidated through distributed networks of expertise (for example European Reference Networks (ERNs) for RD in Europe).

Considered from the user perspective, the continuous contributions of patients and POs to research and clinical initiative seems to maintain RD patients' relational positioning relatively consistently as research users, who conceive the value of this active participation in terms of reducing the effects on individuals and families of the often lengthy and difficult undiagnosed 'patient odyssey'. At the same time patients and POs are integrated in the efforts of basic researchers to generate value in terms of advancing genomic knowledge and clinicians to enhance diagnostic processes and outcomes – crucially through exchange and use of knowledge that each produces in their main context of operation. In this example then, the identification of relatively indirect beneficiaries from improved diagnosis of RDs may be better focused on knowledge accretion into policy and practice for common diseases or the repurposing of orphan drug products.

Our third example involves a banal everyday technology, electronic gaming machines (EGMs), also known as slots or gambling machines. Once mechanical devices in which three cylindrical reels were spun by hand using lever pull, EGMs are artefacts that embed a range of science and technology in a virtualised consumer gambling device. EGMs are ICTs programmed to assign symbols to a video interface that emulate the experience of the spinning wheels of the mechanical devices. Each bet is activated by the gambler, triggering a random number generator (RNG) that assigns symbols to the virtual reels on the screen. The assignation of symbols is controlled by a programmed random reinforcement schedule derived directly from the research of behavioural psychologist B. F. Skinner. These random reinforcement schedules distribute 'wins' to gamblers, combined with other calibrated sound and light stimuli, creating a hybrid device that forms

human addiction by design (Dow Schull 2012). Individual devices are then connected to networks that enable the scaling up of top prizes through linked and timed jackpots that create increased opportunities to provide reinforce and generate excitement among gamblers distributed across socio-geographic space.

Contemporary EGM manufacturers employ computer scientists, psychologists, and mathematicians, patenting innovative new and updated versions of these hybrid devices to create market cycles. Gambling venues then utilise spatial and lighting design research to set-up their gambling rooms so as to produce an immersive experience designed to extend the time spent gambling by individual consumers. While social science research produces varying results in different national regulatory contexts, combined with different levels of accessibility of EGMs and varying cultural attitudes toward gambling, social research consistently finds that somewhere around half of all EGM gambling losses come from around 10 per cent of the EGM gamblers. The medicalisation of this social segment as 'problem gamblers' then draws on a range of other research outputs, particularly psychology, to 'treat' those afflicted. At the same time, a distinct body of public health research focuses on the 'production of harm' by EGM devices, attempting to shift control of gambling addiction upstream to the disproportionate availability of EGMs in lower socio-economic areas and to the 'predatory' calibration of the science-based elements of the devices themselves. In contrast, interested industry actors seek to focus attention on individuals using labels such as 'flawed consumers', 'addicts' or 'disordered gamblers'.

In this example the major research user role is occupied by the gaming machine manufacturing industry, dominated by stock market listed companies with large patent holdings and revenues, competing for market shares in liberalised gambling economies such as Australia, Macau (PRC), the UK and the USA. Gaming machine manufacturers also form industry associations that lobby government regulators and pay academics and consultants for research that reinforces a vision of gambling addiction based on a medicalised model of psychologically impaired individuals who lack appropriate self-control. The conception of research value for these users is focused on 'building a better mousetrap' that most efficiently returns profits to gambling licence holders, in order to obtain and retain the best market share possible in new EGM sales.

A major beneficiary of the gaming machine manufactures integration of multiple strands of science and technology are gaming venues and licensees. Owning and operating EGMs

generates profits that, depending on the calibration of the devices and the level of top prizes permitted, can be very substantial. Yet EGM operators also interact with industry intermediary, collating and analysing machine and venue level data, experimenting with the mix of devices and arrangements, in a research and development driven strategy to increase the use of the devices and enhance financial returns. These data feed into wider strategies including providing detailed (bet level) information to manufacturers on device performance 'in the wild'. Venue proprietors can thus shift from being relatively passive beneficiaries of the gaming machines operating in their venue to being active contributors and knowledgeable agents about strategies for monitoring and maximising performance according to their conception value based on private profit. Indeed, many gambling venues offer subsidised food and drinks to customers to potentially entice greater participation in EGM gambling given the np-risk profitability associated with the long run mathematical certainty that gambler-citizens will collectively lose.

Another major beneficiary of gaming machine device technology is government, at whatever level has responsibility for licensing and taxing gambling activity. Gambling machine taxes returned to governments can constitute very significant proportions of total government revenue and an 'irreversible' techno-economic network of governmental, commercial and consumer agents can become consolidated (Callon 1990). While clearly relationally positioned as financial beneficiaries of EGM gambling, governments must also weigh this apparent benefit against other responsibilities for the welfare of the citizenry. Government agents regular commission or conduct their own research on the 'prevalence' of 'problem gamblers' and estimate social costs, including phenomena such embezzlement from employers to funding addictions, and including the direct costs of state-funded counselling and recovery services. Governments roles shifts to the production and use of knowledge for formulating gambling policy that conceptualises value in terms that are frequently conflicting – on the one hand the inflow of (highly regressive) secondary taxation revenues and the (highly disputed in the research) value of hospitality job creation, and on the other hand the 'acceptable' level of social harm, to individuals and families and businesses, that can be tolerated (and must be paid for) as an effect of the addictive capacities of EGMs.

Who then is the end-user, the pure and ultimate beneficiary of the research that is commodified in gambling machines? This must be the general public, citizens who realise

value from EGM gambling as relaxation, fun, and the shared enjoyment of consuming harmless entertainment in a social venue, with the chance they may even pay for their night out – or something better – as a manifestation of pure random chance. Certainly, for some cohorts of citizens this is the case (users of electronic gaming machines are a minority of the overall population in all countries). The fact that no form of tactical or skilled play can influence the outcome of the random processes of the device reduces the cultural barriers (rules, tactics, etiquettes) that restrict entry to skilled gambling games for some consumers, makes gaming machines the easiest way for individuals to take the role of 'a player' and enter into the seemingly free circulation of capital and the marking out of winners and losers. However, if we look a little closer, we learn that around ten per cent of regular EGM gamblers develop compulsive gambling problems and are soon being introduced to new forms of information, about the 'odds' of winning, about the way gambling machines work, and are being re-framed into a new social cohort of 'problem gamblers' with their own community of support and emergency resources. They often then become research participants, providing testimony about the experiences to feed into gambling and community health policy processes. And what of the citizens who do not gamble, but whose family members, friends, colleagues, or employees – some of them mobilise data and research to campaign against the commercial gambling industry, or to remove gambling machines from their local hotel or club, or to seek retribution through the courts for losses due to embezzlement or theft of assets to fund gambling. We see here the fractals of impact that spread out around the shifting cohorts of research users, end users and beneficiaries, and the formation of a 'concerned group' (Callon and Rabeharisoa 2007) that, rather than conceptualising value as emerging from this industrial scale research and innovation effort, see only the deleterious social and economic effects that neo-classical economics researchers so adeptly set outside the frame of calculation with their concept of 'externalities'.

Contestation in the policy sphere is another domain in which the identities and roles of research users and beneficiaries shift. Australia, Norway, and UK have all conducted gambling reviews that have included assessing the harm associated with electronic gambling machines (DCMS 2018; Engebo 2010; Engebo et al. 2021; Productivity Commission 1999, 2010). Formal submission of evidence including by industry, academic researchers, gamblers and concerned citizens contributed to constructing the evidence base

for potential policy reform. Citizens once cast as beneficiaries presented evidence (often their own case history) to lobby for greater protections for gamblers; the gaming machine industry presented evidence designed to protect the 'rights' of consumers who are entertained by gambling machines without any negative side effects. In all three cases, acknowledgement of the harmful capacities of EGMs underpinned proposed policy reform. These reforms were moderate in Australia, with a reduction in the largest denomination of currency that could be entered into a device, and in the UK with a reduction in the maximum bet on certain categories of machines. In Norway by contrast, the entire gaming machine industry was nationalised, with all existing machines being removed (2007) and recalibrating at relatively safe levels of potential consumption (2009), combined with removing banknote acceptors and introducing an individual access identity that tracks consumption and allows the setting of personal limits that cannot be overridden in the short run (Engebo 2010; Engbo et al 2021). Crucially, in both the case of Norway and the UK, the regulating authorities did not rely on their role as users of others' research but placed strong value on their own internal research outputs (based on network data and surveys) in formulating policy responses (DCMS 2018; Engebo et al. 2021). The markedly different policy outcomes reached, based on a largely overlapping knowledge base, reflect how distinctive conceptions of value are actively configured in specific contexts where knowledge is used (in this case for policy) (Edler et al 2020). Considered from the research user perspective then, we can see there are myriad repercussions of research value – positive and negative - generated from just one banal and seemingly trivial consumer device.

Collectively our three examples have tried to illustrate the relational definition of researcher users, end users and beneficiaries, and how these roles and identities can shift around distinctive conceptualisations of research valorisation. The precise logics and factors that shape these relational dynamics in the specific contexts where value is actively configured remain to be properly explored in systematic research starting out from the user perspective, about which we say something in our concluding remarks. Nevertheless, the consistency among our examples lead us to formulate our fifth and final principle that *end users and beneficiaries of research value can shift identities to become research users engaged in valorisation processes* under certain conditions. As our three examples hopefully illustrated, viewing the specificities of different contexts of research valorisation

from the user perspective opens up a rich panorama of actors, affordances, and shifting roles, that can offer insights into how research value proliferates and makes a difference in society. We would argue that these examples of tracking the shifting role of 'research user' right through to the evolution of policy cycles in consolidated health and industry sectors highlights why deeper engagement with the user side can add value to our understanding of research impact.

4 Concluding remarks

In the first part of this paper, we reviewed the literature on methods for assessing the impact of scientific research. We found that work in this area has been very successful in developing a variety of sophisticated approaches, often tailored to a particular problem or policy context, to construct plausible and credible sets of sequences linking research to societal outcomes – despite enormous technical problems related to time-lag and appropriate causal-type attribution. This literature has also been successful in identifying and testing relevant institutional, organisational, and individual factors that appear to influence the translation of research results and/or their take up by research users. These approaches have tended to treat the roles of research users, end users and beneficiaries as functionally appended to the impact trajectory they construct, as either recipients of research outputs or beneficiaries of research-based outcomes.

In the Discussion section, we derived from this literature some (methodological) principles regarding the user perspective on research impacts that can apply to research impact conceived as produced through chains of knowledge interactions between actors or through the take-up of research outputs by interested parties. We do not consider these principles to be exhaustive in scope or consolidated in form, rather they constitute our initial attempt at their formulation. Our impression from undertaking this review and attempting to derive some general principles from the research user perspective is that there is considerable potential for re-framing research agendas to consider the user role and its dynamics more fully in understanding research value and impact. We have noted the strong importance of understanding the researcher as a shifting role and identity, but what determines or shapes the fluidity of role and identity shifts in contexts of research value generation and

realisation? It is apparent from the methods we reviewed that the affordances of research results are important here, but systematic work to connect the epistemic, material, and symbolic affordances of research with the active struggle to conceptualise value by research users seems needed (Hellström and Jacob 2017). At the same time neither the 'fitness' of different knowledge agents to be prepared to cycle through the research user role is well understood, nor is their 'intentionality' in relation to problematisation processes and the conceptualisation of research value. Finally, we think the process of undertaking this work has made it clear that taking a step away from an increasingly consolidated 'impact agenda' to focus on how research value is actively generated and realised from the user perspective is desirable. A perspective emphasizing users and value could provide a complementary way of seeing to enrich impact-focused approaches generally and, potentially, contribute new elements to existing methods toolboxes for theory-based assessments of the impact of specific interventions, programmes, and activities.

We also consider that relevant policy insights may be developed from our proposed approach. For example, from a policy perspective our first principle states that to effectively generate research value a variety of different actors, with relevant capabilities and distinctive objectives, should be able to cycle fluidly through the role of research user. This is different to stating that a diverse set of actors should interact and collaborate. According to our second principle the struggle to realise value from research need be neither narrowly or *a priori* locked in, nor a 'survival of the strongest' contest underpinned by a zero-sum logic. Rather research valorisation can be understood as inherently multiple and pluraliz-able. Currently, certain translation measures that may be considered 'efficient' may rather operate to segregate translatable research value from diverse institutional fields. While such thinking is speculative at this point, it seems to us that our discussion here does contain elements of potential interest for those policymakers concerned that their 'impact agenda' could be refreshed by an infusion of thinking that takes a different perspective as both its starting and anchor point.

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