Reaping Impacts from Funding Transnational Research Infrastructures

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Austrian Institute of Economic Research

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Big Science Infrastructures (BSI) generate significant economic and societal impacts beyond their primary research activities and procurement revenues. These impacts include knowledge gains that lead to new products and services, skills training, and enhanced reputational standing. This report makes recommendations on how Austria could improve reaping impacts from funding transnational BSI, drawing on international best practice. Key is setting up a dedicated organisation which specialises in BSI procurement, pilot technological development, research collaboration and human resources.

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Executive Summary

- Big Science Infrastructures (BSIs), such as CERN, generate significant economic and societal impacts beyond their primary research activities and procurement revenues. These impacts include knowledge gains that lead to new products and services, skills training, and enhanced reputational standing. BSIs often require pioneering equipment to conduct their experiments and act as important first-time customers, reducing market uncertainty for the companies developing this equipment or software. In essence, BSIs can be important transnational players for the innovation systems of the countries that fund them.
- Due to their high specificity and complexity, several leading innovation countries, including Germany, Sweden, Denmark, Finland, and Switzerland, have established dedicated support organisations. These national Industrial Liaison Office (ILO) organisations employ specialised staff, often with advanced PhD-level backgrounds in science and engineering, to maximise the impacts of funding BSIs at the national level through a comprehensive range of services.
- Currently, Austria lacks similar support structures. Support for doing business with BSIs and engaging in joint technological development or research collaborations is part of the general Austrian export support services. Consequently, Austria may not fully capture the returns from the transnational BSIs that it funds. Regarding innovation policy strategy, Austria's large-scale research infrastructure action plan aims at optimising access to BSIs for research activities. However, impacts beyond research results are not a specific strategic goal of Austrian innovation policy.
- There are various ways to establish a dedicated BSI support organisation. Similar to Big Science Sweden, which offers a comprehensive range of services, it could be funded by grants from the Austrian Research Promotion Agency (FFG) and the Austrian Science Fund (FWF). Staff could have shared positions, devoting some time to the regional university technology transfer office, benefiting from knowing both BSIs and the local innovation ecosystem. A variety of organisational and funding arrangements is possible to deliver on a range of important tasks.
- A dedicated support organisation could connect the various actors in the Austrian Innovation system with the BSIs. This includes not just firms or research institutions, but also funding agencies or technology transfer offices at universities. To support its bridging function, all three Austrian Ministries tasked with research, technology and innovation policies could be involved in setting up and overseeing a dedicated support organisation.
- The following table summarises key impact pathways, tasks, and cooperation partners of a dedicated unit overseeing the potential returns from Big Science Infrastructures.

Table 1: Impact pathways, tasks and cooperation partners of a dedicated Big Science Infrastructure support organisation

Impact Pathway	*Specific Task*	*in cooperation with…*
General	Establishing relationships with BSI staff / procurement departments, obtaining specialised BSI knowledge	BSIs
	Intra-organisational ILO exchange and pooling of know-how on interacting with BSIs or their activities	
	International ILO know-how exchange	PERIIA, Big Science Business Forum
	Establishing and promoting success stories	BSI information
Off-the-shelf procurement and procurement for innovation	Establishing a network / database of firms likely to be a BSI supplier	BSI supplier databases, Advantage Austria, TTOs of universities
	Advice on BSI tendering rules	BSIs, Big Science Business Forum Procurement Handbook
	Invite firms to Big Science Business Forum	Big Science Business Forum
Procurement, pilot technological development and research collaboration	Organise visits of BSI for firms, research organisations	BSI, Advantage Austria
	Invite BSI to country tour of firms, research organisations	BSI
	Encouraging small innovative firms to participate in procurement / pilot technological development for BSIs	FFG, AWS, university incubators
	Funding for small innovative firms to engage in pilot technological development for BSIs	FFG, AWS
	Encouraging research organisations / universities to participate in research collaboration with BSIs, e.g. through contract templates or success stories	University TTOs
	Financial guarantees for research collaborations of research organisations (exports of services)	OeKB, FFG, AWS
Technology transfer	Technology transfer from BSI towards Austrian firms or research organisations, potentially using innovative formats such as "AIMday"	University TTOs, Advantage Austria
Trained human resources	Organise job fairs at BSI for Austrian firms and research organisations	BSIs, …
	Foster interest in science and STEM studies by organising visits to BSIs, or inviting them for lectures	BSIs

Source: Author. Abbreviations: BSI Big Science Infrastructure, ILO Industrial Liaison Office, PERIIA Pan-European Research Infrastructure ILO Association, TTO Technology Transfer Office, FFG Austrian Research Promotion Agency, AWS Austrian Promotional Bank, OeKB Oesterreichische Kontrollbank, AIMday Academic-Industry-Meeting, STEM Science, technology, engineering, and mathematics.

1. Introduction: reaping impacts from funding transnational research infrastructures[1]

Large-scale research infrastructures, referred to here as "Big Science Infrastructures (BSIs)," such as the European Organization for Nuclear Research (CERN), typically generate a wide range of economic and societal impacts beyond their scientific research outcomes. Figure 1 provides a stylised summary of the existing evidence (e.g., Autio et al., 2004; Castelnovo et al., 2018; Florio & Sirtori, 2016; Mayernik et al., 2017; Scarrà & Piccaluga, 2022).

These impacts include increased commercial revenues for companies and higher salaries for graduates. They also encompass additional knowledge related to new technologies and the broader benefits of science. Furthermore, BSIs enhance the skills and competencies of research staff and firm employees and improve reputation effects from working with a BSI. The augmentation of knowledge, human capital, and reputation subsequently leads to higher productivity among workers and firms. Additionally, there may be cultural and tourism benefits, as well as environmental impacts. These impacts can occur both during the construction and operational phases of the research infrastructure.

In addition to financial benefits, the construction of large-scale research infrastructures often involves developing pioneering equipment for specific purposes, which can generate know-how applicable to other opportunities. The development of highly specialised equipment for scientific experiments distinguishes large-scale research infrastructures from "small science" university research and underscores their importance within an innovation system[2]. BSIs are typically long-term, capital-intensive, and highly specialised research endeavours, and they often "… act as an important first customer for emerging technologies" (Autio et al., 2004, p. 118). During the operational phase, research activities and results contribute to skill development among researchers, the training of new researchers, and the expansion of the knowledge base, which can be relevant for numerous applications outside the research infrastructure. For instance, the vast amounts of data produced by research infrastructures frequently necessitate new information and communication technologies for analysis, such as the World Wide Web, which was pioneered at CERN.

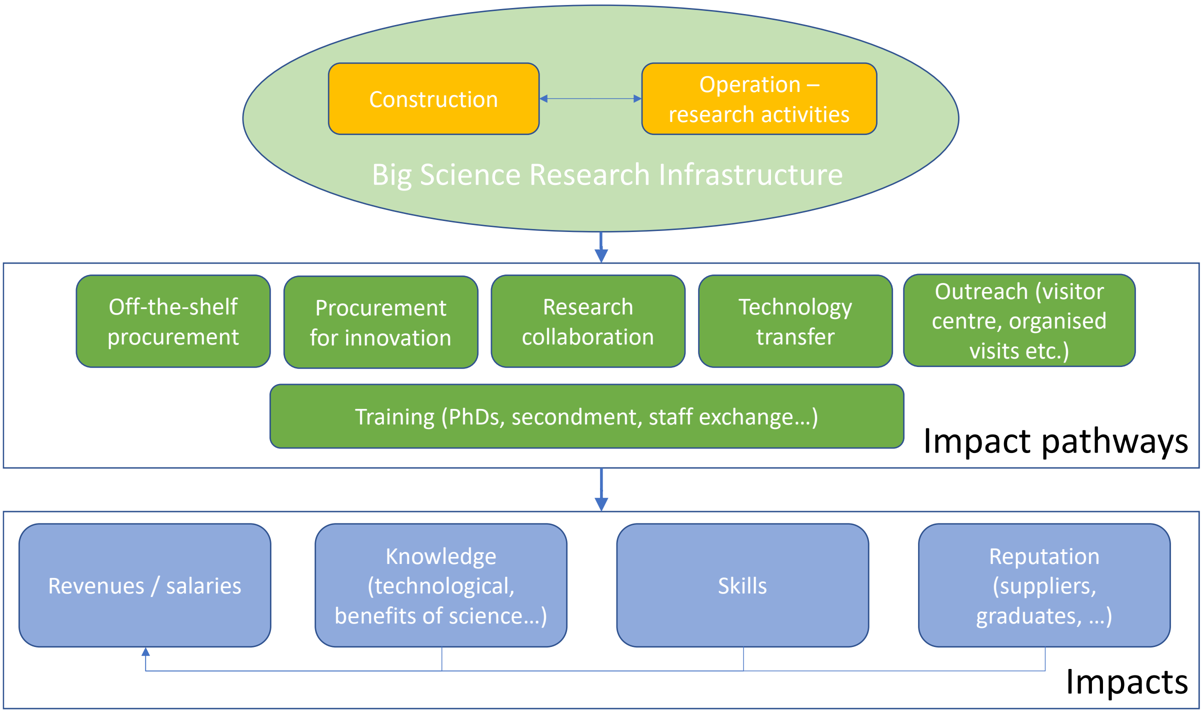
There are various **impact channels or pathways** through which these impacts materialise. Many studies discuss standard procurement as well as procurement for innovation, where BSIs specify the parameters of new equipment or services necessary to conduct scientific experiments (Bastianin & Del Bo, 2021; Castelnovo & Dal Molin, 2021; Dal Molin et al., 2023). Some BSIs, such as CERN, have their own technology transfer offices, which operate through various mechanisms, such as licensing intellectual property or directly contacting potentially interested firms. Human capital formation can occur in multiple ways, including students participating in research activities, as well as through secondments and site visits. Many BSIs also engage in outreach

[1] We thank Dr Fredrik Engelmark (Big Science Sweden) and Patrick Sagmeister (Advantage Austria) for interviews.

[2] "Big Science centres operate as technological and engineering specification factories, which translate extremely demanding theoretical performance standards into highly detailed technological and engineering specifications. These aspects of Big Science centres make them very interesting constituents of transnational innovation systems" (Autio et al., 2005, p. 45).

activities, such as visitor centres, which not only attract visitors but also facilitate science communication, thus bolstering public support for the sometimes extremely expensive research sites. These impact channels often overlap; for example, procurement for innovation may also lead to training effects for both the BSI's and the firms' staff. Figure 1 provides a stylised summary of impacts and impact channels. Figure 3 illustrates the impacts and impact pathways from CERN for the UK, as reported by Technopolis Group in 2020.

Figure 1: Economic and societal impacts from large scale research infrastructures, on top of scientific research results



Source: Author.

Large-scale research infrastructures funded internationally raise the question of returns on investment for the funding countries, beyond their use for research activities. How can countries ensure they benefit from the impacts of the BSIs they fund?

Some research infrastructures, such as CERN, follow a policy of "juste retour", where the share of total procurement contracts awarded to a specific country should match that country's share of total BSI funding. However, this is only one criterion in CERN's procurement policy. The other, more important criteria relate to quality (the ability to meet the technological specifications of the product or service demanded) and price (Bastianin & Del Bo, 2021).

Evidence shows that this "juste retour" is rarely achieved (Bastianin & Del Bo, 2021). As elsewhere – witness gravity approaches to international trade (Chaney, 2018) – geographic proximity will usually work in favour of a "home premium", implying that it is challenging to optimise benefits through the immediate return via contracts. Yet countries use observably different approaches to "re-patriate" some of the benefits from their investment in BSIs on top of scientific research collaborations or making use of the BSI to conduct scientific experiments. While the industrial liaison officer recommended by the European Strategy Forum on Research Infrastructures (Innovation Working Group, 2018) has long been a standard at CERN, there are many ways to enhance the economic and societal impacts from investment in BSIs beyond their research outcomes. Differences between countries in organising or supporting such activities have seldom been investigated, with an exception being Hofer (2005).

This study investigates specific and practicable ways to improve returns from funding international BSIs using the example of Austria, a member state since 1959. The objective is to obtain a share of benefits commensurate with Austria's funding contribution. On the one hand, this is challenging, as home bias will continue to play a role even for BSIs comparatively close to Austria such as CERN. On the other hand, measuring "juste retour" solely by procurement income is akin to looking at the tip of the iceberg only.

Figure 1 illustrates that benefits may not be immediate but can emerge over time through procurement for innovation, research collaboration or training. The knowledge and reputation gained can lead to new products and markets, whose revenues may significantly exceed immediate procurement returns. Societal and environmental benefits from applications linked to BSIs, as well as inspiring people, students, and pupils to pursue careers in science, are also beyond the scope of traditional "return" indicators. A fuller understanding of the benefits of funding BSIs requires a more comprehensive measurement of such benefits over time, including indirect impacts, such as BSIs acting as first customers.

In the following, we present five ways to help improve returns for Austria. They could form the nucleus of a general policy to maximise returns from funding large scale research infrastructures. This is even more important as Austria currently lacks an explicit policy to systematically ensure the benefits of BSIs. The "Action Plan 2030 for Research Infrastructure" (FTI Arbeitsgruppe Forschungsinfrastruktur, 2022) does not mention this. Austria's focus is very much on core research impacts, but less on innovation and skills (whereas the UK for example, as shown in figure 3 in the annex, adopts a broad impact perspective).

2. Potential levers to optimise the returns from investment in Big Science Infrastructures

2.1 Systematic encouragement of and support for Austrian firms to participate in BSI procurement bids

Currently, industrial liaison with BSIs works through the Chamber of Commerce's (WKÖ) trade delegation offices. E.g., the Zurich office hosts the official industrial liaison officer of CERN. It is hence part of the general export promotion infrastructure Advantage Austria[3], similar as described by Hofer back in 2005 (Hofer, 2005). The Austrian trade delegates usually switch countries after several years in a foreign market. They often have a business management background, providing e.g. export market related information to Austrian firms looking to export to the country they are currently representing, so that their primary task is getting to know the specificities of the general market. This makes sense, as usually the procurement needs of even a large organisation such as CERN are dwarfed by the amount of bilateral trade flows.

However, direct revenue from procurement contracts may only be the tip of the iceberg of the potential impacts of BSIs. They are very specific, long-term research institutions, capital-intensive with specialised procurement needs. In such a setting, specific knowledge about the BSI and establishing long-term relationships with staff helps the industrial liaison officers understand the procurement needs.[4] This is often facilitated by a background in science and engineering to understand roughly what the procurement is about, as well as a database or a standing network of firms potentially interested in supplying a BSI.

CERN, e.g., has built supplier databases per country itself, based on past procurement actions. But this covers only the past, not new firms that could become suppliers of CERN in the future. Setting up an own database building on knowledge about technological competence, or declared firm interest, will hence open up opportunities which cannot be exploited by BSIs and their procurement staff on their own. In a nutshell, getting to know a BSI, establish relations there as well as getting to know the specialised supplier base in a country, comes with an important fixed cost in terms of the time necessary. For any organisation not focusing on them, or where BSIs are just a small part of their overall work, it will be very hard to know these BSIs well and making the most of the opportunities they offer.

This may be a reason why several countries have established dedicated organisations or networks specialising in making sure that the potential benefits of funding BSIs are reaped. Examples from countries which often serve as comparators for the performance of Austria's innovation system are Big Science Sweden[5], the German Coordination and Liaison Office (CLIO)[6], the Italian Network of Industrial Liaison Officers[7], the Swiss Industry Liaison Office[8], the Finnish Big

[3] https://www.advantageaustria.org/

[4] This finding is a general result of the literature on industry-science-interaction (Carioli et al., 2024).

[5] https://www.bigsciencesweden.se/

[6] https://pt.desy.de/clio/index_ger.html

[7] https://www.ilonetwork.it/

[8] https://www.swissilo.ch/about/mission-statement

Science Business[9] or the Danish BigScience.dk.[10] The Spanish and Dutch ILOs are part of their national research promotion agencies. While each one of them is different in how they operate, as well as in their range of tasks, they share the characteristic that staff or industrial liaison officers specialise in one or more BSIs, but in addition they form part of a national network or organisation, exchanging information and establishing an organisational knowledge pool on how best to build links with BSIs. Staff usually spends significant time each year at the BSI they specialise in, getting to know the BSI staff and establishing relations with them, in the case of Big Science Sweden, at least 4 weeks a year.

This exchange of information also happens at the European level: There are efforts underway to connect European Big Science ILOs through PERIIA (pan-European Research Infrastructure ILO Association).[11] There are also regular meetings of Big Science ILOs with BSI procurement departments in the framework of the Big Science Forums[12] which have established a procurement handbook for several European Big Science Infrastructures[13].

An explicit task of dedicated national Big Science ILOs is to **maintain a network or database of national firms** likely to be a supplier for CERN or other BSIs. Big Science Sweden or BigScience.dk do this within a membership model of about 300 firms each, the German CLIO – overlooking a much bigger country – runs a specialised database (the CLIO database). While information on procurement higher than 200 000 CHF is posted by CERN on its procurement website (see Bastianin & Del Bo, 2021, for a detailed account of CERN's procurement mechanisms), dedicated liaison organisations or networks can provide added value in pro-actively contacting the firms who they know are most likely to be interested.[14] For orders between 50 000 and 200 000 CHF, CERN informs the ILOs, who can in turn suggest additional firms to be contacted, highlighting again that the process relies on personally knowing firms through, e.g., a dedicated database, as long as standardised procurement platforms are not used as a matter of default.

This requires some amount of technological understanding. As an example, Big Science Sweden's and Denmark's CERN ILO industrial liaison officers are trained PhD physicists. Big Science Sweden's team looks jointly at CERN tenders, pooling the expertise of several highly qualified staff, to determine which firm could be most interested in the opportunity. Some – the Swiss ILO e.g., – will link firms up with other firms in other countries, in order to build consortia for common bids. ILOs participating in the Big Science Business Forum will invite selected firms to participate in this Forum, enabling them to showcase their relevant products and services directly to the procurement departments of the participating BSIs.

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[9] https://bigsciencebusiness.fi/

[10] https://www.bigscience.dk/english/

[11] https://www.periia.eu/

[12] https://www.bsbf2024.org/

[13] https://www.bsbf2024.org/procurement-handbook/

[14] Autio et al., 2004, p. 122 remark "Big-science construction projects are often in a constant state of flux as technological solutions are tested and updated, so constant monitoring of emerging opportunities is necessary" – especially small firms, but even large firms, cannot devote resources to such monitoring.

Further instruments / tasks relate to **reducing information asymmetries for newcomers or small and medium-sized firms:**

- ➔ Some national ILOs take selected firms for visits to CERN while making sure not to unfairly provide advantage to one firm over another.
- ➔ The other way round is done as well, i.e. inviting CERN's procurement office for a country visit, arranging for talks / presentations on future opportunities of collaboration.
- ➔ Help with tendering rules.
- ➔ Establishing and promoting success stories, pointing among other benefits to the reputational gains of supplying to CERN or other large BSIs (see, e.g., Sirtori et al., 2019).

This range of tasks, combined with the level of expertise necessary to e.g. master the specific, non-standard way procurement is done at BSIs, and understanding highly complex technological specifications, speak in favour of dedicated job positions, in ILO organisations or networks. In principle, Advantage Austria could establish such a dedicated unit, potentially drawing on public support from the "Go International"-Initiative.[15] It would however work quite differently to the Austrian trade representatives looking after national-level exports, specialising on research infrastructures rather than geographic markets. Other actors which could set up dedicated units are research funding organisations such as the FFG (Austrian Research Promotion Agency), as is done in Spain or the Netherlands. However, the FFG does not cover the full potential range of tasks linked to BSIs, such as standard procurement or technology transfer.

An alternative is setting up a dedicated ILO organisation or network, where agents, presumably with a technological or even research background, specialise in the business opportunities of large research infrastructures and concomitant knowledge of businesses, pro-actively networking BSIs and interested firms among other tasks (see below). Such staff is more common in the technology transfer offices (TTO) of (technological) universities. Indeed, e.g., the staff at Big Science Sweden has shared positions in the TTOs of several Swedish universities, which provides the additional benefit of knowing both the university and the regional firm supplier base, by comparison with a national-level ILO organisation not anchored in regional knowledge institutions (see also Hofer, 2005, on that point).

At the core, supplying a BSI is a relationship between a firm and a research institution – this is the specific objective of TTOs, they establish links between firms and research institutions, rather than a general export promotion agency, which – put very simply – establishes links between importing and exporting firms. A dedicated Austrian ILO organisation could be financed by the Austrian research and innovation funding agencies, FWF (the Austrian Science Fund, specialising in funding basic research projects) and FFG (the Austrian Research Promotion Agency, specialising in funding applied research of both higher education institutions and firms). This would

[15] It is a publicly funded export promotion initiative which complements the WKÖ-member financed Advantage Austria (https://www.go-international.at/).

be similar to Big Science Sweden, which is financed by temporary grants from the Swedish equivalents, the Swedish Research Council and Vinnova.

Whichever way such a dedicated ILO office for BSI is organised, it should work in collaboration with Advantage Austria, as they can spread information on the services of such an organisation much more widely to Austrian firms. In this way, Austria could create a strong support service for firms interested in supplying BSIs.

2.2 Fostering procurement for innovation – BSIs as pilot factories

This option can be seen as a specific application of a broader strategy to systematically encourage and support firms in supplying BSIs. As previously mentioned, BSIs are typically at the cutting edge of building and designing new equipment essential for research projects. Consequently, firms that supply BSIs during the new equipment construction phase are often involved in developing new technologies. BSIs serve as crucial first customers, significantly reducing demand uncertainty. They can act as powerful instruments for public procurement of innovation, a demand-side approach to fostering innovation, as opposed to subsidizing firm research activities (Castelnovo & Dal Molin, 2021; Edler & Georghiou, 2007; OECD, 2011).

The benefits of reducing demand uncertainty are most significant for start-ups, young or small firms, which often struggle to secure external funding to develop ideas into market-ready products or services. This is particularly relevant for Austria. Although Austria invests heavily in R&D support and its established firms are innovative, the private risk capital market is limited, resulting in insufficient growth financing for young start-ups looking to scale up (Janger & Slickers, 2023). This comes in spite of many specialised research firms which are created in the wake of research projects.[16] Moreover, Austria is characterised by its small and medium-sized firms, lacking large homegrown technology-intensive firms.[17] Using BSIs as first customers for new products, as a kind of pilot factory, for proof of concept and low risk demonstration of close to market technologies, could attract potential customers and further investors, helping to address this issue.

Connecting small, innovation-intensive firms or start-ups with BSIs requires specialised knowledge about both. Information sources can include funding agencies for small firms and start-ups, such as the FFG and the Austrian promotional bank AWS. These agencies can direct small firms towards the ILO organisation as a routine part of information flows within the funding relationship. Further information sources or bridging organisations include incubators[18] of Austrian universities, which look after university spinoffs, often likely to be frontier technology firms, or the venture capital funds invested in Austrian firms. Specialised intermediaries – such as a national BSI ILO organisation – can invest time in establishing BSI development opportunities, in

[16] See, e.g., the Austrian Startup Monitor (https://austrianstartupmonitor.at/).

[17] Which was precisely the reason to establish a strong export promotion agency within the Chamber of Commerce.

[18] E.g., the one by the TU Vienna (https://i2c.tuwien.ac.at/) , by the TU Graz (https://www.sciencepark.at/) , or the one by ISTA (https://xista.com/).

collaboration with the start-up specific infrastructure, such as the university incubators, in addition to providing success stories.[19]

In case of significant development costs not covered by any potential procurement income, firms could be supported by FFG funding in developing such pilot applications, not necessarily on a cash grant basis, but also in the form of a loan, the repayment of which is secured against the future commercial income stream of the application developed originally for the BSI. The ILO staff can outline key factors of success for collaborative development relationships between a BSI and a supplier. From experience, this typically works better if firms send employees to be based at the BSI to work directly with the scientists and engineers (Dal Molin et al., 2023), which may again be difficult for small firms. Specialised ILO staff who know how it works, drawing from similar experiences in the past, can inform much better ex ante about risks and opportunities, reducing information asymmetries and facilitating complex decision making for the firms.

Of course, procurement for innovation is also relevant for large firms[20], but they generally need less support, particularly financial support from entities like the FFG. However, they too could benefit from the informational advantages provided by specialised ILO staff.

2.3 Research and development collaborations with universities and research institutions

Research collaborations involving several hundred universities, research centres, and companies are part of the daily business of large BSIs such as CERN or ITER. However, they may also partner with universities and research institutions outside of their scientific experiments. One notable example is the collaboration between the Vienna-based University of Natural Resources and Life Sciences and CERN. This partnership focuses on developing technology to recycle the massive amounts of material excavated during the construction of a new particle collider. The recycled material can be used for arable and forest soils and has potential applications in other construction projects involving similar types of excavated earth (molasse) in the region spanning from Lake Geneva to Hungary, north of the Alps, such as tunnel construction for railways, motorways or underground lines.[21]

However, there is a lack of understanding among Austrian research institutions regarding the conditions and potentials for research collaborations. These institutions often fear uncovered payment obligations due to co-financing requirements. Similar to small firms, universities and research institutions must take on risks without sufficient resources to buffer potential losses. Assessing such risks is much easier with a knowledge base that includes insights from previous experiences, success stories, and potentially contract templates. This would reduce information

[19] See e.g., https://bigsciencebusiness.fi/2018/03/15/how-small-high-tech-companies-can-do-business-with-cern-story-of-advacam-oy/.

[20] See e.g. the cooperation between CERN and ABB (https://www.bigsciencesweden.se/news-media/news/abb-and-cern-in-new-innovation-partnership/); in Austria, VOESTALPINE has developed high quality steel for applications at CERN (https://cds.cern.ch/record/2670056/files/CERN-BOOKLET_DIGITAL-VPC.pdf).

[21] https://forschung.boku.ac.at/en/projects/15930

asymmetries between CERN, which frequently collaborates with universities, and research teams or departments at universities, which typically have limited prior experience working with BSIs.

Universities may have their own support services for collaborative research projects (in this case, a BSI is probably closer to a firm than a research institution, as it looks to build equipment).[22] However, similar to the general export promotion agency, projects for BSIs are likely to constitute only a small portion of their available time, which may not justify investing effort in understanding the intricacies of BSIs. Another organisation which provides information on collaborations or EU grants is the Austrian Research Promotion Agency FFG. Advising on collaborative research with CERN or other BSIs would however also be new for them. The other option is again a specialised ILO organisation, which knows the BSIs and is able to provide information, working together with technology transfer offices/collaboration services of universities. If ILO staff has shared positions at universities as outlined above, they would have in addition specialised university knowledge.

To support taking on risks in collaborative research with BSIs, beyond providing more information, there could be a guarantee mechanism which insures universities against any losses arising out of such projects, similar to well-known export insurance tools administered in Austria by the OeKB.[23] If the OeKB, or other organisations such as the AWS or FFG, would be more suitable for this new type of support, remains open for discussion.

2.4 Improving knowledge or technology transfer from BSIs

While knowledge transfer could be regarded as inherent to procurement or collaborative research relationships with BSIs (Dal Molin et al., 2023; Nilsen & Anelli, 2016) another direction is more active transfer of technologies developed in the collaboration projects hosted by BSIs to interested firms and organisations in the funding countries, for instance in the health sector. The MedAustron project[24], where CERN technologies were transferred to Austria, was a successful example for this approach and can serve as a blueprint for such initiatives. In principle, the knowledge transfer office at CERN focuses on technologies developed by CERN[25], which can for example be licensed by firms.[26] However, it is usually difficult to take technologies off the shelf and use them without a collaborative context, or a relationship with the researchers who have developed the technology.

This is why knowledge or technology transfer often needs intermediaries, who know the local firms and can pro-actively contact firms if they were to be interested in a new technology coming out of a BSI. While Austrian universities and research institutions all have technology

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[22] E.g., TU Vienna Research Technology Innovation (https://www.linkedin.com/company/tuw-rti/).

[23] https://www.oekb.at/en/

[24] https://www.medaustron.at/en/

[25] https://kt.cern/

[26] Of course, there are many formal and informal knowledge transfer channels at CERN, see Nilsen & Anelli (2016) on commercial and non-commercial transfer; seminars, informal contacts, publications, secondments and staff exchange and training; as well as open source software.

transfer offices, there is not really a dedicated organisation looking after potential knowledge transfer from international BSI which Austria funds **towards Austrian firms** or organisations. Initiatives such as the Go International Technology Programme[27] do currently not focus on BSIs and are more designed to market and support technology-intensive Austrian firms abroad, rather than enabling incoming BSI technology transfer which would ask for specialised knowledge of both BSI technologies and Austrian firms. The National Contact Point for Intellectual Property[28], a dedicated ministerial unit to support knowledge transfer, is more focused on transferring knowledge from Austrian institutions to firms, rather than from BSIs located abroad, but funded by Austria.

One option for improvement is the establishment of a dedicated ILO unit. This unit could, for example, create permanent links and relationships with BSI's knowledge transfer staff, ensuring timely awareness of new technologies and being able to propose these technologies first to the network of Austrian firms registered in an ILO database or membership model. Even with the support of dedicated staff and local intermediaries, such "technology push" models may not always be successful. Big Science Sweden makes use of the "Academy-Industry-Meeting"-concept, AIMday[29], to discover potential transfer opportunities. In this concept, developed by Uppsala University, industry and university representatives sit together for an hour, with industry tasked to formulate short questions regarding their technological needs and university sketching potential responses from their knowledge pool. Knowledge transfer is hence encouraged as a response to problems faced by firms, different to a "push" model, where knowledge or technologies are looking for an applying organisation. Big Science Sweden has extended this format to BSIs, inviting them to such sessions to Sweden. Often, this is not a one-way transfer, but usually both partners learn from the collaboration.

Big Science Sweden also tries to integrate technology transfer in all its activities, even in standard procurement activities. As an example, it once supported a firm sending 4 employees to CERN to learn a new welding technology, which they acquired there and brought back home to Sweden.

2.5 Using BSIs for skills development and outreach activities

Most ILOs focus on the knowledge/research side of firms and universities and are less active in promoting their home country as a potential workplace for BSI graduates, or use BSIs to boost interest in science and STEM studies among pupils and students, with exceptions e.g., Big Science Sweden and Finland. Large BSIs attract many young highly qualified researchers and other staff, typically staying a limited amount of time at them to then go on and look for attractive jobs elsewhere, capitalising on their BSI experience.

According to sources cited in Florio & Sirtori (2016), 40-60% of students working in CERN eventually go on to industry. Camporesi (2001), writing about "high-energy physics as a career springboard", finds that out of 600 students working at the LEP accelerator, 43% found their first job

[27] https://www.go-international.at/foerderungen/technologie.html

[28] https://www.ncp-ip.at/ueber-ncpip/der-ncp-ip

[29] https://aimday.se/

after LEP in the private sector. In 2022, according to figures provided by CERN, there have been about 6 500 doctoral and post-doctoral researchers, administrative students, technical students, trainees and apprentices in a variety of different programmes at CERN, either funded by CERN, by member countries or by other research institutions which pay for students/researchers to use CERNs facilities.[30] ITER also has its own education programme.[31]

One way to capitalise on this could be through regular (e.g., yearly) job fairs at large BSIs such as CERN, where potential employers present job opportunities in research organisations or firms in Austria, showcasing the diversity of knowledge-intensive jobs available. Such job fairs would need to be a collaborative effort between a national organisation and a BSI, potentially involving several funding countries. Firms could be contacted through a dedicated BSI ILO organisation in Austria, which would maintain a database of companies. BSIs could support these efforts by providing statistics on the types and numbers of individuals who will soon enter the job market. Systematic personnel and alumni tracking at BSIs would be a prerequisite for achieving this, as an information source for firms or other employers on deciding whether to attend such job fairs.

Linked to overcoming shortages of skilled workers, some ILO organisations, such as Big Science Sweden, furthermore use large BSIs such as CERN to boost interest in STEM studies, or appreciation of science more generally. Having established acquaintance with BSI staff beforehand, they invite them to Sweden to give lectures on striking research results to high-school students. They also organise for several Swedish high-school students to work on a report for school at CERN for a week.

Similar to the lack of venture capital, using BSIs as a source of human capital is particularly relevant for Austria, where industry experiences shortages of highly qualified employees (Reinstaller & Kügler, 2022). Thus, while Austria funds CERN, it does not fully exploit all the potential benefits of this funding.

[30] See CERNs annual report (https://cds.cern.ch/record/2864316/files/English.pdf), CERN personnel statistics (https://cds.cern.ch/record/2858688/files/CERN-HR-STAFF-STAT-2022.pdf) and https://cms.cern/collaboration/people-statistics.

[31] https://www.iter.org/Education

3. Summary and conclusions

Big Science Infrastructures (BSIs) generate significant economic and societal impacts beyond their primary research activities and procurement revenues. These impacts include knowledge gains that lead to new products and services, skills training, and enhanced reputational standing. Due to the high specificity and complexity of BSIs like CERN, several funding countries, including Germany, Sweden, Denmark, Finland, and Switzerland, have established dedicated support organisations or networks. These national Industrial Liaison Office (ILO) organisations employ specialised staff, often with backgrounds in science and engineering, to maximise these impacts at the national level through a comprehensive range of services.

Currently, Austria lacks similar support structures, except for the official industry liaison officers, which are usually part of Advantage Austria, the general Austrian export promotion agency within Austria's Chamber of Commerce, which primarily manage bilateral trade between the country hosting the BSI and Austria. If reaping the benefits of a BSI constitutes only a small part of the responsibilities of the staff, there is likely to be insufficient time to become familiar with BSI procedures and personnel, or to form long-term relationships with BSI employees. Empirical studies have shown that these relationships favour collaboration and procurement from BSIs, in addition to supporting initiatives such as outreach activities. Distributing building links with BSIs across multiple organisations in terms of procurement, skills development, and knowledge transfer will almost certainly result in inadequate resources being dedicated to managing such complex entities effectively.

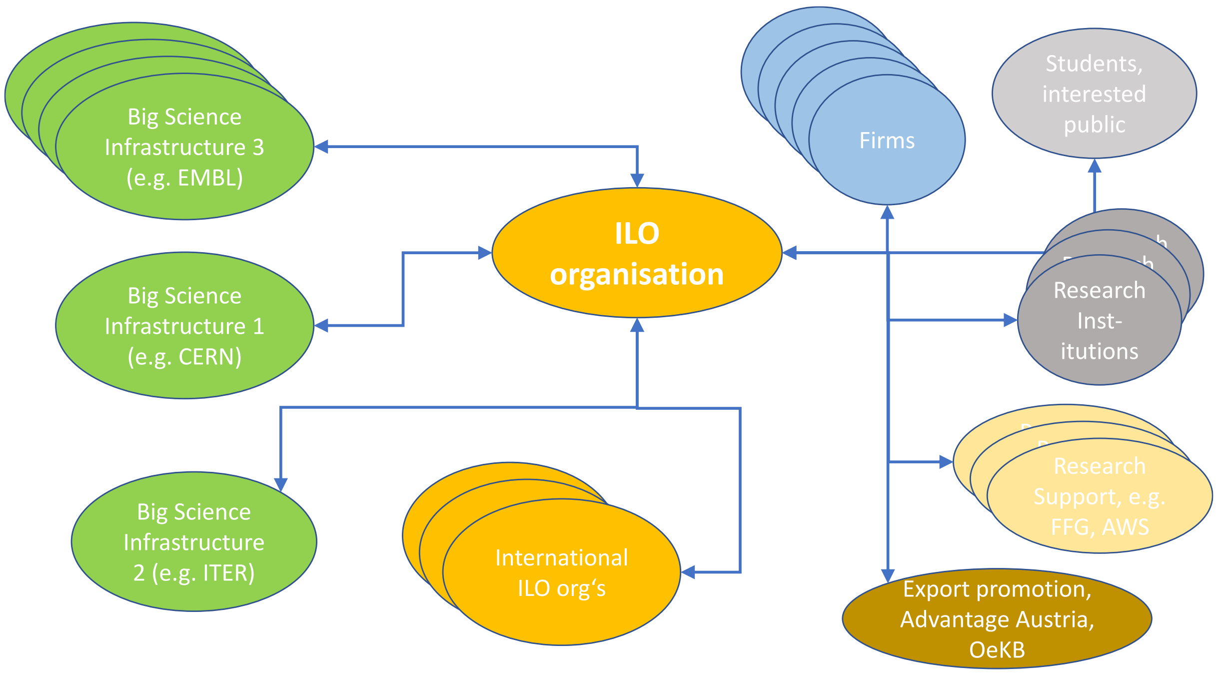
An alternative approach is to consolidate BSI-related tasks within a dedicated organisational unit or network, with the objective of increasing the contribution of BSIs to national innovation performance, ultimately increasing national returns towards a fair relationship with national funding. This would allow for the recruitment of specialised staff, providing them with the time to build long-term relationships with BSIs, and the resources to cover the **fixed costs** associated with understanding BSIs and their opportunities. A dedicated organisation also facilitates the accumulation of organisation-specific knowledge on how to maximise the benefits from BSIs, with industrial liaison officers (ILOs) from different ILOs sharing information within one entity.

Furthermore, there are European networks of such organisations, enabling the adoption of international best practices. The biennial Big Science Business Forums provide a platform for procurement departments of BSIs, BSI ILO organisations, and selected firms to meet, offering invaluable opportunities to overcome **information asymmetries**. This is a clear benefit of dedicated BSI ILO organisations. Reducing information asymmetries not only benefits interactions between BSIs and ILO organisations but also allows these organisations to build specialised supplier databases. These databases serve as unique tools for proactively contacting and informing firms most interested in the Big Science Market.

Adopting a model similar to the Swedish approach, Austrian BSI ILO staff could hold shared positions at the technology transfer institutes of universities. This arrangement offers the additional benefit of leveraging the university's expertise and understanding the spin-out environment. BSI ILOs can also act as intermediaries between specialised funding agencies and firms or research organisations seeking financial support to manage the risks associated with the initial development of new equipment or applications for BSIs. In Austria, examples of such support include the Austrian Research Promotion Agency (FFG) for R&D support, Austria Wirtschaftsservice (AWS) for start-up support, and the Oesterreichische Kontrollbank (OeKB) for export guarantee mechanisms. These mechanisms could help mitigate the risks of development collaborations with large BSIs such as CERN for universities or research organisations. Figure 2 illustrates the diverse roles a BSI ILO could play, such as connecting BSIs with firms and research organisations, reaching out to other international BSIs, and linking with other national support agencies.

To support its bridging function, all three Austrian Ministries tasked with research, technology and innovation policies could be involved in setting up and overseeing a dedicated support organisation.

Figure 2: Bridging or intermediating function of a dedicated ILO organisation in a national innovation system



Source: Authors.

The economic argument in favour of publicly funded support services for reaping the benefits of funding transnational BSIs is similar to export promotion. Because there are substantial information asymmetries which grow with the distance to the BSI, support services are justified to work against the home premium, to ensure a level playing field. Moreover, there is also a substantial fixed cost involved in getting to know BSIs, as well as potentially large economic externalities which could not be realised by purely privately funded organisations. Table summarises the potential options in setting up a dedicated ILO unit for BSIs in Austria, in terms of funding, organisation and staff profile.

Table 2: Characteristics of dedicated ILO organisations

Characteristics	Option 1	Option 2	Option 3	Option 4
Funding	Grant by FWF/FFG*		FFG	Advantage Austria/Go International
Organisational set-up	Independent organisation	Hybrid, with shared positions with TTOs* of (technical) universities	Subsidiary of FFG	Subsidiary of Advantage Austria
Staff profile	Experience with technology transfer, advanced/PhD-level STEM* qualification, local innovation eco-system knowledge, interest and motivation to specialise in BSI relations			

Source: Author. TTO Technology Transfer Office, STEM Science, Technology, Engineering and Mathematics.

Table summarises the potential tasks of such a unit, grouped by impact pathway from Figure 1 in section 1.

Table 3: Tasks of dedicated ILO organisations

Impact Pathway	*Specific Task*	*in cooperation with…*	*Task enables...*
General	Establishing relationships with BSI staff / procurement departments, obtaining specialised BSI knowledge	BSIs	Reduction of information asymmetry
	Intra-organisational ILO exchange and pooling of know-how on interacting with BSIs or their activities		Reduction of fixed cost in dealing with BSI, best-practice-adoption
	International ILO know-how exchange	PERIIA, Big Science Business Forum	Reduction of fixed cost in dealing with BSI, best-practice-adoption
	Establishing and promoting success stories	BSI information	Reduction of uncertainty
Off-the-shelf procurement and procurement for innovation	Establishing a network / database of firms of all sizes likely to be a future BSI supplier	BSI supplier databases, Advantage Austria, TTOs of universities	Reduction of information asymmetry
	Advice on BSI tendering rules	BSIs, Big Science Business Forum Procurement Handbook	Reduction of information asymmetry
	Invite firms to Big Science Business Forum	Big Science Business Forum	Reduction of information asymmetry
Procurement, pilot technological development and research collaboration	Organise visits of BSI for firms, research organisations	BSI, Advantage Austria	Reduction of uncertainty
	Invite BSI to country tour of firms, research organisations	BSI	Reduction of information asymmetry
	Encouraging small and medium size innovative firms to participate in procurement/pilot technological development for BSIs	FFG, AWS, university incubators	Reduction of uncertainty, information asymmetry
	Funding for small and medium size innovative firms to engage in pilot technological development for BSIs	FFG, AWS	Reduction of financial constraints

	Encouraging research organisations/universities to participate in research collaboration with BSIs, e.g. through collaboration agreement and contract templates or success stories	University TTOs	Reduction of uncertainty, information asymmetry
	Provide financial guarantees for research collaborations of research organisations (exports of services)	OeKB, FFG, AWS	Reduction of financial constraints
Technology transfer	Technology transfer from BSI towards national firms or research organisations, potentially using innovative formats such as "AIMday"	University TTOs, Advantage Austria	Reduction of information asymmetry
Trained human resources	Organise job fairs at BSI for national firms and research organisations	BSIs, …	Reduction of information asymmetry
	Foster interest in science and STEM studies by organising visits to BSIs, or inviting them for lectures	BSIs	Reduction of information asymmetry

Source: Author. Abbreviations: BSI Big Science Infrastructure, ILO Industrial Liaison Office, PERIIA Pan-European Research Infrastructure ILO Association, TTO Technology Transfer Office, FFG Austrian Research Promotion Agency, AWS Austrian Promotional Bank, OeKB Oesterreichische Kontrollbank, AIMday Academic-Industry-Meeting, STEM Science, technology, engineering, and mathematics.

Austria has the potential to benefit particularly from the effects on small firms and start-ups of BSIs taking on the role of first-time customers, reducing market uncertainty and compensating deficits in the availability of growth finance or risk capital in Austria. A further important aspect of leveraging Austria's funding of international BSIs may be increased recruitment of highly qualified engineers and researchers. A dedicated, specialised ILO-organisation along the lines, e.g., of the Danish or Swedish organisations, can connect the dots and leverage the otherwise well-developed Austrian research and firm support infrastructure to make the most of the "Big Science Market". Austria can learn from other countries' experiences, although at the moment there is little empirical evidence on which type or which characteristics of ILO organisation can lead to increased returns for national innovation systems, other than repeated interactions, the intensity of collaboration or geographic proximity. In this regard, there is still a gap in the literature when compared, e.g., with the available evidence on the determinants of effectiveness of technology transfer offices at universities (Debackere & Veugelers, 2005).

The observable differences in how other countries organise their ILO activities for BSIs – regarding organisational structure, staff tenure and competencies, specialisation, and range of services provided – warrant a reconsideration of Austria's current approach to BSI ILO activities: from firm-to-firm relationships in the context of export promotion, to a firm-to-research institutional setting. Adopting improved support models based on the successful practices of other countries does not guarantee that all potential benefits will be realised. However, it may at least lead to a better understanding of the role transnational BSIs can play in the national innovation system. Currently, Austria primarily focuses on the direct research impacts from research infrastructures, while paying much less attention to the indirect impacts on innovation and skills.

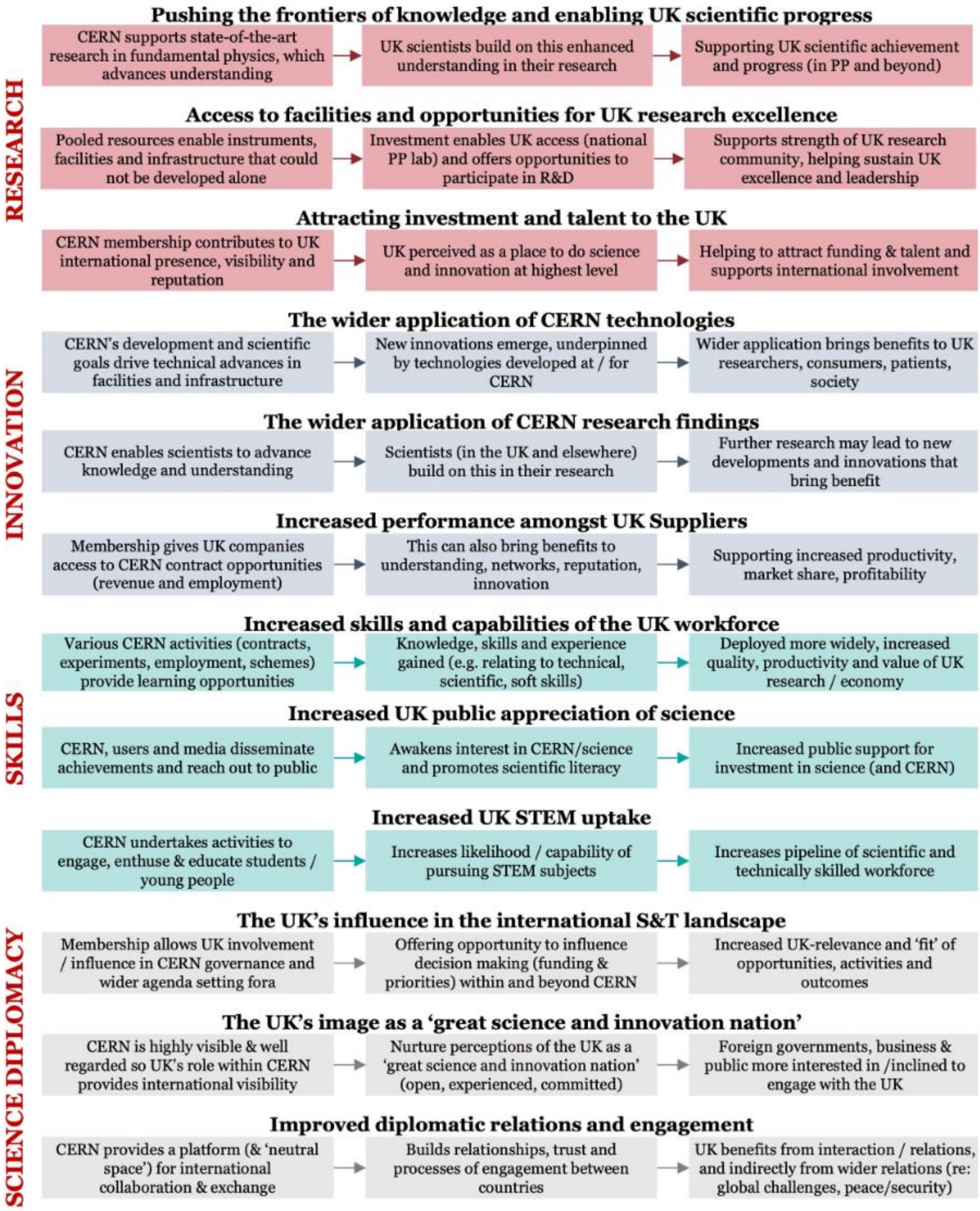
In any case, the simple financial volume of procurement contracts should not be taken as the only benchmark for returns to investment in international research infrastructure. This volume can be dwarfed by indirect revenues arising from improved knowledge and skills, as well as market access. An important part of efforts to get a return on investment in BSI would hence be improved measurement of indirect economic and societal benefits. Currently, this is not done on a systematic basis. Ad hoc individual empirical studies – often for CERN - include Autio et al., 2005; Castelnovo et al., 2018.

Regular monitoring would be required to build up a database of BSI spin-offs (as NASA does via https://spinoff.nasa.gov/), analyse patent citations and enquire about indirect benefits, such as finding new customers or entering new markets. Such regular surveys could be conducted by BSIs together with national ILO organisations, which can encourage firms to respond to the survey. Over time, a much fuller picture of BSI impacts per country could arise.

4. Annex: Impacts from CERN in the UK

The figure below is taken directly from a report by Technopolis Group (2020) on CERN impacts.

"Figure 3: CERN Impact Pathways"



Source: Technopolis Group, 2020, p. 2, https://www.technopolis-group.com/report/evaluation-of-the-benefits-that-the-uk-has-derived-from-cern/.

5. References

Autio, E., Bianchi-Streit, M., & Hameri, A.-P. (2005). Technology transfer, technological learning and innovation from the large hadron collider procurement activities: Main outcomes and recommendations for future projects. International Journal of Technology Management, 2005, 1–14.

Autio, E., Hameri, A.-P., & Vuola, O. (2004). A framework of industrial knowledge spillovers in big-science centers. Research Policy, 33(1), 107–126. https://doi.org/10.1016/S0048-7333(03)00105-7

Bastianin, A., & Del Bo, C. F. (2021). Public procurement in Big Science: Politics or technology? The case of CERN. Industrial and Corporate Change, 30(3), 740–761. https://doi.org/10.1093/icc/dtaa051

Camporesi, T. (2001). High-energy physics as a career springboard. European Journal of Physics, 22(2), 139. https://doi.org/10.1088/0143-0807/22/2/306

Carioli, P., Czarnitzki, D., & Rammer, C. (2024). Industry-Science-Interaction in innovation: The role of transfer channels and policy support. DRUID.

Castelnovo, P., & Dal Molin, M. (2021). The learning mechanisms through public procurement for innovation: The case of government-funded basic research organisations. Annals of Public and Cooperative Economics, 92(3), 411–446. https://doi.org/10.1111/apce.12311

Castelnovo, P., Florio, M., Forte, S., Rossi, L., & Sirtori, E. (2018). The economic impact of technological procurement for large-scale research infrastructures: Evidence from the Large Hadron Collider at CERN. Research Policy, 47(9), 1853–1867. https://doi.org/10.1016/j.respol.2018.06.018

Chaney, T. (2018). The gravity equation in international trade: An explanation. Journal of Political Economy, 126(1), 150–177. https://doi.org/10.1086/694292

Dal Molin, M., Scarrà, D., Piccaluga, A., & Valsecchi, V. (2023). Technology transfer from procurement relationships in big science contexts. Industry and Higher Education, 37(4), 537–550. https://doi.org/10.1177/09504222221145434

Debackere, K., & Veugelers, R. (2005). The role of academic technology transfer organisations in improving industry science links. Research Policy, 34(3), 321–342. https://doi.org/10.1016/j.respol.2004.12.003

Edler, J., & Georghiou, L. (2007). Public procurement and innovation—Resurrecting the demand side. Research Policy, 36(7), 949–963. https://doi.org/10.1016/j.respol.2007.03.003

European Strategy Forum on Research Infrastructures : Innovation Working Group. (2018). Innovation-oriented cooperation of research infrastructures. ESFRI.

Florio, M., & Sirtori, E. (2016). Social benefits and costs of large scale research infrastructures. Technological Forecasting and Social Change, 112, 65–78. https://doi.org/10.1016/j.techfore.2015.11.024

FTI Arbeitsgruppe Forschungsinfrastruktur. (2022). Forschungsinfrastrukturaktionsplan 2030.

Hofer, F. (2005). Dissemination of CERN's technology transfer: Added value from regional transfer agents. Industry and Higher Education, 19(4), 315–324. https://doi.org/10.5367/0000000054615469

Janger, J., & Slickers, T. (2023). Wissensproduktion und Wissensverwertung in Österreich im internationalen Vergleich. WIFO-Monatsberichte, 96(10), 699–714.

Mayernik, M. S., Hart, D. L., Maull, K. E., & Weber, N. M. (2017). Assessing and tracing the outcomes and impact of research infrastructures. Journal of the Association for Information Science and Technology, 68(6), 1341–1359. https://doi.org/10.1002/asi.23721

Nilsen, V., & Anelli, G. (2016). Knowledge transfer at CERN. Technological Forecasting and Social Change, 112, 113–120. https://doi.org/10.1016/j.techfore.2016.02.014

OECD. (2011). Demand-side innovation policies. OECD Publishing.

Reinstaller, A., & Kügler, A. (2022). Herausforderungen und Bestimmungsfaktoren der Wettbewerbsfähigkeit österreichischer Industrieunternehmen. Ergebnisse der WIFO-Industriebefragung 2022. WIFO-Monatsberichte, 95(7), 467–476.

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

Sirtori, E., Giffoni, F., Pancotti, C., Caputo, A., Catalano, G., & Florio, M. (2019). Impact of CERN procurement actions on industry: 28 illustrative success stories.

Technopolis Group. (2020). Evaluation of the benefits that the UK has derived from CERN [Commissioned by STFC].