Observation, Analysis and Evaluation of the Industrial Contribution to the Peer-Reviewed Public Access of the ESRF: A Pilot Study

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Abstract Although achieving excellent science remains the primary goal for Research Infrastructures (RIs), RI stakeholders share an increasing interest in understanding the broader contribution of RIs to tackle societal challenges. In such a context, an attempt has been made to identify the direct synergies between the ESRF (European Synchrotron Radiation Facility) and industry, as industrial contribution to publicly funded initiatives provides a key route to understanding the socio-economic impact. While all activities at the ESRF result in effects on the innovation process, direct synergies with industry act as one of the only attributive mode of innovation leading a tangible way to sustain innovation. Therefore, this contribution zooms in on the ESRF's peer-reviewed public access and how industry is directly and indirectly involved in generating not only scientific but also potentially social and economic impact of the facility.

Keywords Industrial engagement · Socio-economic impact · Research infrastructure · Synchrotron facility · Innovation

1 Introduction

As emphasized by the OECD (2019), the impact of RI is not limited to fostering knowledge for the scientific community but also affecting their environment socially and economically. With scientific excellence being the core mission of RIs, RI stakeholders, including researchers, policy-makers and the public, share an increasing interest in understanding the broader contribution of RIs to tackle societal challenges. In this regard, RIs act as focal points for continuous interaction between scientific, technological and socio-economic development [25]. Understanding the link between infrastructure investment and development outcomes has therefore become

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one of the most popular for debate in recent decades [4, 28, 27]. The demand to assess socio-economic impact of RIs has triggered the need to develop a standard methodology for impact assessment in the European context [13, 15, 23]. The existing studies cover a wide range of methods which can be categorized into four general strands: (1) analytical framework reflecting return of investment and net contribution of RIs, such as input–output and cost–benefit analysis (CBA) models [10, 16, 17], (2) mixed-method approach to performance indicators [13, 23], (3) theory-based approach with a focus on context analysis or to impact pathway analysis [3, 25], and (4) case study approach, including both within-case and cross-case studies [2, 8].

While the notion of "impact beyond science" is centered in today's impact evaluation of RIs, defining "what to evaluate" in terms of socio-economic impact and "how to evaluate" the impact remains a challenging task. The definition of "socio-economic impact" often leans towards the idea of economic rather than social impact. On the one hand, justifying the financial return of funding is rather the original and fundamental motivation for the impact assessment of RIs. On the other hand, economic impact, in comparison to social impact, is a rather tangible and quantifiable element throughout the lifecycle of a RI. The existing literature also leave the impression that socio-economic impact assessments are often approached with a focus on quantification of scientific quality and financial productivity as the justification of social contribution. Overall, recognition of the heterogeneity of RIs and their impact has led to the mutual understanding that "one-size-fits-all" approach is no longer an option for establishing a holistic approach to socio-economic impact assessment [13, 19, 31]. The pilot study of the ESRF zooms in on its industrial engagement through the peer-reviewed public access as on one of the main tracks to generating socio-economic impact at large-scale and publicly funded RIs. Among many of the impact generation pathways, engaging with industry does not only contribute directly to innovation but it also provides a tangible way to assess and demonstrate the potential impact.

2 From Industrial Involvement to Socio-economic Impact

Recent research on knowledge ecosystem for large-scale RIs emphasizes on the important role of RIs in developing innovation by being a platform for scientific and technological collaborations between academia and industry [24]. Knowledge cultivated in such an ecosystem, although fundamental, often leads to breakthrough innovation that can impact varying fields and sectors and benefit the economy and society at large [26]. There is broad consensus that interactions between scientific research and industry are significant fuels to the advancement of knowledge innovation [29]. These interactions can take a variety of forms from co-authorship to formation of start-up companies through different channels from informal collaborations to contracted joint research projects. In the past decades, there has been a growing interest among academics and policy makers in the involvement of industrial partners in the process of knowledge and technology transfer. Empirical literature

recorded an increasing level of academic commercial activities accompanied by an increase in research joint ventures and joint scientific publications [11]. On the one hand, from the RIs' point of view, academia-industry collaborations contribute to the potential application of fundamental research and expansion of scientific knowledge through technological breakthroughs. The pure scientific quality does not tell a full story about a RI's socio-economic value. By engaging with industry, research organisations are able to sustain scientific and technological progress and eventually bring about societal benefits [21]. It also provides an alternative way to track the socio-economic return of a given investment in a RI as scientific discoveries often have implicit indirect benefits to society. On the other hand, it is also observed that industry is motivated to partner with RIs for a diverse set of reasons, including increased problem-solving competence, product quality discoveries, and scientific learning processes [2]. Although there is still a lack of understanding in RI-industry linkages possibly due to the variety of channels through which knowledge and technology transfer takes place, industrial involvement remains a significant way for innovation to manifest in the context of RI.

3 The ESRF's Pathways to Engaging with Industry

Located in Grenoble, France, the ESRF is one of the most intense synchrotron light source worldwide providing research scientists from both academia and industry a unique tool to investigate materials and living matter. Since its establishment in 1988, ESRF has become an internationally renowned centre for scientific excellence with a strong commitment to applied and industrial research. As an international organisation, the ESRF's capital and operational costs are supported by 21 partner nations. Similar to other RIs, the ESRF considers contribution to innovation through knowledge and technology transfer as one of the core missions as well as one of the major indicators for impact of publicly funded initiatives. As defined by European Commission [14], RI missions focus on the conduct of research and the fostering of innovations in the relevant fields. Similar to other synchrotron facilities, there are two routes to accessing beamtime at the ESRF: the peer-reviewed public access and the proprietary or commercial access. The majority of research activities at the ESRF take place through the peer-reviewed public access; this mode of access is free of charge to all users who are granted experimental beamtime based on a competitive application process and who commit to publish scientific results. In comparison, the proprietary access is popular among industrial users for confidential experiments. In this study, tracking contributions from industry on the research conducted and knowledge produced through the peer-reviewed public access provides evident indicators of the ESRF's broader socio-economic impact on society. While all activities at the ESRF contribute to the innovation process, direct synergies with industry lead directly and in tangible ways to innovation. It is commonly agreed that the impact of RIs can be complex to trace due to the attribution problem. Similar to higher education institutions, research infrastructures also face the challenge in identifying

and cataloguing the impacts that are generated from a high volume of research activities from diverse scientific fields [27]. The fundamental nature of research activities facilitated at the ESRF creates another layer of difficulty in tracking the research outcomes, let alone the socio-economic impact of these outcomes. Other than the attribution problem, there are also the problem of causality in which it is not clear which impact can be attributed to which cause as well as the timescale problem which often results in ignoring or under-evaluating the long-term potential impact of research [6]. To effectively assess the ESRF's impact on society through engaging with industry, it is useful to explore how much of the knowledge produced at the ESRF is obtained with a direct contribution or investment of industry. The idea is similar to the concept of Return on Research Capital (RORC), which is a metric that describes the revenue generated by a company as a result of capital spent on R&D. Overall, the ESRF engages with industry through four different modes. The first three modes refer to industry as the ESRF's client or user, while the fourth one refers to industry as a provider. The four modes are specified as follows:

(a) In the first mode, industry can access the ESRF through either the peer-reviewed public access or the proprietary access.
(b) The second mode involves industry interacting with the ESRF is a collaborative effort, for example, as a partner based on publicly funded grant agreements or consultancy contracts.
(c) The third mode highlights the most traditional technology transfer activity, where the ESRF own partial IP (Intellectual Property) derived from an effort in product development and valorise it in the usual ways, such as licensing and commercialisation of products.
(d) Finally, the fourth mode emphasizes the role of industry as a supplier, in some cases with a pre-competitive procurement approach.

All modes can result in the generation of joint IP. In this study, only the generation of societal impact deriving from a context where industry is an ESRF's client or user will be analysed (i.e. the first three modes). Despite the above-mentioned challenges faced in assessing the impact of RIs, there are multiple ways to capture the direct and potential engagements with industry at the ESRF. On the one hand, the study performs analysis on publications and patents using bibliometric techniques. As all research proposals approved through the peer-reviewed public access share the commitment of producing peer-reviewed publications, the ESRF's publication database allows not only the path to observe industrial collaborations in research activities, for example, through co-authorship, but also an understanding of possible applications of the knowledge created through patent citations. On the other hand, we attempted to estimate the ESRF's involvement with industry based on existing data on the industrial contribution towards academic partners as well as to collect first-hand data through surveying ESRF users.

4 Industrial Engagement in Publications and Patent Citations

There are various types of collaborations between academia and industry which can result in variety of outputs from co-authored papers to spin-offs. Bibliometric techniques are used to support the mapping of university-industry collaborations and to provide performance indicators for assessing research quality stemmed from such collaborations [1, 5, 9]. Over the past decades, analysts and scholars have produced bibliometric evidence to record the increase of jointly authored papers reflecting the growing interest of research collaboration from both universities and industry. Although studies have measured research collaboration using bibliometric indicators such as co-authorship and citations, there are inadequacies in using this method [7]. Not only do co-authorship based indicators have the limitation on detecting a substantial amount of collaborations considering that many collaborations do not result in co-published papers, but they also fail to capture sufficient information on the type of collaborations and the relationship between collaborators. At the ESRF, industry can play a role in different collaboration models, including research-industry collaboration, pure academic collaboration and pure industry collaboration. During the pilot study, it is observed that existing bibliometric tools, such as Web of Science and InCites,[1] indeed have a lack of accuracy when it comes to identifying industrial engagement in publications from works done at the ESRF. Hidden industry presence exists in pure academic collaboration and research-industry collaboration when industry acts as a sponsor or sample provider. Whilst in the case of pure industry collaboration, the use of outsourced research services results in the difficulty of recognising outsourcing companies as they may not be affiliated with the co-authored papers. In addition, companies such as SMEs and start-ups are often not recorded in the database of existing bibliometric tools, which causes a lower number of industrial collaborations being identified and reported. Although the above-mentioned barriers significantly limit the acknowledgement of research-industry collaborations through publications, bibliometric data is still a valuable source for estimating industrial engagement in research activities at the ESRF.

To calculate the percentage of ESRF's publications involving industry, the pilot study extracted the number of publications with industrial collaborations based on the publications each year. The publication database was provided by the Joint ILL-ESRF Library. The database consists of two categories of publications, namely publications with authors affiliated to the ESRF and publications replying on access to the ESRF.[2] In the analysis of industrial engagement, both groups are considered the ESRF's publications, or publications from works done at ESRF. Using InCites as the main

[1] Web of Science (https://www.webofscience.com) is a Clarivate *platform consisting literature search databases covering different scientific fields*. InCites (https://incites.clarivate.com/) is a Clarivate citation-based evaluation tool.

[2] In this case, publications are based on experiments done at the ESRF but no author of the publication is affiliated to the ESRF.

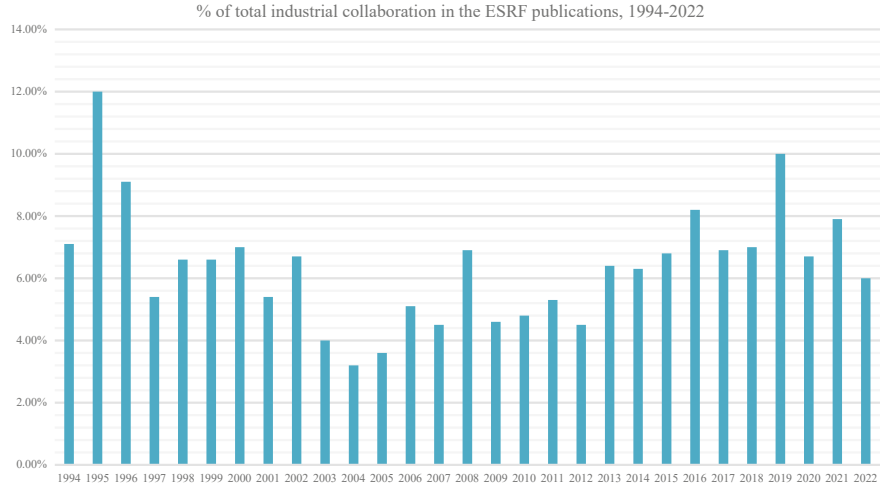

Fig. 1 Percentage of industrial collaboration in the publications from works done at the ESRF between 1994 and 2022. The calculation was done based on data extracted from InCites

bibliometric tool, data extraction of industrial collaborations in the ESRF's publications indicates an average percentage of 6.4.[3] The total number of ESRF publications between 1994 and 2022[4] is 37,299, while the number of ESRF publications involving industrial collaboration is 2038 representing 5% of the total publications.[5] InCites defines an "industry collaborative publication" as "one that lists its organisation type as 'corporate' or 'global corporate' for one or more of the co-author's affiliations" [18]. Figure 1 demonstrates the details of percentage of industrial engagement in the ESRF's publications between 1994 and 2022. The percentage is the number of industrial collaborations at the ESRF divided by the number of publications relying on access to the ESRF on a yearly basis.

To understand the intensity of industrial collaborations at the ESRF, the study compared the number of industry collaborative publications and the number of industrial partners involved in the collaborations. The result suggests that every industrial partner that engages with the ESRF through the peer-reviewed public access, publish an average of 1.2 publications. Figure 2 also indicates a gradual and yet steady increase of the collaboration intensity between 1994 and 2022.

Similar to publications, patents can play a key role in understanding the link between scientific research and its societal application. Although recent debates

[3] The percentage refers to the number of industrial collaborations compared with the total number of ESRF publications (recorded on Web of Science database).

[4] The Joint ILL-ESRF Library provided the publication data in November 2022. Due to the missing data from December 2022 as well as the time lag between a paper's publication date and the time when the publication is recorded in the library database, the analysed publication data in 2022 was incomplete.

[5] The percentage refers to the number of publications involving industrial partners compared with the total number of ESRF publications (recorded on Web of Science database).

Fig. 2 Collaborative productivity of the ESRF's industrial engagement between 1994 and 2022

have questioned the actual value in demonstrating the flow of knowledge due to the multiple functions of and various citation motivations behind patents, many researchers believe that "the embedded knowledge of scientific papers cited in patents indicates the prior usage in the development of these patents" [20, p. 1008]. As scientific linkage, often quantified as the total papers cited in a patent, is a common indicator of scientific application and innovation, it also provides insights into the ESRF's post-publication engagement with industry and its potential impact on society. The present pilot study used patent search tool, Lens PatCite,[6] to identify the patent applications that cited publications from works done at the ESRF (Fig. 3) as well as those citing publications from works done at the ESRF (Fig. 4). The difference between the numbers of granted patents indicated in Figs. 3 and 4 demonstrates a delay of patent applications citing the citations of the ESRF publications. The delay is likely associated with the time lag between publications and citations.

5 Further Estimations on Industrial Contribution

Other than contributing directly to the successful production of research outputs such as publications and patents, industrial support can be hidden behind less tangible contribution including sample provision, training, marketing and engagement support and more. The lack of direct evidence of industrial presence in the above-mentioned areas poses great challenges in accounting the relatively less visible and tangible engagement with industry.

[6] The Lens (https://www.lens.org/lens/patcite) is an online patent and scholarly literature search facility.

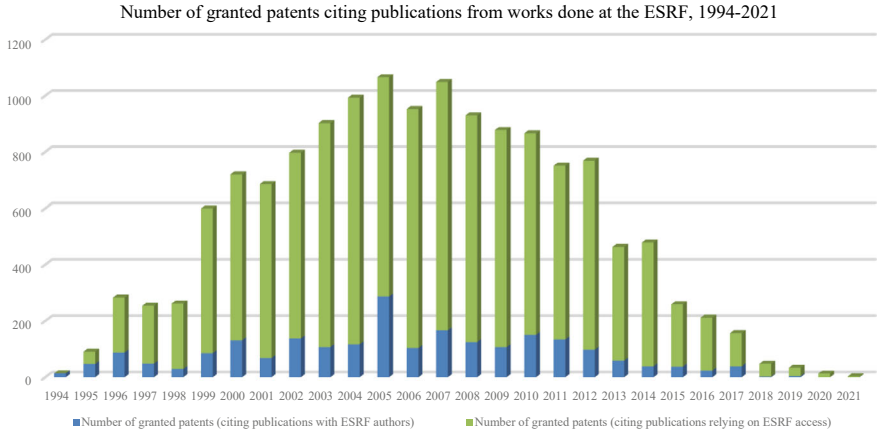

Fig. 3 Analysis of patent citations on publications from works done at the ESRF between 1994 and 2021. Patent data was collected from Lens PatCite in March 2023

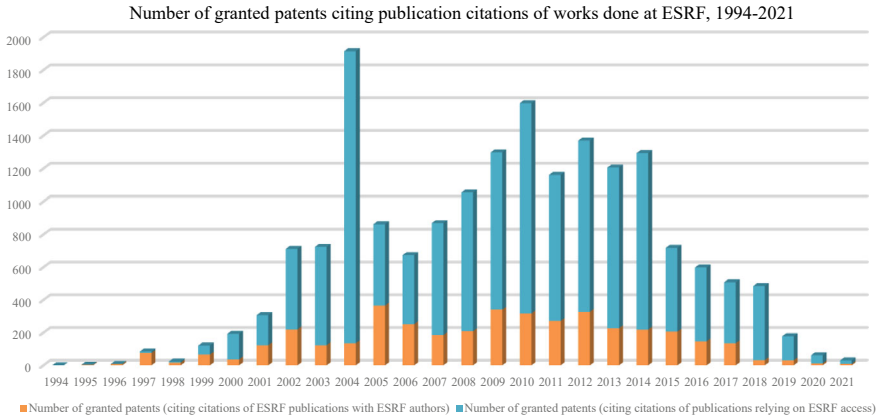

Fig. 4 Analysis of patent citations on citations of publications from works done at the ESRF between 1994 and 2021. Patent data was collected from Lens PatCite in March 2023

In the context of a bigger picture, existing literature has provided indications on industry's contribution to universities and RTOs (Research and Technology Organisations). At the European level, the average industrial involvement in the Horizon 2020 projects increases to 34% when RTOs are involved [12]. According to the Times Higher Education [30], research income from industry is somewhere between 10 and 30% of the total research incomes at universities. The funding share from industry reached approximately 30% in the case of RTOs like Fraunhofer [22]. Taking into consideration that publications produced on ESRF access are roughly equally shared between universities and RTOs, we can estimate that each publication generated at the ESRF, even if do not present any industrial co-author brings, statistically, an

embedded industrial contribution equal to roughly 22.5%. After adding the explicit 5% contribution described above, the overall estimation reaches 27.5%. Although more rigorous calculations are necessary, the estimation sheds light on a potential support from industry, taking into account the crucial role of academic intermediaries.

Besides, efforts have been made at the ESRF to collect first-hand data on the peer-reviewed public access through surveying the ESRF users as well as monitoring the research activities in the proposal stage. The ESRF proposal form requires all users who apply for beamtime through the peer-reviewed public access to categorise their proposed research activities as "Fundamental Science", "Applied Science" or "Industrial Science". According to the 4390 proposals recorded in the proposal database between 2017 and 2022,[7] 6% of the proposals are self-identified entirely or partially as "Industrial Science" while 44% of them are claimed to be entirely or partially "Applied Science". The figures show significant relevance with the results from two further surveys collected both in 2012 and 2023. During the survey distributed to the ESRF users in 2012, 40% of responses indicate that the research outcomes have applications for industrial R&D. The results also suggest that almost 50% of ESRF users have direct links with RTOs and 30% of them received financial support from industry. The 2023 user survey targeted main proposers of beamtime application between 2017 and 2022. Among the respondents, 22% indicated that they always or often collaborate with industry, and almost 20% specified that they have done their research at the ESRF in collaboration with industrial partners. As a step further to understand industrial engagement in various forms, the surveys have suggested the industrial relevance at the ESRF to be between 20 and 30%. Specifically, 25% of the ESRF users characterise their research as "applied science" or "relevant for industrial use". About 20% of them have done their research at the ESRF collaborating with "industrial partners", while around 27% of them collaborated with "applied research organisations". The results validate previous estimation based on secondary sources.

6 Conclusion and Direction of Future Work

The pilot study of estimating the industrial engagement of the ESRF, highlighting the industrial contribution to the ESRF's scientific production, presents one of the important pathways to socio-economic impact. Some pathways involve a more hidden presence of certain stakeholders including industry and less attributive ways to sustain innovation. Despite the difficulties posed by both conceptual and methodological challenges, the study demonstrates possible practices and tools for assessment in the context of analytical RIs and light sources in particular. Understanding not only the direct, but also the indirect contribution of industry to research activities requires attention to both quantitative and qualitative assessment methods as well as a continuous monitoring framework that is feasible and beneficial to the whole stakeholder

[7] The proposal database was provided by the ESRF User Office.

ecosystem of an RI. Ideally, the enhancement of assessment and presentation of socio-economic impact is brought forward together with the shared vision of developing the impact itself.

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References

1. Adams J (2009) The use of bibliometrics to measure research quality in UK higher education institutions. Arch Immunol Ther Exp 57(1):19–32. https://doi.org/10.1007/s00005-009-0003-3
2. Andersen PH, Åberg S (2017) Big-science organizations as lead users: a case study of CERN. Compet Change 21(5):345–363. https://doi.org/10.1177/1024529417724025
3. Angelis J, Griniece E, Vignetti S, Reid A (2019) Charting Impact Pathways of Investments in Research Infrastructures, pp 33–40
4. Battistoni G, Genco M, Marsilio M, Pancotti C, Rossi S, Vignetti, S. (2016) Cost–benefit analysis of applied research infrastructure. Evidence from health care. Technological Forecasting and Social Change, 112, 79–91. https://doi.org/10.1016/j.techfore.2016.04.001
5. Borges P, Franco M, Carvalho A, dos Santos CM, Rodrigues M, Meirinhos G, Silva R (2022) University-industry cooperation: a peer-reviewed bibliometric analysis. Economies 10(10):Article 10. https://doi.org/10.3390/economies10100255
6. Bornmann L (2012) Measuring the societal impact of research. EMBO Rep 13(8):673–676. https://doi.org/10.1038/embor.2012.99
7. Brika SKM, Algamdi A, Chergui K, Musa AA, Zouaghi R (2021) Quality of higher education: a bibliometric review study. Front Educ 6. https://doi.org/10.3389/feduc.2021.666087
8. Brottier MF (2016) The socio-economic impact of research infrastructures: a generic evaluation framework and insights from selected case studies. https://indico.cern.ch/event/558880/contributions/2381524/attachments/1383157/2103580/17_BROTTIER_F.pdf
9. Butcher J, Jeffrey P (2005) The use of bibliometric indicators to explore industry–academia collaboration trends over time in the field of membrane use for water treatment. Technovation 25(11):1273–1280. https://doi.org/10.1016/j.technovation.2004.06.003
10. Del Bo CF (2016) The rate of return to investment in R&D: The case of research infrastructures. Technol Forecast Soc Change 112:26–37. https://doi.org/10.1016/j.techfore.2016.02.018
11. D'Este P, Patel P (2007) University–industry linkages in the UK: what are the factors underlying the variety of interactions with industry? Res Policy 36(9):1295–1313. https://doi.org/10.1016/j.respol.2007.05.002
12. EARTO (2021) The position of research and technology organisation (RTOs) in the EU framework programmes. EARTO—European Association of Research and Technology Organisations. https://www.earto.eu/our-publications/?search=The+position+of+Research+and+Technology+Organisation+%28RTOs%29+in+the+EU+Framework+Programmes
13. ESFRI (2018). Strategy Report on Research Infrastructures: Roadmap 2018. http://roadmap2018.esfri.eu/
14. European Commission (2013) Regulation (EU) No 1291/2013 of the European Parliament and of the Council of 11 December 2013 establishing Horizon 2020. http://data.europa.eu/eli/reg/2013/1291/oj/eng

15. European Commission (2017) Sustainable European research infrastructures: A call for action: Commission staff working document: long term sustainability of research infrastructures. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/76269
16. Florio M (2019) Investing in Science: Social Cost-Benefit Analysis of Research Infrastructures. The MIT Press. https://mitpress.mit.edu/9780262043199/investing-in-science/
17. Florio M, Forte S, Sirtori E (2016) Forecasting the socio-economic impact of the Large Hadron Collider: A cost–benefit analysis to 2025 and beyond. Technol Forecast Soc Change 112:38–53. https://doi.org/10.1016/j.techfore.2016.03.007
18. InCites (n.d.) Collaboration indicators. Clarivate—InCites Help. Accessed 22 Nov 2023. https://incites.help.clarivate.com/Content/Indicators-Handbook/ih-collaboration-indicators.htm?Highlight=industrial%20collaboration
19. Kolarz P, Angelis J, Krčál A, Simmonds P, Traag V, Wain M, Biesma A, Blessing V, Brown N, de Ruiter A, Eljas-Taal K, Eparvier P, Grange S, Mahieu B, Mbengue E, Melin G, Müürisepp K, Nausedaite R, Nielsen K, … Zuijdam F (2017) Comparative impact study of the European Social Survey (ESS) ERIC. Technopolis Group
20. Li R, Chambers T, Ding Y, Zhang G, Meng L (2014) Patent citation analysis: calculating science linkage based on citing motivation. J Am Soc Inf Sci 65(5):1007–1017. https://doi.org/10.1002/asi.23054
21. Magazinik A (2022) Investigating the societal impact of large research infrastructure: a study on the compact linear collider at CERN. Tampere University. https://cds.cern.ch/record/2836841
22. München F-G e.V. (2021) Fraunhofer annual report 2021. Fraunhofer. https://www.fraunhofer.de/s/ePaper/Annual-Report/2021/index.html#0
23. OECD (2019) Reference framework for assessing the scientific and socio-economic impact of research infrastructures [Policy Paper]. OECD. https://doi.org/10.1787/3ffee43b-en
24. Rådberg KK, Löfsten H (2023) Developing a knowledge ecosystem for large-scale research infrastructure. J Technol Transf 48(1):441–467. https://doi.org/10.1007/s10961-022-09945-x
25. Reid A, Griniece E, Angelis J (2015) Evaluating and Monitoring the Socio-Economic Impact of Investment in Research Infrastructures. https://doi.org/10.13140/RG.2.1.2406.3525/1
26. Scarrà D, Piccaluga A (2022) The impact of technology transfer and knowledge spillover from big science: a literature review. Technovation 116:102165. https://doi.org/10.1016/j.technovation.2020.102165
27. Scoble R, Dickson K, Hanney S, Rodgers G (2010) Institutional strategies for capturing socio-economic impact of academic research. J High Educ Policy Manag 32. https://doi.org/10.1080/1360080X.2010.511122
28. Snieska V, Zykiene I (2009) Socio-Economic Impact of Infrastructure Investments. Eng Econ, vol 3
29. Tartari V, Perkmann M, Salter A (2014) In good company: the influence of peers on industry engagement by academic scientists. Res Policy 43(7):1189–1203. https://doi.org/10.1016/j.respol.2014.02.003
30. Times Higher Education (THE) (2020) University industry collaboration: the vital role of tech companies' support for higher education research. Times Higher Education. https://www.timeshighereducation.com/sites/default/files/the_consultancy_university_industry_collaboration_final_report_051120.pdf
31. Van Elzakker I, Van Drooge L (2019) The political context of Research Infrastructures: Consequences for impact and evaluation. Rathenau Institute. https://doi.org/10.22163/fteval.2019.342