

Life, Environmental and Geo Sciences Committee Opinion Paper



The Importance of International Collaboration
for Fostering Frontier Research

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**SCIENCE
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Executive Summary

Currently, scientific communities worldwide are witnessing the need for rapidly growing international collaborations in science and technology. Such collaborations are needed in life, environmental and geosciences because research in these areas addresses scientific questions that deal with global challenges, and as such requires input from a wide range of experts from across the world. These collaborations are often based on large interdisciplinary projects where different scientists contribute to the research findings with their complementary expertise and thereby strengthen the integration of knowledge. Importantly, progress in understanding global challenges and complex living systems depends on fostering collaborative frontier research. This is basic research that reaches beyond disciplinary boundaries, resulting in the advancement of fundamental knowledge on the above-mentioned challenges, giving rise to ground-breaking discoveries and early-stage marketable innovations.

With the European Research Council (ERC) grant scheme being dedicated to investigator-driven research, the current absence of ERC Synergy Grants¹ from the funding schemes, and the Horizon 2020 Societal Challenges primarily focused on near-market applied research, the Committee highlights the limited funding opportunities for collaborative frontier research at EU level. In addition, a gap analysis of international collaborative funding schemes offered by national research funding organisations and various research funders worldwide highlights several challenges. These include an insufficient degree of interdisciplinarity in research funding programmes, limited opportunities for multilateral funding in comparison to bilateral agreements, and a low number of international partners involved in current collaborative schemes. Finally, the Committee underlines the importance of a bottom-up approach in funding schemes designed to capture creative ideas directly from the research community and users.

The Committee recommends that in order to strengthen international collaborative research, the national research funding organisations should consider increasing their efforts to widen the participation of various European countries and global partners in multilateral schemes, whilst fostering interdisciplinarity and knowledge integration. In this context, the national funding

organisations should consider establishing a multilateral funding scheme in support of frontier research that gives rise to ground-breaking discoveries and advancement of fundamental knowledge about complex living systems and global challenges. Any such funding scheme should accommodate 'proof of concept' (POC) research that bridges the gap between a discovery that originated from frontier research and early-stage innovations. Moreover, a bottom-up approach should be adopted in order to collect research proposals that contain novel ideas and solutions, captured directly from the research community and users, thus enabling open innovation.

► Internationalisation of R&D

Scientific research is a global endeavour which bridges different nations and often requires international collaboration. At present, one can witness growing internationalisation of collaborations in science and technology due to the urgent need for solutions related to global challenges such as climate change, food security, sustainable energy, health, management of geohazards, soil, water resources and many more. Because of their order of magnitude, these issues cannot be tackled by one country alone, nor by a limited number of stakeholders or disciplines. Thus, increasing the scale by working in multinational and international settings is crucial in order to enhance the potential impact of research dedicated to tackling these challenges.

The need for further efforts towards worldwide-scale research collaborations and joint funding schemes has been underlined by the Global Research Council (1). This network of heads of research funding organisations from around the world promotes research on a global scale, data sharing, and exchange of best practice for high-quality collaboration.

In recent years, there has been a tendency for researchers to form collaborations that result in co-authored research outputs, with collaboration rates between countries rising from 14% in 2003 to 17% in 2011, as inferred from the Scopus publication database on patterns of co-authorship of research outputs (2, 3). This is the largest abstract and citation database of peer reviewed research literature in the world, providing a good representation of the geographical, language and disciplinary distributions of publications globally.

In addition, bibliometric studies have shown that research outputs obtained from international collaborative research have a higher citation impact than those that are limited to one country or a single institution (3). In Europe and the US, citation impact tends to grow as the geographic extent of collaborations increases with the inclusion of worldwide partners. In 2011, Europe (defined as consisting of the 41 countries with direct eligibility for the Seventh Framework Programme) produced 33.4% of the world's research outputs (articles, reviews and conference papers), while the US accounted for 23.4%, according to analysis of the Scopus database. The international research scene is changing quickly with new and important actors joining, such as China and

South Korea. China has large human resources and rapidly increasing budgets dedicated to R&D; these reached 1.07% of GDP in 2002 and 1.97% in 2012 (4, 5). Whilst South Korea reached the highest percentage of R&D spending in the world, equalling 4.36%, the EU-28 spent 2.06% on R&D in 2012 (4, 5). In this context, strategies for funding research on a global scale need to be revisited in order to strengthen the competitiveness of European research worldwide.

► **Interdisciplinarity of Research Projects**

Besides greater internationalisation of research, another emerging trend is towards larger interdisciplinary projects. Expert teams cover different disciplines that deal with various aspects of global challenges. For example, impacts of climate change are analysed by life, environmental and geoscientists, and include experts from the social sciences and humanities. These integrated efforts allow in-depth analysis leading towards a better understanding of the nature, mechanisms and social context of global changes.

Scientific progress is often achieved by these collaborative teams, where interdisciplinary research efforts are becoming crucial in fostering knowledge integration. This trend is distinctly illustrated by the current developments in 'Big Data Science'. The current rise of 'Big Data', facilitated by rapid advances in high-throughput technologies combined with fast progress in computational science, has provided increasing possibilities for data collection worldwide. This, in turn, allows for in-depth analysis and integration of collected data into improved predictive models aimed at forecasting global events such as climate change, patterns of diseases, agricultural productivity, emerging geohazards, impacts of various phenomena on the environment and public health, analysis of the molecular make-up of individuals in diverse populations, as well as many others. In this context, the added value of international collaborative research is undeniable and, indeed, in many cases critical.

► **Challenges in Funding Collaborative Frontier Research**

For the purpose of this paper, the Committee defines frontier research as basic research that reaches beyond disciplinary boundaries and the frontiers of current understanding. Frontier research gives rise to the advancement of fundamental knowledge of complex living systems and global challenges, breakthrough discoveries, and earliest stage marketable innovations.

In the full research and innovation cycle, deep innovations and technological breakthroughs often spin off from discoveries that originated from frontier research. These discoveries can be further tested using so-called POC research in order to determine whether they may actually work in practice, and thus whether it is worth investing the financial resources (in particular the resources of industry) into truly applied research on a given topic. These practically validated discoveries are

further translated into products and applications that tackle unmet public needs. For example, the discovery of new drugs, vaccines, therapies, new crop varieties, potential sources of bioenergy, mechanisms underlying climate, biodiversity, and environmental changes, emerging geohazards and even the functional analysis of the human gene sequence, starts with frontier research that gives rise to breakthroughs and the generation of fundamental knowledge.

At present, the ERC provides funding for frontier research largely by supporting investigator-driven research (6). However, currently within this scheme there are no funding opportunities for collaborative research conducted by international teams, independently from the fact that ERC grant holders are likely to be participating in other international projects. In 2011, the ERC introduced Synergy Grants intended to enable a small group of principal investigators and their teams to bring together complementary skills, knowledge, and resources in new ways, to jointly address research problems. This particular grant scheme is currently unavailable whilst it is under review (7).

The ERC also offers POC funding, with a view to bridging the gap between discoveries and the earliest stage of a marketable innovation. However, this funding opportunity is offered only to successful applicants already in possession of a running ERC grant (6). Such an approach should be encouraged and extended to other funding schemes beyond ERC, to capture potential contributions from the scientific community at large.

The Committee has also analysed funding opportunities for frontier research in the Horizon 2020 Societal Challenges (8). Its conclusion is that the work programmes released to date are very much focused on near-market applied research without taking into account the fact that discoveries, new products and applications often originate from frontier research at the earliest stage of commercialisation. In the current work programmes, a new product is expected to be delivered within five to seven years. This proposed time scale does not match the average of ten to 15 years required by the pharmaceutical industry to complete the full research and innovation cycle starting from the discovery of, for example, a new drug compound to finishing with a product on the shelf (9, 10).

In the context of the Horizon 2020 Societal Challenges, the first calls for the 2014-2015 work programme dedicated to the Challenge 'Climate action, environment, resources efficiency and raw materials' put strong emphasis on applied research such as improved management of various resources, re-use, and near-market product development. The proposed topics related to climate change include provision of reliable science-based climate information, climate services, environmental economics, and facilitated engagement of citizens. Very little attention is dedicated to basic research, for example aimed at an in-depth understanding of the mechanisms underlying climate, biodiversity and environmental changes.

In the life sciences, the proposed topics are also very close to near-market research products and applications, with few opportunities for funding of breakthrough frontier research and the development of new technologies. The same is true for the Horizon 2020 Challenge 'Health, demographic change and wellbeing', where topics are very specific and focused on applied research (8). Hence, this disproportionate attention given to applied near-market research is expected to result in widening the existing knowledge gaps in our understanding of the complexity and interdependencies of living systems and a decline in breakthrough discoveries that are the bedrock of the innovation process.

European national research funding organisations support frontier research by offering doctoral and postdoctoral fellowships to individual scientists and by awarding research grants. These organisations also support collaborative research between national research institutions and international partners, mostly through bilateral grants. However, the opportunities for frontier collaborative research on a large international scale, involving multiple teams and interdisciplinary research on a global scale are rather scarce. In the next section, the Committee performs an analysis of different funding opportunities for such endeavours.

► **Gap Analysis of International Collaborative Funding Schemes**

So far, the Committee has underlined the need to foster international collaborative research on the worldwide scale that involves interdisciplinary teams. The Committee concluded that in Horizon 2020 there are insufficient funding opportunities for collaborative frontier research that gives rise to breakthrough discoveries and the advancement of fundamental knowledge on the nature and mechanisms underlying global challenges and complex living systems. In this context, the Committee has analysed some of the existing funding schemes that are offered by the national research funding organisations and other funders of research worldwide.

Multilateral Schemes Offered by National Research Funding Organisations

National research funding organisations support international collaboration through bilateral or multilateral agreements and tools, through a portfolio of various bottom-up and top-down funding schemes. Whilst there is an observable abundance of bilateral grants for research, provision for multilateral collaborations involving European researchers and worldwide partners are rather scarce and limited to a small number of countries, or they have a limited degree of interdisciplinarity. In the context of research on grand challenges that require data collection, analysis and knowledge integration on a global scale, bilateral agreements are often insufficient for addressing the complexity and magnitude of the research questions posed. Some European national funding organisations have already increased efforts to develop specific international collaboration models that include multilateral programmes with overseas partners. Some examples of top-down and bottom-up funding schemes are outlined here.

Top-down Collaborative Funding Schemes

NordForsk

This organisation under the Nordic Council of Ministers provides funding for Nordic research co-operation as well as advice and input on Nordic research policy. Five countries (Finland, Sweden, Denmark, Iceland, and Norway) support various programmes with several national organisations dedicated to implementation and distribution of funding (11, 12)². The latter is provided for research collaborations in national priority areas. The programme includes calls for proposals on global challenges such as climate change, the environment, health, food and nutrition. However, in order to be eligible for funding, the proposed research collaboration must generate Nordic added value by enhancing the existing research activities in the five Nordic countries as well as the autonomous areas of the Faroe Islands, Greenland and the Aaland Islands (11). Although this funding opportunity might support interdisciplinary frontier research, global challenges are tackled on a regional scale. This, in turn, may hamper the knowledge integration that is needed to fully understand the overall impact and interdependence of global changes on the worldwide scale.

ERA-NETS and Joint Programming Initiatives

In Horizon 2020, the ERA-NET instrument is established to foster the establishment of public-public partnerships, to support their implementation, and to co-ordinate joint activities. This instrument also allows for the funding of joint calls, supported by Member States with top-up funding from the European Commission. These joint calls target transnational research and innovation in selected areas of high European added value and relevance for Horizon 2020 (13). Although this funding mechanism allows for the pursuing of international collaborative research, often the scientific portfolio is limited to existing and pre-defined national research priorities leaving little space for breakthrough bottom-up frontier research. Moreover, there may be insufficient provisions to foster interdisciplinarity on a global scale.

Joint Programming Initiatives (JPIs) were established to foster further co-ordination of European national research programmes with a cross-cutting research scope dedicated to topics such as climate change, food security, land use, healthy diet and life and water challenges. JPIs each develop a Strategic Research Agenda (SRA), which might include joint funding activities. Whilst the funding offered fosters interdisciplinarity, calls are often limited to one per year and are dedicated to a pre-defined topic. This current approach, in turn, provides rather limited funding opportunities for the European research community as a whole (14).

Moreover, JPIs and ERA-NETs can introduce a high level of administrative burden, require increased human resources, and the complexity of the governance can create a bottleneck and prevent organisations engaging more in this type of instrument.

G8 Research Council and Belmont Forum

This initiative came from the Heads of Research Councils from the G8 countries (G8-HORCs), offering multilateral research funding dedicated to excellent research on pre-defined topics of global relevance, which can address global challenges in ways that are beyond the capacity of national or bilateral activities (15). The funded projects included global issues such as modelling earthquakes and climate at extreme scales, and developing models for exascale Earth system simulations. The programme is supported by the Natural Sciences and Engineering Research Council of Canada (NSERC), the French National Research Agency (ANR), the German Research Foundation (DFG), the Japan Society for the Promotion of Science (JSPS), the Russian Foundation for Basic Research (RFBR), the Research Councils of the United Kingdom (RCUK), and the US National Science Foundation (NSF) (15).

The third call for proposals organised by the G8-HORCs ran in collaboration with the Belmont Forum. The latter is a group of high-level representatives from several international and European national funding organisations, making up a high-level group of the world's major and emerging funders of global environmental change research³. The Belmont Forum programme has Collaborative Research Actions (CRAs), which are dedicated to global and socially-relevant environmental challenges (16, 17). This funding scheme also aims at creating new partnerships of natural scientists, social scientists and various users, and it is a part of the Future Earth programme (18). Funded projects have included freshwater and food security, land use change, coastal vulnerability, biodiversity, the arctic, climate services, e-infrastructures and data management. Moreover, in July 2013 a joint funding call was launched between the Belmont Forum and the Agriculture, Food Security and Climate Change Joint Programming Initiative (FACCE-JPI), aimed at supporting excellent research on the theme of Food Security and Land-use Change (17).

Both the G8 Research Council and the Belmont Forum represent interdisciplinary funding schemes that have the potential to support frontier research on global challenges through international collaboration. However, these schemes would benefit from wider participation of both international and European partners, as it is currently limited to five European countries. Moreover, both schemes have similar scientific scope. This, in turn, has already resulted in joint calls for proposals organised by pooling available resources from both funding schemes.

In conclusion, while over recent years a number of good multilateral initiatives have been established by some European national research funding organisations, various challenges have emerged. Global challenges such as climate change, food security, the environment and emerging diseases are sometimes tackled on a regional scale. Integrating regional programmes into wider global

initiatives might increase the impact of research, as global challenges require wider international collaboration in order to gather and integrate the knowledge generated by various experts on a worldwide scale. In addition, some of the above-mentioned funding schemes are running in parallel and sometimes have similar scope, which may lead to some scientific areas being well funded while others are underfunded. In the long run this strategy could lead to gaps in knowledge, in turn leading to a lack of products, applications and interventions. For example, insufficient funding for international collaborative frontier research on neglected tropical diseases (NTDs), as currently highlighted by the Ebola haemorrhagic fever outbreak, results in their being perceived as endemic diseases with low potential for causing a worldwide infection, which leads to a lack of drugs, vaccines, and intervention strategies for diseases that nowadays can spread worldwide.

Bottom-up Collaborative Funding Schemes

Open Research Area (ORA)

This funding scheme was introduced to strengthen international collaborations in any field of social sciences. The four national funding organisations that contributed to the establishment of this scheme are the French National Research Agency (ANR), the German Research Foundation (DFG), the Economic and Social Research Council of the UK (ESRC), and the Netherlands Organisation for Scientific Research (NWO) (19). This programme provides funding for integrated projects by researchers coming from at least two of the four participating countries. Other funding organisations from overseas might be invited to join the scheme. For example, there will be a special opportunity for co-operation with projects in Japan in 2015 (19). Although this bottom-up funding scheme fosters collaborations in social sciences, it is nonetheless restricted to a single disciplinary area. Creating links with other disciplines and widening the participation of partners from other countries in Europe and beyond might give rise to a comprehensive interdisciplinary funding scheme that would be able to tackle global challenges that require involvement of a wider pool of experts.

Future and Emerging Technologies (FET) Open Programme

Besides the top-down approach of Horizon 2020, the European Commission offers a bottom-up programme: FET Open, an instrument targeting breakthroughs that can open new research directions, and supporting early-stage research on any idea for new technology (20). It encourages scientists and engineers from multiple disciplines to work together on game-changing science and technology research, expanding well beyond the traditional technological disciplines. Whilst this programme fosters interdisciplinary projects that are highly technology oriented and collects novel ideas for radically new applications, it is not suitable for all aspects of frontier research, namely that which is aimed at the generation of fundamental knowledge and discoveries that are further away from a direct application or commercialisation.

Bill and Melinda Gates Foundation

The Global Health Discovery Translational Science Programme offers private funding to accelerate scientific research in public health (21). Although this funding scheme may contain elements of frontier research, it is mainly focused on the translation of discoveries into solutions that improve people's health. It is an open programme allowing participation of various partners from all over the world, largely focused on topics dedicated to agricultural development (21). As such it does not foster in particular frontier research and deals with a specific but limited portfolio of disciplines.

Human Frontier Science Programme (HFSP)

This bottom-up international research programme provides funding for postdoctoral fellowships, career development awards, and collaborative international research teams (22). It allows top scientists from across the world to come up with innovative approaches to a range of problems. In its current form, the programme mainly funds frontier research by addressing fundamental biological problems with an emphasis on novel and interdisciplinary approaches to increase our understanding of the complex structures and regulatory networks that characterise living organisms, their evolution and interactions (22). A total of 38 countries worldwide provide financial support to HFSP, either directly or indirectly via the contribution from the European Union⁴. Hence, the HFSP serves as an interesting example of an open programme that provides bottom-up funding opportunities in support of collaborative frontier research on the international scale. Unfortunately, in its current form it is mostly limited to the life sciences. The widening of the scientific scope of this programme to many other scientific disciplines by fostering interdisciplinarity would provide the scientific community with a truly comprehensive funding instrument. Hence this programme, because of its international dimension, might serve as a source of inspiration for national research funding organisations in Europe.

► Conclusions and Recommendations

In this Opinion Paper, the Committee stresses that research on global challenges and complex living systems requires international collaboration and interdisciplinarity in order to tackle the challenges ahead and to integrate knowledge relevant to various global events. In this context, frontier research plays a crucial role in advancing fundamental knowledge, giving rise to breakthrough discoveries and laying down the base for earliest stage marketable innovations.

Currently, with insufficient funding for collaborative frontier research from the ERC, and with the Horizon 2020 Societal Challenges focused on near-market applied research, the Committee concludes that collaborative frontier research and POC schemes need additional financial support. The gap analysis of the international funding schemes offered by European national research funding organisations and other international funders of research worldwide indicated several challenges. Each individual international collaborative programme tends to have a limited participation of European and international partners and as such does not represent a truly global funding scheme. This might result in an incomplete integration of knowledge and thereby lead to an insufficient understanding of the global challenges occurring worldwide. Moreover, funding schemes are often restricted to one discipline or a selected number of themes. This, in turn, is expected to have a limiting effect on the impact of generated science and knowledge integration. These shortcomings could be addressed by fostering greater interdisciplinarity. Some international funding schemes are running in parallel and are similar in scope to one another, which could mean that other research areas are underfunded. If this approach continues to be pursued in the long term, it could result in significant gaps in knowledge, followed by a lack of products, applications and interventions. The Committee also underlines the importance of a bottom-up approach in funding schemes in order to attract creative ideas directly from the research community and users.

The Science Europe Scientific Committee for the Life, Environmental and Geo- Sciences proposes the following recommendations to national research funding organisations in Europe:

- With the rapid internationalisation of R&D, strategies for funding research on a global scale need to be revisited in order to strengthen European research worldwide. These efforts should include widening the participation of various European countries and global partners in multilateral collaborations whilst fostering interdisciplinarity and knowledge integration.
- The national funding organisations should consider the potential for establishing a multilateral funding scheme in support of frontier research that gives rise to ground-breaking discoveries and the advancement of fundamental knowledge on complex living systems and global challenges.
- Any such funding scheme should also accommodate 'proof of concept' (POC) research that has its origin in frontier research and bridges the gap between breakthrough discoveries and early-stage marketable innovations.
- A bottom-up approach should be adopted in order to collect research proposals that contain novel ideas and solutions, captured directly from the research community and users, thus enabling open innovation.

Taken together, the national research funding organisations should reflect on the ways in which they could play a crucial role in pooling financial resources to establish a bottom-up multilateral funding scheme in support of frontier research, interdisciplinarity and international collaboration on a global scale.

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- 4) http://en.wikipedia.org/wiki/List_of_countries_by_research_and_development_spending
- 5) http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/R_%26_D_expenditure
- 6) <http://erc.europa.eu/funding-schemes>
- 7) <http://erc.europa.eu/synergy-grants>
- 8) <http://ec.europa.eu/programmes/horizon2020/h2020-sections>
- 9) http://oi.ulster.ac.uk/newsletter/horizon_2020/files/questionnaire.pdf
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- 20) <http://ec.europa.eu/programmes/horizon2020/en/h2020-section/fet-open>
- 21) <http://www.gatesfoundation.org/>
- 22) <http://www.hfsp.org/>

▶ Notes

1. ERC Synergy Grants intended to enable collaborative research where small research groups could exchange skills, knowledge, and resources in new ways, to jointly address research problems.
2. The Academy of Finland (AKA), TEKES, the Research Council of Norway (RCN), the Swedish Research Council (VR), the Swedish Research Council for Environment, Agricultural Science and Spatial Planning (FORMAS), the Swedish Council for Health, Working Life and Welfare (FORTE), VINNOVA, the Danish Agency for Science, Technology and Innovation (DASTI), the Iceland Centre for Research (RAN-NIS), the Faroese Research Council.
3. The Natural Sciences and Engineering Research Council of Canada (NSERC), the National Natural Sciences Foundations of China (NSFC), the São Paulo Research Foundation (FAPESP), the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO), the South African National Research Foundation (NRF), the Ministry of Earth Sciences of India (MOES), the Japanese Science and Technology Agency (JST), the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT), the US National Science Foundation (NSF), the International Council for Science (ICSU), and the International Social Sciences Council (ISSC), the French National Research Agency (ANR), the German Research Foundation (DFG), the German Federal Ministry of Education and Research (BMBF), the Austrian Federal Ministry for Science and Research (BMWF), the Research Council of Norway (RCN), the UK Natural Environment Research Council (NERC), and the European Commission Directorate General for Research and Innovation.
4. Australia, Austria, Belgium, Bulgaria, Canada, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, the Republic of Ireland, Italy, Japan, the Republic of Korea, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Singapore, Slovakia, Slovenia, Spain, Sweden, Switzerland, the UK, and the US

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