Input paper from the European Organization for Nuclear Research (CERN) to the European Commission, May 2017.

Collaborative Basic Research and the next EU Framework Programme

As Horizon 2020 enters its last cycle, the mid-term evaluation exercise will provide a solid evidence base for designing future European Research, Development and Innovation (R&D&I) policy initiatives and actions. As already stated by the European Commission (EC), the evaluation exercise is an important instrument for informing EC and Member State policy-making bodies, the R&D&I community and the general public about the progress achieved[1]. The results will help pave the way for the next Framework Programme. The challenging context of evaluating the existing programme and taking the first steps for building a new one requires all European R&D&I stakeholders to collaborate proactively and constructively to support the policy makers. The development and consolidation of the European Research Area through the growth and diversification of the Framework Programmes constitutes a unique success story that, as Europeans, we need to perpetuate. This input paper from the European Organization for Nuclear Research (CERN) is written in this spirit. As a world-recognised European-based organisation, which has contributed to the excellence of basic research in Europe for over 60 years, CERN would like to emphasise its strong and continuous support to modelling a bright future for R&D&I in Europe. This paper underlines the three, in our view, fundamental aspects of collaborative basic research. The term "collaborative basic research" refers, in this context, to research carried out in projects by a consortium of partners[2]. The themes developed in this document are intended to provide European policy-makers with some food for thought in building the next European Framework Programme for R&D&I.

1. Increasing public investments in basic research

In order to keep pace with global competitors, Europe needs to boost public investments in basic research.

Even though the global socio-economic climate is still affected by the after-shocks of the financial crisis, the most competitive economies continue to increase their investments in basic research, especially through the public sector. The rationale for this is the recognition that strengthening the excellence of the science base is a key means of overcoming stagnation by seeding the basis for a future sustainable economic recovery[3]. It is interesting to consider briefly some examples of what is happening outside Europe:

- South Korea aims to increase its R&D investments to 5% of its Gross Domestic Product (GDP) this year and to boost annual basic science funding levels by 36% by 2018, to about

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[1] https://ec.europa.eu/research/evaluations/index_en.cfm

[2] In contrast to mono-beneficiary projects such as the ones funded through the European Research Council.

[3] *G20 Report on Innovation*, Report prepared for the G20 Science, Technology and Innovation Ministers Meeting (Beijing, China), OECD, 2016; *The Knowledge Future: Intelligent policy choices for Europe 2050*, Report for the European Commission by an expert group on Foresight on Key Long-term Transformations of European systems: Research, Innovation and Higher Education (KT2050), 2015.

2 trillion won. Increasing investment in basic research is the cornerstone of their "leading R&D model" strategy[4].

- China is breaking away from the trend of historically low basic research investments (about 5% of its total R&D expenditures in 2012 and 2013, compared with 10–25% in other developed nations) by making a significant increase of 12.5% in 2017. This is an explicit recognition of the contribution of basic research to technological progress and the development of an innovative economy[5].
- Japan's ongoing 5th Science and Technology Basic Plan (2016-2020) continues to foster world-class basic research with focus on the development and shared use of advanced research facilities as well as open data and open science infrastructures[6].
- The United States aim to continue growing basic research investment by providing $15 billion in 2017, an increase of over $900 million over the level enacted in 2016[7], thus recognising the role of fundamental science in catalysing transformative innovations[8]. It will be interesting nevertheless to follow new policy developments for the coming fiscal years.
- Many emerging economies like India, Malaysia and Brazil as well as several countries in Africa continue to raise their overall R&D investments dedicated to basic science[9].

The importance of increasing the funding for basic research as one of the pillars of a sustainable society and planet was also recently emphasised in the final report of the Scientific Advisory Board to the UN Secretary General[10].

2. Better understanding of the macro-economic impact of basic research

Recent studies in the USA and Europe demonstrate the socio-economic impact of basic research in both qualitative and quantitative terms.

The direct benefits of basic research on industrial productivity at the enterprise and sector level have been well analysed[11]. Nevertheless the macro-economic impact on aspects such as training and employment have been less well understood[12]. Recently though, a number of

[4] *Basic Science in Knowledge-Based Society,* Intervention of President Se-Jung Oh (Institute of Basic Science), preparatory Conference for Daejeon Global Innovation Forum, Daejeon City, Republic of Korea, 25-26 September 2013.

[5] J. Qiu, China goes back to basics on research funding, *Nature, vol. 507, March 2014*; W. Yang, Boost basic research in China, *Nature, vol. 534., June 2016*; H. Wang et al, An Explanation for China's Economic Growth: Expenditure on R&D Promotes Economic Growth, *Journal of Service Science and Management, vol. 8, 2015*.

[6] The Cabinet Office official English translation of the 5th S&T Basic Plan can be found here: Main document *http://www8.cao.go.jp/cstp/english/basic/5thbasicplan.pdf* and Outline *http://www8.cao.go.jp/cstp/english/basic/5thbasicplan_outline.pdf*

[7] The President's Budget for Fiscal Year 2017, https://obamawhitehouse.archives.gov/omb/budget ; S. Reardon at al., *Nature News, 14 December 2014*.

[8] *The Future Postponed: Why Declining Investment in Basic Research Threatens a U.S. Innovation Deficit*, A Report by the MIT Committee to Evaluate the Innovation Deficit, Massachusetts Institute of Technology (MIT), 2015.

[9] *UNESCO Science Report: towards 2030* – Executive Summary, UNESCO, 2015.

[10] The Future of Scientific Advice to the United Nations, Report by the United Nations Educational, Scientific and Cultural Organization, 2016.

[11] J.D. Adams, Fundamental stocks of knowledge and productivity growth, *Journal of Political Economy vol. 98, 1990.*

[12] C. Macilwain, What science is really worth, *Nature News, vol. 465, June 2010; P. David et al*., Analysing the economic payoffs from basic research, *Economics, Innovation and New Technology, vol. 2, 1992;* Sohvi Leih and David Teece, *Basic Research* , The Palgrave Encyclopaedia of Strategic Management, Editors: Mie Augier, David J. Teece Palgrave Macmillan October 2015.

studies have started to provide both qualitative and quantitative evidence in this respect. The STAR METRICS and UMETRICS initiatives, both in the United States[13], have focused on evaluating the impact of research investments on employment. UMETRICS has combined data from the administrative records of graduate students from eight universities supported by research grants with data from the U.S. Census Bureau; the exercise covered 2010–2012 earnings and placement outcomes of doctorates in 2009–2011. The analysis has shown that almost 40% of supported doctorate recipients found jobs in industrial sectors with significantly high wages[14]. Within Europe it is worthwhile to mention the first studies carried out by the European Research Council (ERC) analysing the wider societal impact of funded projects. More than 40% of the projects have already had an impact on the economy and society for example by creating spin-off companies (existing, new or planned) to bring the results to the market. This underlines the importance of the ERC approach of giving researchers the freedom to undertake curiosity-driven frontier research[15]. Other studies go deeper still by quantifying the direct economic and industrial contributions of European Research Infrastructures as drivers of basic research innovation. These contributions range from enhancing the competitiveness and innovation across industrial sectors to providing strong opportunities and skills to young Europeans entering the job market[16].

3. Basic research connects Open Science with Open Innovation

Collaborative basic research offers the main ingredients for implementing the Open Science to Open Innovation paradigm.

The need to anticipate sustainable solutions to the challenges faced by humankind has never been more urgent[17]. Within this context, the strategic policy paradigm "Open Innovation, Open Science and Open to the World" has been proposed by Commissioner Carlos Moedas[18]. The transition from Open Science to Open Innovation entails a complex cultural change[19]. New ways of thinking and acting are needed to generate and implement novel practices and ecosystems in which competition and collaboration coexist and create shared value. Basic research leads the way in this respect. Historically, full openness in the dissemination of scientific theories and experimental data has enabled the fundamental scientific advances that

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[13] https://www.starmetrics.nih.gov/ and https://www.btaa.org/projects/umetrics .

[14] N. Zolas et al, Wrapping it up in a person: Examining employment and earnings outcomes for Ph.D. recipients, *Science, vol. 350, December 2015*; B. A. Weinberg at al., Science Funding and Short-Term Economic Activity, *Science, vol. 344, April 2014*.

[15] *Qualitative Evaluation of completed projects funded by the European Research Council*, European Research Council Report, July 2016.

[16] *The impact of the ESRF and its Upgrade Programme*, Report European Synchrotron Radiation Facility (ESRF), June 2013; *The Value and Impact of the European Bioinformatics Institute*, Report European Molecular Biology Laboratory (EMBL) and European Bioinformatics Institute (EBI), 2016; A. Fernandes et al., Does astronomy generate economic benefits? Technological innovation seen through the lens of the European Southern Observatory's Very Large Telescope, *International Journal of Technology, Policy and Management, vol. 14, 2014*; *The Impacts of Large Research Infrastructures on Economic Innovation and on Society: Case Studies at CERN*, Report OECD, 2014; M. Florio, et al. *Cost-Benefit Analysis of the Large Hadron Collider to 2025 and Beyond, 2015*, available at http://arxiv.org/pdf/1507.05638v1.pdf; Final Report on the Space Economy 2016, ESA Studies, available at http://www.esa.int/About_Us/Business_with_ESA/Space_economy/ESA_Studies .

[17] Transforming our world: the 2030 Agenda for Sustainable Development, United Nations, 2015.

[18] *Open Innovation, Open Science, Open to the World– a vision for Europe*, Publication European Commission, Directorate-General for Research and Innovation, Brussels, 2016.

[19] S. Friesike et al., Opening science: towards an agenda of open science in academia and industry, *The Journal of Technology Transfer. Vol. 40, 2015.*

have, in turn, triggered transformative changes in society. Examples of this direct influence are numerous but, just to illustrate, it is worthwhile recalling that today's electronics industry has its roots in our understanding of the behaviour of matter at the quantum level. Similarly, the pharmaceutical industry originates from our detailed understanding of the basic components and interactions in the realm of biological and chemical sciences, among others. Over the centuries, the communities involved in basic research have managed to combine openness and trust with competition in the pursuit of excellence[20]. Moreover, as demonstrated extensively, major research infrastructures are unique actors and platforms enabling the Open Science to Open Innovation process[21]. Like Open Science, Open Innovation implies a broad engagement of the actors participating in the innovation process[22]. It thus appears that the combination of the principles behind collaborative basic research with those proposed by the open innovation framework can help to implement the cultural change needed to create and capture shared economic and wealth value for society. The new Framework Programme will constitute an ideal platform to test how such combinations should be structured and implemented. The long tradition of European Research Infrastructures in attracting and training top scientific talent will continue to serve as one of the catalysts in this process.

Reflections on the next Framework Programme

With the next Framework Programme, Europe needs to strengthen its Science Excellence base by extending support for collaborative basic research, technology development and innovation, training of scientists and engineers, and by using Research Infrastructures as hubs of excellence.

Shared value creation will be key for a sustainable future society[23]. This key element has been historically embedded within the philosophy and practice of basic research[24]. Pushing back the limits of knowledge also requires the construction of ambitious instruments and thus transformative innovations fostering new economic and industrial paradigms[25]. Basic research is a driver of innovation. Moreover, curiosity-driven frontier research in all fields of science and technology helps to inspire and educate young talents with key skills to foster industrial competitiveness. The next European Framework Programme should support basic research as a generator of knowledge that transforms societies. It will be essential to strike the correct balance between programmes fostering collaborative basic research and funding

[20] P. David, *From keeping 'nature's secrets' to the institutionalization of 'open science'*. Oxford University Economic and Social History Series 023, Economics Group, University of Oxford, 2001.

[21] M. Florio et al., Social benefits and costs of large scale research infrastructures, *Technological Forecasting and Social Change, vol. 112, 2016*.

[22] H.W. Chesbrough, *From Open Science to Open Innovation*, ESADE Working paper, Science|Business Publishing 2015.

[23] T. Piketty, *Capital in the Twenty-First Century*, Belknap Press, 2014; B. Milanovic, *Global Inequality. A New Approach for the Age of Globalization*. Harvard University Press, Cambridge, Massachusetts, 2016.

[24] P A. David, Understanding the emergence of 'open science' institutions: functionalist economics in historical context, *Industrial and Corporate Change, vol. 13, 2004*.

[25] M. Stefik and B. Stefik, *Breakthrough: Stories and Strategies of Radical Innovation*, MIT Press (2004).

mechanisms that target single investigator-driven projects such as the ERC ones[26]. In this regard, five general implementation avenues could be explored:

- Implementing programmes for strengthening the acquisition of skills by young researchers involved in curiosity-driven frontier research projects and transferability of those skills towards the future job market[27].
- Introducing new, flexible and risk-bearing funding mechanisms that allow further development and upscaling of technologies generated in basic research projects from low to high Technology Readiness Levels in a continuous process.
- Supporting long-term basic research projects, leveraging the capacity of fundamental research to generate disruptive thinking, knowledge and innovation.
- Strengthening support for European Research Infrastructures in order to contribute, at the EU level, to their long-term sustainability as centres and key enablers of fundamental science excellence and generators of sustainable innovation for Europe.
- Development of ecosystems of actors and institutions capable of translating the transformative value generated by collaborative basic research into wealth for European citizens.

Since its conception and launch at the Lisbon European Council in 2000, the European Research Area (ERA) has constituted the framework in which scientific knowledge, technology and researchers circulate freely[28]. Nevertheless, evidence shows progress can still be made towards a truly integrated ERA that will form the solid substrate for a European Innovation Union. The role of collaborative basic research in this respect has been crucial and, if supported by future policies and programmes, will continue in the same vein[29]. Strengthening the European science excellence base is essential to creating sustainable opportunities for future generations.

CERN, May 2017.

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[26] *The strength of collaborative research for discovery in Horizon 2020,* Note from the League of European Research Universities (LERU), August 2016.

[27] *The Future of Jobs: Employment, Skills and Workforce Strategy for the Fourth Industrial Revolution*, Report World Economic Forum, 2016.

[28] H. Delanghe, U. Muldur, and L. Soete, *European science and technology policy: Towards integration or fragmentation?* Cheltenham, UK, Edward Elgar, 2009.

[29] A. Chessa et al., Is Europe Evolving Toward an Integrated Research Area, *Science, vol. 339, February 2013*.