GRC 2019 Annual Meeting

Expectations of Societal and Economic Impact

Political decision-makers worldwide apply substantial amounts of public funds to support and foster scientific research on behalf of the society they represent. In return, they expect publicly funded research to generate impact. Research funding organisations have a key role in identifying research that generates impact, as they channel public funding into research projects using specific funding criteria and decision-making processes.

Recently, there has been growing unease with an alleged lack of short-term tangible impact of publicly funded research. Political decision-makers and other societal stakeholders seem increasingly concerned about a perceived deficit of science in contributing to the solution of societal problems or in fostering innovation.[1] Consequently, demands for research that generates more immediate and visible impact on society and the economy have considerably increased over the last decades.

Addressing expectations of societal and economic impact

The focus of the 2019 Annual Meeting of the Global Research Council (GRC) will be to discuss two ways of how research funding organisations have responded to the increased expectations of societal and economic impact.

(1) Some research funding organisations have introduced **societal or economic impact as funding criteria** for research projects. A discussion on mechanisms and implications of this approach is included in **Annex I**.

(2) Other research funding organisations have focused on improving the **assessment and demonstration of the impact of research of funded projects after their completion**. A discussion on mechanisms and implications of this approach is included in **Annex II**.

For the first time, the GRC will therefore focus on one topic – "expectations of societal and economic impact" – and discuss two approaches of how to address it. Both approaches have different objectives. The rationale behind "introducing societal or economic impact as funding criteria" is that the societal and economic impact of research can and should be maximised. The rationale behind improving the "assessment and demonstration of the impact of research of funded projects" is that research often has societal and economic impact, which needs to be better assessed and made more visible. Both approaches are not mutually exclusive and can complement each other.

This paper introduces the overall topic with a definition of the impact of research and a call to balance different forms of research. A visual presenting the two approaches of how to address the expectations of societal and economic impact is then followed by a set of questions to guide the debate at the Regional Meetings. The two annexes go into greater depth and thus provide the basis for an informed discussion at the Regional Meetings.

[1] The perceived deficit in contributing to the solution of societal problems or to fostering innovation is sometimes considered a part of an overall legitimacy crisis of science, which is also nurtured by reported cases of scientific misconduct such as plagiarism and fabrication of results, false claims of authorship or the replication crisis.

Different forms of research impacts

No research is impact-free, but the impact of research can have different forms. It can for example lie in the advancement of knowledge[2], in contributions to societal challenges or in fostering innovation.[3] Accordingly, the EU Commission distinguishes between "scientific", "societal" and "economic" impact in its draft for the EU framework programme Horizon Europe (2021-27).[4] Some funding organisations distinguish even more forms of impact.[5] Speaking of "impact" in this paper and in the two annexes, we broadly refer to all forms of impact. If we refer to a specific form of impact such as "economic impact", it will always be mentioned.

The different forms of impact can complement each other or come in different degrees at different points of time. Some research might primarily contribute to the advancement of knowledge, but also materialise in societal and economic effects. Other research might be geared towards solving a particular societal challenge, but also result in groundbreaking knowledge. The impact of research will also differ according to the form of research. The impact of fundamental research will typically be less predictable and more long-term than the impact of research in mission-oriented settings directed towards particular goals in specific timeframes.

Balancing different forms of research

In its 2017 "Statement of Principles on the Dynamic Interplay between Fundamental Research and Innovation", the Global Research Council (GRC) recognises that the relation between fundamental research and innovation is complex.[6] While mission-oriented, applied or priority-driven research creates more immediate and plannable societal and economic returns, curiosity-driven, fundamental and non-thematic research will also contribute to societal benefits or economic development, however in rather unexpected ways and timeframes.

For a long time, scientists, political decision-makers and the public agreed on Vannevar Bush's "linear model of innovation"[7] that basic research would generate broad knowledge, which applied research could then draw upon. This would lead to innovation and progress and thus generate impact on society or the economy. This meant that research funding organisations focussed primarily on the "scientific excellence" of proposals and their potential contribution to the advancement of knowledge because this would ultimately also benefit society and the economy, even if only incrementally so and largely unplannable. There was an unspoken agreement that what was good for science would also be good for society. However, this assumption has become fragile. There is growing scepticism whether self-referential "science for the sake of science" will ultimately contribute to societal challenges or to fostering innovation.

Research funding organisations need to address the increased expectations of more immediate societal and economic impact. However, in doing so, they should not forget that both immediate returns and the virtue of fundamental research to push scientific frontiers are essential

[2] Alternative terms for "the advancement of knowledge" are "scientific", "intellectual" or "academic" impact.
[3] Science Europe, which represents research funding and research performing organisations in Europe, advocates using the notion of „value" of research instead of "impact" in order to better reflect the contribution of research to the advancement of knowledge. See Science Europe (2017): On a New Vision for More Meaningful Research Impact Assessment, Science Europe Position Statement (https://www.scienceeurope.org/wp-content/uploads/2017/07/SE_PositionStatement_Impact.pdf).
[4] European Commission (2018): Proposal for a Regulation of the European Parliament and of the Council establishing Horizon Europe – the Framework Programme for Research and Innovation, laying down its rules for participation and dissemination (https://ec.europa.eu/commission/sites/beta-political/files/budget-may2018-horizon-europe-regulation_en.pdf).
[5] E.g. The Science Foundation Ireland distinguishes eight forms of societal impact: Economic, societal, international engagement, policy & public service, health and wellbeing, environmental, professional services and human capacity. See Science Foundation Ireland (2018): Research impact (http://www.sfi.ie/funding/award-management/research-impact/).
[6] Global Research Council (2017): Statement of Principles: The Dynamic Interplay Between Fundamental Research and Innovation (https://www.globalresearchcouncil.org/fileadmin//documents/GRC_Publications/Statement_of_Principles_for_The_Dynamic_Interplay_Between_Fundamental_Research_and_Innovation.pdf).
[7] Vannevar Bush (1945): "Science: The endless frontier", Washington: United States Government Printing Office.

elements for vibrant national and international research ecosystems. It is the task of such ecosystems to balance between these different forms of research in order to maximise the overall impact of the research they fund. Regaining societal trust by maximising short-term societal and economic impact of research should not come at the cost of jeopardising the capacity of science to contribute to future problems.

Addressing expectations of societal and economic impact

Annex I: Societal or economic impact as funding criteria

Some funding organisations have introduced societal or economic impact as funding criteria aiming primarily at maximising the societal and economic impact of proposed research projects.

Potential methods:

- *Ex ante* or *ex post* assessment of societal / economic impact as funding criterion besides scientific impact (different weighting)
- Dividing the evaluation procedures for excellence and impact: E.g. Experts review the expected impact of preselected scientifically excellent projects
- Open Science as funding criterion to achieve higher societal impact

Annex II: Assessing and demonstrating the impact of funded research

Some funding organisations have resorted to assessing previous research results, primarily aiming at making the impact of research on the advancement of knowledge, society and/or the economy more visible.

Potential methods:

Assessment:
- Bibliometric and patent studies
- Econometric studies
- Case studies
- Surveys
- Programme evaluation

Communication:
- to the research community
- with society
- with policy makers, legislative and executive branch

Input from the regional meetings
(see questions next page)

Questions for discussion at the GRC Regional Meetings

The discussion at the Regional Meetings of the GRC could focus on the following questions, which are by no means exhaustive:

- Do GRC participants share the assumption of an alleged or real deficit of societal or economic impact of publicly funded research?
- What experience do GRC participants have with societal and economic impact as funding criteria as well as with assessing and demonstrating the impact of funded projects?
- In balanced and diversified research ecosystems: In which funding schemes do GRC participants see potential for societal or economic impact as an evaluation criterion? Are there funding schemes that should remain free from short-term impact expectations?
- Do GRC participants believe that ex-ante impact assessments in the funding decision-making process provide the right incentives for researchers?
- Do GRC participants have examples of how to demonstrate better the often unplannable and more long-term societal and economic impact of curiosity-driven research?
- Do GRC participants have ideas of how to disseminate the different impacts of research to different target groups (research community, general public, government officials and representatives)?

The aim of the Regional Meetings of the GRC will be to gather the different perspectives, experiences and approaches of research funding organisations worldwide. Possible outcomes could be:

- Assessment of the benefits and challenges of using societal and economic impact as funding criteria
- Ideas and examples of how to assess the expected societal and economic impact of research in funding decision-making processes
- Examples of the long-term societal and economic impact of curiosity-driven research
- Ideas and examples of how to assess and demonstrate the different impacts of funded projects
- Ideas and examples of how to disseminate the different impacts of research to different target groups

Annexes

Annex I: Societal and Economic Impact as Funding Criteria

Annex II: Assessing and Demonstrating the Impact of Research on the Advancement of Knowledge, on Society, and on the Economy

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Annex I: Societal and Economic Impact as Funding Criteria

Research funding organisations base their funding decisions primarily on the scientific excellence of a research proposal. Peer reviews may also include impact assessments, but typically focus on the contribution of research projects to the advancement of knowledge.[1] Scientific peers look *ex ante* at the potential impact of a proposal to scientific advances (e.g. theory, methods, application etc.). The evaluation often also includes elements of an *ex post* evaluation of the previous contribution of a researcher to the advancement of knowledge by looking at his/her previous scientific accomplishments.[2]

However, there has been growing unease amongst policy-makers and the public with an alleged lack of immediate societal or economic impact of publicly funded research. The idea that excellent research will ultimately also benefit society and the economy, even if only incrementally so and largely unplannable, has come under scrutiny. In response to this, many research funding organisations have introduced additional assessments of the societal or economic impact of funded research. These assessments can focus on the potential societal or economic impact of a proposal (*ex ante*) and/or on a researcher's previous contribution to society and economy (*ex post*). The rationale has been that this would generate research results with more immediate societal and economic impact. Thus, researchers and funding organisations would regain the societal trust necessary in order to justify that their research would continue to be publicly funded.

The implications of relying on societal or economic impact as funding criteria have increasingly made it to the agenda of national and regional science policy debates.[3] The aim of the Regional Meetings of the Global Research Council (GRC) will be to gather the different perspectives, experiences and approaches of research funding organisations worldwide with regard to societal or economic impact as funding criteria. This paper shall provide the basis for an informed discussion.

Examples for impact assessments of research funding organisations

There are several examples for research funding organisations, which nowadays include an *ex ante* or *ex post* assessment of societal and economic impact as funding criterion.

Since 1997, the US National Science Foundation has included a "broader impacts" criterion as one of two evaluation criteria beside "intellectual merit" applicable to the evaluation of all funding proposals since 1997.[4] For applicants to UK Research and Innovation, describing the prospective "academic", "economic" and "societal" impact has been an essential component of

[1] Alternative terms for "the advancement of knowledge" are "scientific", "intellectual" or "academic" impact.
[2] Scientific impact can be assessed quantitatively by focusing on bibliometric studies such as the number of scientific outputs and citations, the combination of both in the so-called "H(irsch) index", total research dollars or journal impact factors. Scientific impact can also be assessed qualitatively through narratives or by interpreting awards and other proxies for recognition of excellence. Some of these assessment methods are controversial and deserve their own debate.
[3] E.g. Science Europe, which represents research funding and research performing organisations in Europe, has worked extensively on the implications of societal impact assessments within its Scientific Advisory Committee and its Working Group on Research Policy and Programme Evaluation. See Science Europe (2017): Building a Scientific Narrative on Impact and Societal Value of Science, Symposium Report (https://www.scienceeurope.org/wp-content/uploads/2017/07/SE_PositionStatement_Impact.pdf); Science Europe (2017): On a New Vision for More Meaningful Research Impact Assessment, Science Europe Position Statement (https://www.scienceeurope.org/wp-content/uploads/2017/07/SE_PositionStatement_Impact.pdf).
[4] National Science Foundation (2013): Chapter III - NSF Proposal Processing and Review (https://www.nsf.gov/pubs/policydocs/pappguide/nsf13001/gpg_3.jsp).

their research proposals and a condition of funding since 2010.[5] The Netherlands Organisation for Scientific Research (NWO) has asked applicants since 2013 to describe how their research contributes to society and to the economy.[6] "Knowledge utilisation" is one of three main criteria across all funding programmes besides "the quality of the researcher" and "the quality, innovative character and academic impact of the research proposal". The three criteria are weighted differently across funding programmes.

In some funding research organisations, the introduction of societal and economic impact as funding criteria has also raised the question why scientific peers should remain the only suitable persons for evaluating research. The Science Foundation Ireland uses international experts from other societal areas to review and rank the impact statements of preselected scientifically excellent projects.[7] These impact reviewers include company directors, heads of translational institutes, technology transfer professionals or investors in scientific/technology early-stage companies for example.

Open Science agendas also serve as a way to increase the societal impact of research. More and more funding organisations mandate researchers to publish open access, require applicants to make their data available online or encourage the inclusion of societal stakeholders. By doing this, the European Commission for example aims at achieving "higher societal impact".[8] Open Science has not become a funding criterion so far, but could become "an element to consider in the evaluation of proposals" of the EU framework programme "Horizon Europe" (2021-27).

The benefits of a societal or economic impact assessment

There is consensus that one of the roles of science is to address specific themes and contribute to certain goals (e.g. the Sustainable Development Goals). The establishment of defined impacts is therefore a valid and often necessary strategy in mission-oriented settings, applied research or priority areas (e.g. governments dealing with health or energy crises, industry developing new products, etc.). Here societal and economic impact assessments will orient researchers towards *ex ante* expected, intended and short-term impact. Thus, they are a valuable tool in selecting those research proposals for funding, which are expected to be better capable of contributing to specific objectives.

Highlighting the variety of potential impacts already at the proposal stage will encourage researchers to think about how their research will benefit society and the economy.[9] Researchers may become aware earlier of how their research can possibly be translated into application. Earlier engagement with relevant societal stakeholders will also improve the researchers' understanding of what is actually relevant and of interest to stakeholders and thus shape both the research questions and ultimately the research results towards more immediate impact. In return, societal stakeholders might show more interest in and understanding of the research outcome than can usually be expected from post-research communication.

Beyond the research process, assessing the societal and economic impact of research will help research funding organisations to deliver on the accountability expectations of society and

[5] Applicants are allowed to depart from this rule, but they need to give reasons for this. See UK Research and Innovation (2018): Pathways to Impact (https://www.ukri.org/innovation/excellence-with-impact/pathways-to-impact/).
[6] The Netherlands Organisation for Scientific Research (2018): Knowledge utilisation (https://www.nwo.nl/en/policies/knowledge+utilisation).
[7] Science Foundation Ireland (2018): Research impact (http://www.sfi.ie/funding/award-management/research-impact/). See also Science Europe (2017): Building a Scientific Narrative on Impact, p. 12.
[8] European Commission (2018): Commission Staff Working Document Impact Assessment, Accompanying the documents for Horizon Europe – the Framework Programme for Research and Innovation (https://ec.europa.eu/info/sites/info/files/swd_2018_307_f1_impact_assesment_en_v6_p3_977548.pdf), pp. 103-107.
[9] Cf. for the following: Kate Harland & Helen O'Connor (2015): Broadening the Scope of Impact. Defining, assessing and measuring impact of major public research programmes, with lessons from 6 small advanced economies, Public issue version: 2 (http://www.smalladvancedeconomies.org/wp-content/uploads/SAEI_Impact-Framework_Feb_2015_Issue2.pdf).

its political representatives towards publicly funded researchers. Moreover, it can help research funding organisations as an advocacy tool in budget negotiations. At the same time, it will help political decision-makers to better justify research expenses to society.

Recognising the unplannable nature of research

"Science for the sake of science" (i.e. science that contributes primarily to the advancement of knowledge) will have societal or economic impact as well, although researchers do not explicitly calculate it or plan for it prior to conducting their research. Most curiosity-driven, fundamental and non-thematic research will fall into this category. Its impact often is unexpected, unintended and very long-term, as understanding the consequences of new knowledge takes time and requires scientific results to be connected with methodologies and insights from other scientific disciplines or with society. Contingent on the availability of such complementary knowledge, societal or economic impact of fundamental research often materialises years or decades later, which, however, can then lead to disruptive innovations. Research funding organisations should therefore be cautious with regard to relying only on *ex ante* or *ex post* impact assessments as funding criteria.

Moreover, as *ex ante* societal or economic impact assessments of research proposals orient researchers towards expected, intended and immediate impact ("known unknowns"), there is a risk that this could happen at the expense of pushing scientific frontiers to the "unknown unknowns" – the problems, which society did not even conceive of at the time of research. Many research projects, which resulted in key technological advancements, did not foresee any future societal or economic impact.[10] Examples include Hertz's electromagnetic waves, Einstein's general theory of relativity, Drude's investigation of the reflexion of metals, and Bardeen, Brattain, and Shockley's work on semiconductor contacts, without which there would be no radio communication, no transparent touchscreen, no integrated circuits, processors or memory chips and no GPS. The digitisation of society goes back to insights from quantum physics of the 1920s. The Radon transform from 1907 enabled the development of X-ray computed tomography in the 1960s.

Basing funding decisions on societal or economic impact assessments could also lead to gaps in scientific knowledge in areas, which are not of societal interest at one point of time, but might be so later, as societal challenges change over time. If there is a lack of fundamental knowledge to draw upon, it will be difficult to react adequately to suddenly emerging, so far unprecedented societal challenges. Moreover, demanding societal or economic impact equally from all scientific fields in all topics could also disadvantage certain disciplines such as the humanities or mathematics, in which it will generally be harder for a research project to make a plausible case for concrete and immediate societal or economic effects than in the engineering sciences.

Finally, requesting statements on societal or economic impact in project proposals could lead to a proliferation of ultimately undeliverable promises, which will not necessarily increase societal trust in research. On the other hand, in order not to fail impact promises and possible penalisation in future proposal reviews, researchers might opt to only promise less ambitious projects (low-hanging fruits), which will less effectively contribute to a thriving research and innovation system.

The need for a balanced approach

There is therefore a need for a diverse and balanced approach towards the establishment of societal and economic impact as funding criteria. Research funding organisations could for

[10] Cf. Science Europe (2017): Building a Scientific Narrative on Impact, p. 8.

example employ societal and economic impact criteria according to their specific organisational missions and the purpose of their funding instruments instead of introducing them generally across all funding instruments. They could also weight impact areas differently according to their missions and instruments. Research funding organisations focussing on applied research might put a particular emphasis on economic impact; other research organisations focussing on societal challenges might evaluate the societal impact of the researchers they fund.

At the same time, the national or international research ecosystem should give enough room for research, in which impact assessments should remain limited to the advancement of knowledge. However, shifting political priorities and budget constraints have increasingly made it difficult for research funding organisations to uphold the most effective balance between different forms of research. The economic aspects of innovation and the need to contribute to societal challenges tend to dominate the discussion, obscuring the more long-term impacts of research. Targeting immediate returns could however sacrifice long-term breakthroughs. The GRC has addressed this challenge in its 2017 "Statement of Principles on the Dynamic Interplay between Fundamental Research and Innovation"[11], where it says: "Maintaining long-term, stable support for publicly funded fundamental research is essential, as focusing too much on short term results will put the future seeds of innovation at risk."

Another question is whether it is possible to include the long-term effects of research in societal and economic impact assessments. In its 2018 background paper on peer review, the GRC demands "any system evaluating impact to be sufficiently long-term to not limit research to applications of or innovations based on the already known."[12] Science Europe also suggests including "the value that research can create for future generations" in impact assessments.[13] However, a societal or economic impact assessment, which can take into account the unplannable nature of impact, still needs to be developed.

In addition, funding organisations are increasingly expected to reflect scientific excellence, impact and open science in their funding decision-making processes. However, there might be a conflict of goals between scientific excellence, impact and openness. Excellent research might not have immediate societal or economic impact or vice versa. Open science might not automatically be better science.[14] It remains to be seen whether research funding organisations will be able to satisfy demands to fund excellent science, which is at the same time open and to the immediate benefit of society.

Discussion at the GRC Regional Meetings

This Annex shall serve as a starting point for the discussion at the GRC Regional Meetings. Many of the discussion items might look more relevant at first sight for research funding organisations with a broad funding portfolio (from fundamental towards mission-oriented research) and considerable funding resources. However, the discussions should also be interesting for research funding organisations with a stronger focus on a particular mission or with less available funds, as they are part of national and international research ecosystems in which the various kinds of funding need to be balanced.

[11] Global Research Council (2017): Statement of Principles: The Dynamic Interplay Between Fundamental Research and Innovation (https://www.globalresearchcouncil.org/fileadmin//documents/GRC_Publications/Statement_of_Principles_for_The_Dynamic_Interplay_Between_Fundamental_Research_and_Innovation.pdf).
[12] Global Research Council (2018): Background Paper on the Revision of Global Research Council Statement of Principles and Approaches on Scientific Merit Review (http://grc.rfbr.ru/files/Background%20Paper%20on%20the%20Revision%20of%20Global%20Research%20CouncilStatement%20of....pdf).
[13] Science Europe (2017): On a New Vision for More Meaningful Research Impact Assessment.
[14] The European Commission suggests renaming the excellence pillar into "open science" in the draft for the EU framework programme Horizon Europe (2021-27). This nicely illustrates how a gradual paradigm shift seems to take place, which accepts research only as excellent if it is also open. See European Commission (2018): Proposal for a Regulation of the European Parliament and of the Council establishing Horizon Europe.

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Annex II: Assessing and Demonstrating the Impact of Research on the Advancement of Knowledge, on Society, and on the Economy

Summary

Across the globe, governments apply substantial amounts of funds to support and foster research activities. Previous experience shows that excellence based research contributes, given other essential elements, to the creation of economic development and/or societal benefits. Frequently, innovation - the creation and diffusion of new products, processes and methods - benefits from fundamental research. However, the connection between research and innovation is complex and is affected by national or regional policies, behaviours, and opportunities.

Under pressure to demonstrate accountability and return on the investment in research, many countries debate intensely what would be the most effective balance between fundamental and applied research, necessary to achieve the best impact on society. In a context of increasing research costs and tighter national budget conditions, the quest for research that brings short term tangible impact tend to put great tensions on the research funding institutions. The above-mentioned complexity of the relation between fundamental research and innovation many times obscures the discussions and may lead to short-term based reasoning, targeting immediate returns that would sacrifice the future opportunities.

Adding to the already complex challenge, the economic aspects of innovation tend to dominate the discussion, obscuring other aspects such as societal benefits and the intellectual and improvement of societies through the advancement of knowledge.

Many RCs around the world face these challenges and a common conclusion is that it is necessary to better communicate to society about the necessity and benefits of a strong fundamental research enterprise, capable of training the next generation of researchers and creating new ideas that will foster innovation. Councils have used several mechanisms and instruments to this end, from communication to the public to the commissioning of economic studies and publications, including in a few cases involving the public directly in the definition of priorities in an informed way. However, in many cases it seems the efforts tend to fall short.

The discussion of the topic “Assessing and Demonstrating the Intellectual, Social, and Economic Impact of Research” will allow the GRC participants to exchange best-practices and develop new ideas each council might use to keep society not only informed about the relevance of fundamental research for the benefit of all, but involved as a key player and supporter in the organisation of the national scientific enterprise.

Contents

1 Formulation of the problem – what do we mean by research impact

Assessing and demonstrating the benefits of research for society has been a challenge for research funding and research performing organisations for some time. The increase in the use of public funds to support research broadly – in universities, research institutes, and in industry through subsidies and tax breaks – which occurred especially since the end of World War II, made the issue more preeminent.

In the aftermath of the war, many countries organised (or reorganised, with a more relevant role for government funding) their research funding systems. Great influence in this endeavour came from Vannevar Bush's "Science the Endless Frontier"[1], in which the author summarised the benefits that the U.S. society could expect from research in the war against disease, in defence, in the public welfare, and in industrial research.[2]

In recent years, worldwide, it seems that the patience and "good will" of society towards the use of taxpayer money to support research has decreased. The situation is summarised in a recent editorial on Nature magazine, under the title "Researchers should reach beyond the science bubble"[3], which affirms that "it is also clear that the needs of millions of people in the United States (and billions of people around the world) are not well enough served by the agendas and interests that drive much of modern science" and that "scientists in the United States and elsewhere ought to address the needs and employment prospects of taxpayers who have seen little benefit from scientific advances".

The challenge then is how can research-funding bodies across the globe do a better work to assess and demonstrate to the public - and to their representatives - that the impacts from research continue to benefit society, perhaps even more than decades ago?

"Research impact" is a category much broader than "fundamental research impact". In this section, we want to describe some initiatives that might bring useful ideas to the challenge of assessing not only the impact of research in general, but specifically that of research funded with public money.

It is our view that "research impact" encompasses a myriad of channels through which research results can benefit society. To organise the discussion, we will classify these impacts in three broad types that we will consider as "dimensions" of research impact:

a) Intellectual and cultural impacts of research: these are the benefits of research for the advancement of knowledge in all fields, which contribute to make society wiser, and thus more capable of weighting the options ahead of itself, for development, the organisation of society, dealing with unexpected challenges.

b) Societal impacts of research: these would encompass the results of research that create, in a more or less direct way, benefits for society that cannot be appropriated in a private way. Examples would be improvements in managing and conserving the environment, discoveries that improve public health or other public services (education, transportation, defence, safety, habitation).

[1] Vannevar Bush, "Science the Endless Frontier", (United States Government Printing Office, Washington: 1945). https://www.nsf.gov/od/lpa/nsf50/vbush1945.htm.
[2] A well-documented case is the creation of the São Paulo Research Foundation (FAPESP) in Brazil, in 1947, in a movement started by a report by scientists in São Paulo, Brazil, (Carta de Homens de Catedra e Laboratório; see Chapter 1 in MOTOYAMA, S.; HAMBURGER, A. I.; NAGAMINI, M. (Org.) Para uma história da FAPESP; marcos documentais. São Paulo: FAPESP, 1999. 248p; http://www.bv.fapesp.br/pt/103/para-uma-historia-da-fapesp-marcos-documentais/) which reproduced, as an Annex, Bush's "Science the Endless Frontier".
[3] Nature Editorial, "Researchers must reach beyond the science bubble", Nature 542, 391 (23 February 2017).

c) Economic impacts of research: these encompass the results of research that, being potentially appropriated in a private way, can lead to the development of the business sector, or even create new sectors of industry.

In many countries, there are multiple channels of public support for research. Even considering the funding side of research support (as opposed to the research performing), there are many cases in which different missions are designated to different funders. This must be taken into account when research impacts are discussed and demonstrated. A key point here is that the research system is expected to deliver relevant impacts to society, but this does not mean that each component of the system should deliver the same type of impacts as in each national system; different funders might be focused on different aspects of creating such impacts.

2 Previous knowledge - other initiatives and ideas regarding research impact assessment

Robert Solow won the Nobel Prize for Economics for his studies that demonstrated that growth of an economy depended not only on capital invested and labour available, but also on other characteristics associated to technology (the Solow Residual). His prize was awarded "for his contributions to the theory of economic growth" and the related press release explains that, as a result of his model for growth accounting published in 1956,[4] "technological development will be the motor for economic growth in the long run".[5]

During the same period, Zvi Griliches came up with the first specific study measuring the economic impact of the adoption of a technology. He studied the introduction of hybrid corn in the United States.[6] He concluded that "the process of innovation, the process of adapting and distributing a particular invention to different markets and the rate at which it is accepted by entrepreneurs are amenable to economic analysis". In a subsequent article[7], he calculated the rates of return. His overall conclusion, stated in the paper, is worth mentioning here:

> "In this paper I have estimated that the rate of return on public investments in one of the most successful ventures of the past has been very high. This may give support to our intuitive feeling that the returns to such ventures in general have been quite high and to our feeling that "research is a good thing". However, that does not mean that we should spend any amount of money on anything called "research". The moral is that, though very difficult, some sort of cost-and-returns calculation is possible and should be made. Conceptually, the decisions made by an administrator of research funds are among the most difficult economic decisions to make and to evaluate, but basically they are not very different from any other type of entrepreneurial decision."

His idea stimulated a long sequence of works measuring the economic impact that continues to be improved until today.

Ben Martin from SPRU has studied the assessment of publicly funded basic research in several publications. He summarised the economic impact measurements done by other authors in the table shown in Table 1.

[4] Robert Solow, "A Contribution to the Theory of Economic Growth", The Quarterly Journal of Economics, Vol. 70, No. 1 pp. 65-94, (Feb., 1956).
[5] The Royal Swedish Academy of Sciences, "Press Release" (1987). https://www.nobelprize.org/prizes/economics/1987/press-release/.
[6] Zvi Griliches, "Hybrid Corn: An Exploration in the Economics of Technological Change", Econometrica, Vol. 25, No. 4, pp. 501-522 (Oct., 1957).
[7] Zvi Griliches, "Research Costs and Social Returns: Hybrid Corn and Related Innovations", Journal of Political Economy, Vol. 66, No. 5, pp. 419-431 (Oct., 1958).

Table 1: A summary of estimates for rates of return to public R&D spending[8]

Estimates of rates of return to publicly funded R&D

Studies	Subject	Rate of return to public R&D (%)
Griliches (1958)	Hybrid corn	20–40
Peterson (1967)	Poultry	21–25
Schmitz-Seckler (1970)	Tomato harvester	37–46
Griliches (1968)	Agricultural research	35–40
Evenson (1968)	Agricultural research	28–47
Davis (1979)	Agricultural research	37
Evenson (1979)	Agricultural research	45
Davis and Peterson (1981)	Agricultural research	37
Huffman and Evenson (1993)	Agricultural research	43–67

Source: Griliches (1995) and OTA (1986). Many authors of these studies caution about the reliability of the numerical results obtained (cf. Link, 1982).

The data in Table 1 illustrates the range of results, demonstrating the difficulties involved in modelling the relations between research funding and its economic benefits. At the same time, it demonstrates that the rates of return tend to be rather high, ranging from 20 to 67%. It must be pointed out that these are rates of return to public research spending, and not only to "fundamental" research spending.

Martin created a taxonomy of 'exploitation channels'[9] for research results, adding to the dimension of "economic impacts" discussed in the preceding paragraphs. Some channels are more readily measurable than others and most channels listed connect to substantial benefits.

A summary[10] of the channels would be:

1) Increasing the stock of useful knowledge;
2) Training skilled graduates;
3) Creating new scientific instrumentation & methodologies;
4) Forming networks and stimulating social interaction;
5) Increasing the capacity for technological problem-solving;
6) Creating new firms;
7) Provision of social knowledge.

On the more practical side of impact assessment and analysis, Science Europe (SE), an association of European Research Funding Organisations (RFO) and Research Performing Organisations (RPO), issued a position statement in July 2017 "On a New Vision for More Meaningful Research Impact Assessment"[11]. The report summarises several "key principles", of which we highlight:

[8] Ben R. Martin and Salter, A.J., "The economic benefits of publicly funded basic research: a critical review", Research Policy 30, 509–532 (2001).
[9] Martin et al., 1996; Salter et al., 2000; Salter & Martin, 2001; Scott et al., 2002; Martin & Tang, 2006.
[10] Martin, B. "Assessing the Impact of Basic Research on Society and the Economy". (https://www.researchgate.net/publication/228894032_Assessing_the_Impact_of_Basic_Research_on_Society_and_the_Economy).
[11] Science Europe, "On a New Vision for More Meaningful Research Impact Assessment", July 2017 (http://www.scienceeurope.org/wp-content/uploads/2017/07/SE_PositionStatement_Impact.pdf).

a) No impact assessment practice can ever fully capture the value of research. The contributions of research to society across scientific disciplines are highly diverse, in addition to the intrinsic value that research provides for continuous knowledge generation. This diversity cannot be captured by any single practice for impact assessment.

b) Different pathways connect research to its practical applications. The ways in which research contributions find their way into society are also highly diverse. There is no single standardised pathway that links research to its practical applications.

c) A too narrow notion of impact can lead to misinformed decisions and risks undermining research independence. Attempting to assess impact where it cannot be measured, or by using a wrong definition, can be extremely detrimental to the research system. The risk of defining impact as an immediate, one-directional effect of research on society to bring about observable and intended change must be avoided. Consequently, impact assessment should avoid putting additional administrative burden on researchers and research organisations, and it must not have any negative effects on researchers' autonomy and scientific independence.

d) There needs to be methodological diversity for correct assessment of research impact. Evaluation techniques and the availability of specific indicators should not drive assessments. Any research policy decision addressing impact assessment should be coherent with the objectives of the research itself.

e) Trust between research and society reinforces the potential for societal impact of research itself. Productive interactions between researchers and society that lead to a diversified use of knowledge should guide research impact assessment policies.

f) The creation of knowledge that broadens the options available to society ('options value') should be taken into account in impact assessment. Research organisations should identify the value that the research is expected to generate from the start, including the value that it can create for future generations.

SE recommends to their member organisations the following actions:

1) Help to include a broad notion of impact that incorporates the societal value of research in the practices and policies that will be implemented by research organisations, stakeholders, and policy makers in Europe.

2) Invest in understanding how impact processes vary across different environments where research activities or projects are conducted.

3) Adopt flexible approaches for dealing with impact assessment and ensure diversity of methodologies. Any impact assessment methodology should ensure that indicators used as part of an assessment that attempts to show causal links between the research and observable effects, are integrated into narratives and/or quantitative models.

4) Support a process of mutual trust between researchers and society. This includes facilitating close interaction between evaluators, researchers, policy makers, and research managers, as well as developing tools and incentives for researchers to reward their societal engagement.

5) Recognise the impact of international collaboration in research and promote it with appropriate strategies aimed to facilitate the participation of societal actors in this fundamental aspect of research.

6) Adopt meaningful strategies that emphasise the importance of knowledge creation and the wide spectrum of values and options that research brings to society. These should take into consideration the long-term effects of research in developing new impact-assessment policies and in promoting impact pathways.

3 Challenges to impact assessment and demonstration for publicly funded research

Previously, the GRC has recognised that long-term, stable support for publicly funded fundamental research is essential, as focusing too much on short-term results will put the future seeds of innovation at risk. Here we expand the scope of the previous declaration to deal with the impacts of research, not only of fundamental research.

The fiscal challenges that most governments face tend to create a pressure towards the reduction of the budget allotted to publicly funded research, as other demands for public funds seem to show more clear and visible short-term benefits to society. Thus, it becomes essential for research funding agencies to be able to demonstrate, as clearly as possible and especially within the national budget debate in which they participate, the benefits that accrue to society from publicly funded research.

At least three challenges exist to this demonstration:

a) Research results are, many times, not appropriable by the discoverers. For example, in economic theory fundamental results are classified as non-rival and non-excludable goods. They diffuse in a relatively easy way through society. Engineers and applied scientists anywhere can use them freely, as long as they have sufficient training to understand their nuances and complexity, a characteristic sometimes denominated as “absorptive capacity” (causation-attribution-delocalisation).

b) Frequently the application of the results from research happen may years later than the original discovery, and after several additional results and improvements to technology.

c) Some research results may not have any demonstrated economic or social effect other than making humankind wiser. They might, for example, facilitate or stimulate the creation of additional new knowledge. Or increase society’s awareness of the benefits of civilisation, or history, or democracy, affecting culture and society as a whole. For example, knowing that the universe originated from a Big-Bang 13.8 billion years ago does not create new businesses or cures sick persons, still it contributes to answer fundamental questions that most human beings are curious for.

4 Assessment of impact and its demonstration

Many research funding organisations have implemented impact assessment studies for their portfolio of grants. Most initiatives use one or more of five pathways:[12]

1) Bibliometric and patent studies;
2) Econometric studies;
3) Case studies;
4) Surveys;
5) Programme evaluation.

[12] Ben R. Martin and Salter, AJ; Luke Georghiou, “Value of Research”, Policy Paper by the Research, Innovation, and Science Policy Experts (RISE), (European Comission, 2015).

4.1 Bibliometric and patent studies

Bibliometric studies relate mostly to the assessment of the scientific impact of research, but there are relevant studies in the space of patent-public investment relations. Bibliometrics is a topic subject to many agreements and disagreements. The widespread use of the Journal Impact Factor for assessing impact brought a bad name for bibliometrics, but there are ways to use bibliometrics in a much more prudent way. The Declaration on Research Assessment (DORA)[13] and the Leiden Manifesto[14] are relevant documents that defend prudency on the use of bibliometrics, especially when assessing individuals. Here we deal with the impact of a research funding agency, or an S&T system, but still caution is advised when using bibliometrics. On the other hand, bibliometric indicators are easy to access and can provide useful insight about the number of publications or on their citation count. Indicators about international co-authorship or citation count can be useful for research funding agencies to learn about some of their regional challenges.

Patent data can lend itself to use in demonstrations of the impact of publicly funded science in economic development. The classic work in this field is that of Narin and colleagues, demonstrating that the number of scientific articles cited in patents in the U.S. tripled between 1987-88 and 1993-94. The authors also found that seventy-three percent of the papers cited by U.S. industry patents result from public science, authored at academic, governmental, and other public institutions; only 27% are authored by industrial scientists.

A much more recent article by Danielle Li, Pierre Azoulay and Bhaven Sampat[15] studied 27 years of grant-level funding by the U.S. National Institutes of Health. The authors found that about 10% of grants are directly cited by patents suggesting some technological application, and 30% of grants are cited in research articles that are then cited in patents. Five percent of grants result in papers cited by patents for successfully approved drugs, compared with less than 1% that are cited directly by such patents. These patterns hold regardless of whether the research is more basic or applied. Considering only patents for FDA-approved biopharmaceuticals, the same authors estimate that one dollar of NIH funding generates $2 in expected lifetime drug sale.[16]

The connection between scientific articles and patents was re-examined in a much more detailed way than that described in Narin's seminal article by Mohammad Ahmadpoor and Benjamin F. Jones.[17] They found, for example, a prevalence of direct citation of university papers in business patents, consistent with long-standing conceptions that consider university outputs as public goods upon which marketplace invention can draw (see section 3). They also found that, on average, the patent application that directly cites an article happens 6.66 years after the article's publication date. In the case of articles that were cited by other articles that were then cited by a patent, the time delay can be as long as 22.7 years. This lends credibility to the a-synchronicity related challenges mentioned in section 3.

4.2 Econometric studies

Econometric studies deal with the economic impacts of research funding. Table 1 shows the results of some studies of this type, targeting public research expenditures.

[13] https://sfdora.org/.
[14] https://www.nature.com/news/bibliometrics-the-leiden-manifesto-for-research-metrics-1.17351.
[15] Danielle Li, Azoulay, P., Sampat, B., "The applied value of public investments in biomedical research", Science 356(6333), pp. 78-81. (http://science.sciencemag.org/content/356/6333/78).
[16] Pierre Azoulay, Joshua S. Graff Zivin, Danielle Li, and Bhaven N. Sampat, "Public R&D Investments and Private-sector Patenting: Evidence from NIH Funding Rules", NBER Working Paper 20889 (January 2015).
[17] Mohammad Ahmadpoor and Benjamin F. Jones, "The dual frontier: Patented inventions and prior scientific advance", Science 357 (6351), 583-587. (DOI: 10.1126/science.aam9527).

This type of analysis can be done elsewhere: a pioneering study of the type made in Brazil, by Harry Ayer, in the 1970s. Together with George Schuh, they studied the rate of return for the public investments in research related to cotton made by the state of São Paulo, Brazil.[18] The authors found that "the internal rate of return to Brazilian society is estimated to have been approximately 90 percent. The effect on export earnings was large, and consumers benefited via a decrease in the price and an increase in the quantity of cotton cloth." More recently Figueiredo, Barros e Conceição studied the citrus sector in São Paulo, Brazil,[19] and found that each R$ 1.00 invested in agricultural research by the state government adds R$ 13.67 to the value of orange production in the state.

A broader study conducted also in the state of São Paulo, Brazil, found that for the agribusiness economic sector, each R$ 1.00 of public investment by the São Paulo Research Foundation (FAPESP) in agriculture R&D brings an increase of between R$ 6.00 and R$ 23.00 in the production by the private sector in the state.[20]

In the UK, a report prepared for the Department for Business, Innovation and Skills (BIS) by Frontier Economics analysed, in 2014, the rate of return of the public expenditure in research of the UK Research Councils.[21] They found that publicly funded R&D investments in the UK generate significant social rates of return of around 20%. The report also states that there is some evidence that R&D channelled through research councils, and particularly science-based and more applied research council investments, appear to have the greatest impact on private sector productivity growth.

4.3 Case studies

Case studies are many times used for performing impact assessments that cover a much larger set of channels of impact (see page 5). A high-profile application of case studies to assess and demonstrate impact is their use in the well-known UK Research Excellence Framework (REF).[22].

In the U.S., the Association of University Technology Managers (AUTM) has been presenting, for many years, case studies[23] that demonstrate the economic impact of university research in the U.S. and in Canada.

4.4 Surveys

Surveys can be useful tools for assessing some impacts of research. A classic example is the study by Edwin Mansfield, published in 1984, in which he calculated rates of return for industrial R&D expenditures[24]. He found that the rates of return were around 28%.

[18] Harry W. Ayer and G. Edward Schuh, "Social Rates of Return and Other Aspects of Agricultural Research: The Case of Cotton Research in São Paulo, Brazil", American Journal of Agricultural Economics, Vol. 54, No. 4, Part 1, pp. 557-569 (Nov. 1972).
[19] Margarida Garcia de Figueiredo, Alexandre Lahóz Mendonça de Barros e Junia Cristina Peres Rodrigues da Conceição, "Retorno Econômico dos Investimentos em P&D na Citricultura Paulista", Revista de Economia e Sociologia Rural (RESR), Piracicaba-SP, 50(3), p. 493-502, (Jul/Set 2012).
[20] Paulo Cidade de Araújo, "Total Factor Productivity in São Paulo Agricultural Sector and Public Investment in Human Capital", https://www.researchgate.net/publication/309779463_Total_Factor_Productivity_in_Sao_Paulo_Agricultural_Sector_and_Public_Investment_in_Human_Capital.
[21] Frontier Economics Ltd, "Rates of return to investment in science and innovation", (July 2014). http://www.frontier-economics.com/publication/rates-of-return-to-investment-in-science-and-innovation/.
[22] http://www.ref.ac.uk/.
[23] http://www.betterworldproject.org/.
[24] Edwin Mansfield, John Rapoport, Anthony Romeo, Samuel Wagner, George Beardsley, "Social and Private Rates of Return from Industrial Innovations", The Quarterly Journal of Economics, Vol. 91, No. 2, pp. 221-240 (May, 1977).

The same author used a survey[25] among industrial R&D managers to study the sources of ideas that lead to technological innovations. Mansfield assessed the impact of academic research on industrial innovation in a set of companies in the U.S., finding that academic research made an essential and immediate contribution to 10% of the new products or processes introduced by companies over the period studied. He also found that 10% of innovations would have been greatly delayed and 2% of innovations lost without academic research.

AUTM's annual report, built with the help of a survey among university technology managers, presents a wealth of information about start-up creation, patent filing and licensing that provides a useful database for demonstrating economic impact of research.

4.5 Programme evaluation

Programme evaluation can be extremely helpful to assess and demonstrate impact, with the additional advantage that it provides also insight that allows the research funder to improve or correct the effectiveness of their strategies.

Programme evaluation also lends itself to the assessment of a broad set of impact channels (see page 5). The U.S. NSF has been a pioneer agency in programme evaluation. Bozemann and Youtie describe and compare four of these cases in a recent publication.[26]

In Europe, the ERC has recently conducted a highly visible[27] evaluation of its programme of grants.[28] In this case, the ERC evaluated the scientific impact of their completed grants. In Germany, DFG has been conducting programme evaluations on a regular basis since 2003.[29]

In Brazil, the São Paulo Research Foundation (FAPESP) has been performing programme evaluation since 2007, with the first results announced in 2009.[30] Now, programme evaluation has progressed to be a permanent activity.[31]

5 Communicating research impacts to society

As important as assessing research impacts is communicating them effectively to society.

There are at least three broad channels of communications for research councils: a channel to communicate with the research community, another one to communicate with society, and one to communicate with government officials and representatives. In each of these three channels, the most effective instruments might differ and we list below the main instruments used for each channel and may depend on the science literacy level in the region or country.

1) Communicating to the research community:

   a) Council websites
   b) Newsletters
   c) Social media

[25] Edwin Mansfield, "Contributions of new technology to the economy", in Technology, R&D and the Economy, eds. Bruce Smith and Claude Barfield. p. 125 (The Brookings Institutions, Washington, DC, 1996).
[26] Barry Bozemann and Jan Youtie, "Socio-economic impacts and public value of government-funded research: Lessons from four US National Science Foundation initiatives", Research Policy 46 (2017) 1387–1398.
[27] Alisson Abbott, "Major funder tracks impact", Nature 535, p. 477 (2016).
[28] ERC, "Qualitative Evaluation of completed Projects funded by the European Research Council (2017)", https://erc.europa.eu/content/qualitative-evaluation-completed-projects-funded-european-research-council-2017.
[29] http://www.dfg.de/en/dfg_profile/facts_figures/evaluation_studies_monitoring/studies/index.html.
[30] Sergio Salles-Filho, Maria Beatriz Bonacelli, Ana Maria Carneiro, Paula F Drummond de Castro and Fernando Oliveira Santos, "Evaluation of ST&I programs: a methodological approach to the Brazilian Small Business Program and some comparisons with the SBIR program", Research Evaluation, 20(2), pp. 159–171 (June 2011).
[31] http://www.fapesp.br/en/evaluation/.

2) Direct communication with society

    a) Social media
    b) Editing journals and magazines covering research described in terms accessible to the general public
    c) Distributing targeted news clippings or newsletters
    d) Participation of Research Council staff and leadership in news pieces or writing opinion articles in newspapers or TV or social media
    e) Incentives for funded PIs to develop science diffusion and communication activities

3) Communicating with policy makers, legislative and executive branch

    a) Official meetings and hearings in the legislative branch
    b) Organizing joint activities highlighting research results and impact (seminars, work-shops, panel discussions)
    c) Distributing targeted news clippings or newsletters.