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The contribution of RTOs to socio-economic recovery, resilience and transitions

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This paper analyses the evolution of the funding, governance and policy context of research and technology organisations (RTOs) over the last ten years, and the implications of these changes on their ability to achieve their mission. It shows that their contribution to solving societal challenges is now tightly intertwined with their historical mission of supporting innovation in industry and public administrations. Delivering on this increasingly demanding mission in evolving and sometimes unstable funding frameworks has led them to experiment with new internal organisational structures, business models and partnerships. The paper also draws implications for policy makers who play a key role in setting the environment in which RTOs operate and that determines in part their ability to deliver on the twin imperatives of strengthening economic competitiveness and tackling societal challenges.

Keywords: Science and technology, Innovation, societal challenges

JEL codes: O14, O25, O38, Q55

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Finally, the authors would like to thank all those who actively and patiently participated in the study surveys, data-collection template, interviews, and workshops. Many of them also provided various inputs, corrections, and comments during the investigations and process of validation.

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Executive Summary

This study, financed by the European Association of Research and Technology Organisations (EARTO) in 2021, analyses the evolution of the funding, governance, and policy context of Research and Technology Organisations (RTOs) in the last ten years, and the implications of these changes on their ability to achieve their mission, in particular their contribution to solving societal challenges and supporting sustainable transitions. It also draws implications for policy makers. The study mobilises three fieldwork tools: a quantitative data collection template, an online survey, and in-depth interviews with decision-makers in a selection of RTOs.

RTOs: a diverse community with unique features

The study builds upon previous attempts to provide a definition of RTOs that reflects both their uniqueness vis-à-vis the other actors of innovation ecosystems and the diversity among them.

> ***"Research and Technology Organisations (RTOs) are non-profit organisations whose core mission is to produce, combine and bridge various types of knowledge, skills and infrastructures to deliver a range of research and development activities in collaboration with public and industrial partners of all sizes. These activities aim to result in technological and social innovations and system solutions that contribute to and mutually reinforce their economic, societal and policy impacts."***

The study also proposes a typology of RTOs. Four types are distinguished: i) Network-based RTOs; ii) Application sector-focused RTOs; iii) Technology-focused RTOs and; iv) Medium to large integrated RTO.

The missions of RTOs: ensuring synergies between economic and societal impacts

While achieving economic impact is still considered the primary objective of RTOs, the objective of achieving societal impact experienced the greatest increase in importance in the last 10 years. These changes of RTOs' *de facto* missions are gradual and mostly related to evolutions of the demand from their clients and needs from the society in general, often mediated or amplified by policy and regulatory changes that necessitate RTOs' shift in activities. The COVID-19 pandemic has accelerated this shift. It has improved the recognition of RTOs' roles beside services to industry and provided numerous demonstrations of their capacity to quickly mobilise to contribute to solving societal problems in larger and more complex initiatives.

Societal challenges often have a systemic nature that requires not only a broader range of competencies, less 'techno-centric', but also the adoption of a different perspective, more holistic, *i.e.* involving different sectors and disciplines at the same time rather than responding to their respective needs and demands. Many RTOs are led to play a role that is in the process of being defined, sometimes described as, for instance 'system intermediaries' or 'orchestrators'.

The need to balance a wide portfolio of activities and outputs in a changing environment

The majority of RTOs combine different type of short-, mid- and long-term research and innovation activities. While the most important activities in their portfolio, as assessed by RTOs, were the ones with a shorter time horizon 10 years ago, midterm activities are now considered as important as short term ones, and long term activities are catching up. The latest type experienced the strongest increase of the three types of activities. The ability to deliver on complex and challenging missions increasingly depends on the ability of RTOs to balance these activities and manage flows of knowledge and resources between them.

Increased co-creation of innovation activities by RTOs and their various partners

All RTOs have increased their collaboration with all types of partners over the last ten years from SMEs and large firms to universities, other research performing organisations and public sector organisations. The nature of these relationships is also changing as RTOs increasingly co-create outputs with their partners, far from a mere role of service providers.

Towards a virtual challenge-based organisation of RTOs to combine, scale, scope and agility

The imperative to tackle 'wicked' societal challenges that are more complex, uncertain and, more generally, systemic calls for RTOs to strengthen (i) their strategic consistency to be able to create critical mass on some selected priorities; (ii) their "transversality" to promote interdisciplinary and intersectoral collaborations, within each RTO and between RTOs and partners. Against this backdrop, several RTOs have established 'virtual' challenge or mission programs or clusters which draws on the staff and equipment of different parts of the organisation as necessary, and can be recombined when new priorities arise.

Disparities of RTO funding models

Reflecting their growth during the period, the budgets of the sampled RTOs have increased very significantly since 2007. The funding structure of RTOs greatly differs among RTOs as well as between units/centres within RTOs. While the 'ideal' RTO model is presented as one wherein there is equal funding share of basic, competitive, and commissioned funding, in reality many permutations exist. Basic funding represents less than 20% of their total income for 60 RTOs, hence about half RTOs in the study sample.

Important trends with significant consequences for RTOs are the expansion of the number and range of selection and monitoring criteria related to societal and environmental impact and the trend towards larger projects, more challenge-based/mission-oriented in the context of new type of directional policies.

Implications for policy

The fieldwork, analysis and consultations conducted in the context of this study, call for:

1. Launching a pilot study with a few countries to measure the specific contributions of RTOs to their national policies, paving the way toward a more systematic recognition of RTOs in national classifications;

2. Reviewing and benchmarking RTOs' national basic funding schemes to enable them to best contribute to societal challenges with the adequate time horizons, scale and scope;
3. Enabling the structural changes of RTOs and network of RTOs;
4. Improving the specific framework conditions at national and supranational levels to ensure a fair and homogenous treatment of RTOs;
5. Ensuring the funding of the experimentation of novel sociotechnical solutions, including through the support to the development and maintenance of technology infrastructures;
6. Conducting a reflection on how to strengthen European networks of RTOs with unique expertise and infrastructures in key technology areas to gain scale and increase capabilities;
7. Reviewing and improving the various collaborative incentives and funding

Chapter 1. Introduction

This study, financed by the European Association of Research and Technology Organisations (EARTO) in 2021, analyses the evolution of the funding, governance, and policy context of Research and Technology Organisations (RTOs) in the last ten years, and the implications of these changes on their ability to achieve their mission. Based on the analysis of the past and current situation, the study also addresses future trends relevant to RTOs, including the consequences of the Covid-19 crisis, and how these organisations adapt to seize future opportunities. Although the study considers all types of RTOs activities, particular emphasis is put on their contribution to solving societal challenges and supporting sustainability transitions, how this role could be enhanced in the coming years and what policy can do to support these organisations in delivering on their mission.

1.1. Study rationales

EARTO defines RTOs as non-profit organisations whose core mission is to harness science and technology in the service of innovation, to improve quality of life and build economic competitiveness. While this role in delivering knowledge and innovation that contribute to both strengthening competitiveness and solving mounting societal challenges is acknowledged (EARTO, 2020), it remains based on anecdotal evidences and there is no systematic analysis of what are the factors that limit or enable RTOs to play this role. In addition, there are few insights on how these organisations function in practice, what is their funding and delivery model, their roles and position in national and international science, technology and innovation (STI) systems and, especially, how these have evolved in line with changes in the funding and governance landscape in recent years.

This knowledge gap on the role of RTOs is largely due to their diversity in terms of legal status, internal governance structure and modes of funding (OECD, 2011). RTOs' hybrid nature compounds this diversity: most of them serve different missions for various public and private beneficiaries and partners, financed through multiple funding streams. Consequently, RTOs are difficult to handle as one consistent category in statistics and analytical work (EARTO, 2021; EARTO, 2015).

Furthermore, the strategic and policy context in which RTOs operate has changed. The necessity of dealing with mounting societal challenges has triggered a shift towards more 'directional' and pro-active STI policy. This trend is reflected for instance in the experimentation of mission-oriented innovation policies in an increasing number of countries and at EU level over the last 10 years (Larrue, 2021a). As evidenced by previous studies, high-level policy orientations have a strong influence on the activities of RTOs (OECD, 2011; Intarakumnerd and Goto, 2018). This shift towards more directional policies, as well as other trends such as the increasing accountability pressure and the emergence of new types of funders, led to changes in the number and types of funding instruments and policies (and various conditions attached to these). This might require from RTOs to change their organisational structures and process, and adapt their business models. These changes may also generate new

opportunities for the exploitation of the specific 'comparative advantages' of RTOs in national innovation systems. RTOs are already active players in various types of mission-oriented policies, taking advantage notably of their ability to act as 'systemic intermediaries' (Weber, 2020).

1.2. Key questions addressed

The main questions addressed in this study are:

- How did RTOs' missions evolve over the last 10 years, notably to contribute to addressing mounting societal challenges and supporting sustainability transitions?
- How did changes in RTOs' funding and business models in the last 10 years impact on their ability to deliver on their missions?
- How do RTOs foresee changes in their role and missions in the next 5 years, and how do they envisage to adapt and seize emerging opportunities?

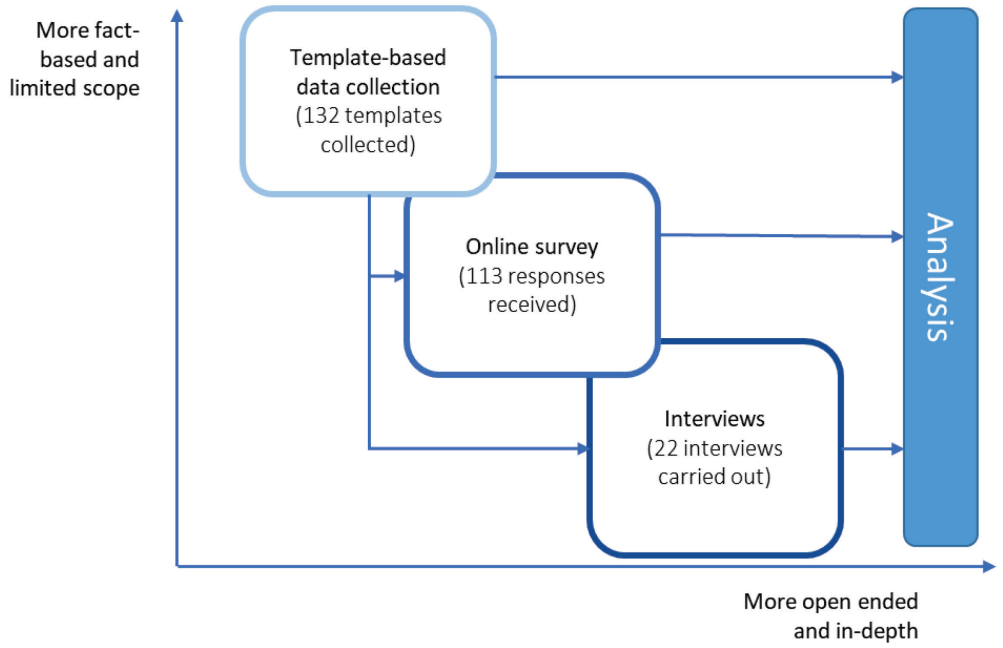
This study aims to provide inputs into the strategies and practices of RTOs and their 'principals', and partners, regarding the adequacy of current and future RTOs' funding and delivery models to best contribute to the transition toward more sustainable and resilient socio-economic systems. The study also draws the implications for policy makers who play a key role in setting the environment in which they operate and that determines in part their ability to deliver on their mission.

The study was conducted in close cooperation with EARTO and was monitored by a dedicated task-force composed of representatives of EARTO members.

Chapter 2. Study methodology

The evidence-base underpinning the study draws on three main fieldwork tools: a quantitative data collection template, an online survey, and in-depth interviews with decision-makers in a selection of RTOs. The study leverages the respective strengths of the three tools in terms of scope, depth and robustness (see Figure 1).

Figure 1. A three-pronged methodology



2.1 The data collection template

The template was used to collect data (on funding, human resources, clients, patents, etc.) that can serve as a somewhat narrow but reliable basis regarding the main evolutions of RTOs key inputs and outputs. For the sake of efficiency and continuity, it was based on a selection of indicators already present in EARTO's annual template sent to its members. While more limited in terms of indicators than EARTO's, this study template had a larger timeframe (from 2007 to 2020) and respondents' base (all European and international EARTO members and some additional RTOs).

The data collection template included 14 indicators structured into three groups: 1) human resources; 2) knowledge and technology transfer indicators; and 3) organisation funding model (see Table 1).

Table 1. Data collection template indicators

Group	Indicators
Human resources	1. Number of employees (headcount);

	2. Number of employees (FTE); 2.1. Number of R&D employees; 2.2. Number of non-R&D employees
Knowledge and technology transfer	1. Number of patent applications (first filings) during the year; 2. Revenue from IP/licensing/royalties/equity during the year; 4. Number of industrial clients; 5. Number of international clients; 6. Number of SME clients; 7. Number of spin-offs created during the year; 8. Number of privately commissioned projects; 9. Number of publicly funded projects
Funding model	1. Institutional ("basic") public funding; 2. Competitive/project-based income from public programmes; 3. Private commissioned project income; 4. Other sources of income

These indicators had to be filled in for 4 time periods: 2007-08, 2011-12, 2015-16, 2019-20.

The definition of indicators and necessary metadata were those set by EARTO as part of its own data collection and other projects with its members. This considerably smoothed the process and avoided confusions. Respondents whose national currency is different than euro (one third of respondents) had to indicate initial currency and conversion rate used to adjust for inflation.

The template was sent to all EARTO members (both European and International, directly or indirectly via regional or national associations) and 57 other RTOs for which coordinates were available. 132 RTOs filled in the template, hence a response rate of 50% (74% for EARTO members).

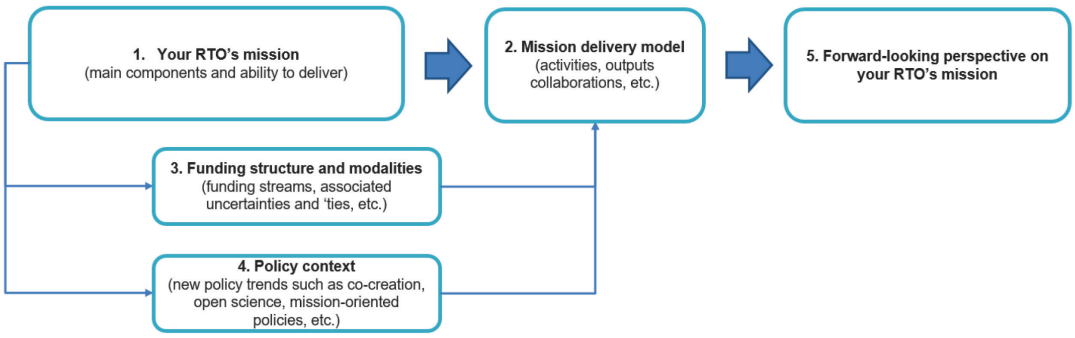
2.2 The online survey

The online survey was developed to address a more comprehensive set of indicators and markets. While opinion-based, it mainly consisted of systematic rating questions on a number of issues. Several questions related to actual RTO indicators, which could therefore be informed by RTOs' data, or at least by informed opinions.

It was designed by OECD in close collaboration with EARTO. It was first sent to five EARTO members during a pilot phase. Their feedback and advice were used to revise the survey, which was then discussed during the first meeting of the project task-force. The word version of the survey is presented in annex C.

The survey systematically and consistently collected information on the evolution of the modes of funding and business/delivery/service model of RTOs over the past ten years and the implications of these changes. It was composed of five main sections including eight rating questions and 11 open text questions (see Figure 2).

Figure 2. Structure of the OECD/EARTO online survey



The survey was sent on the 4th of June 2021 to the same population of 263 RTOs used for the template and administered by OECD until the 9th of July 2021. There were 113 RTOs that replied to the survey, making the combined response rate of 43 % (75% for EARTO members).

Ultimately 132 RTOs contributed to the data collection and/or online survey (hence a 50 % response rate). The Table 2 summarises the response rates per category of RTOs.

Table 2. Rates of response by category of RTOs

	EARTO direct members	EARTO members via regional/national associations	Non-EARTO members	Total
RTOs contacted	63	143	57	263
Data collection template				
Answers received	47	72	12	132
Response rate	*74%*	*50%*	*21%*	*50%*
Survey				
Answers received	47	56	10	113
Response rate	*75%*	*39%*	*18%*	*43%*
Data collection template and/or survey				
Answers received	47	72	12	132

2.3 Interviews

22 interviews have been carried out with decision makers in selected RTOs and RTO associations to complement the data collection and online survey. These interviews allowed for more in-depth discussions on RTOs' challenges, opportunities and forward-looking issues.[i]

Interviews lasted between 1h and 1h30 in most cases. They were divided in two parts: 1/ general questions on RTOs evolution and changes; 2/ specific questions based on the RTO's response to the survey. Interview guidelines were sent prior to the meeting.2.4 Consultations

The study greatly benefitted from various opportunities to interact with relevant stakeholders, including RTOs' top management but also policy makers.

2.4 Consultations

A dedicated EARTO Task Force met several times to monitor the progress of the study and comment on early versions of the report. The project results were also presented before the EARTO Impact Group and the EARTO Board.

Intermediary results were presented at the CONCORDi 2021 conference 'Industrial innovation for competitive sustainability' on 25 November 2021 organised by the European Commission-Joint Research Centre in collaboration with EARTO, OECD and UNIDO and a workshop jointly organised by the OECD TIP and EARTO. Intermediary results were also discussed in depth with RTOs and policy makers during the workshop 'The contribution of RTOs to socio-economic recovery, resilience and transitions' organised by the Working Party on Innovation and Technology Policy and EARTO on 19 November 2021.

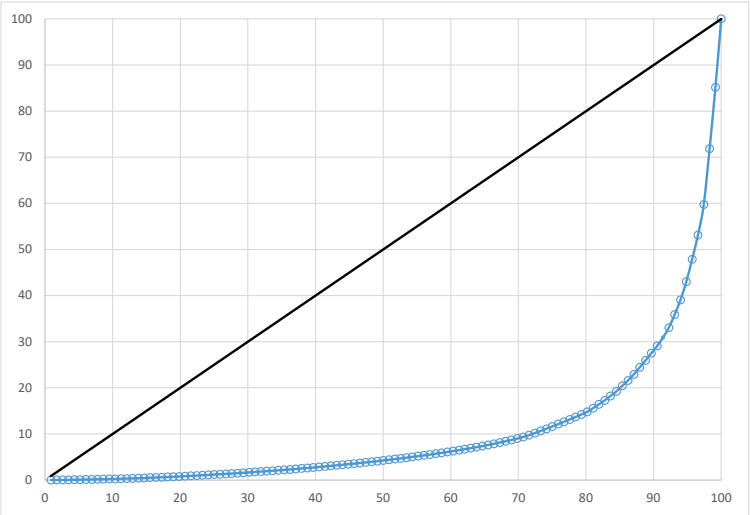
Finally, this report was reviewed and declassified by written procedure by the Committee on Science and Technology Policy in May 2022.

2.5 Caveats

Even though the demand for historical data via the template and the survey were quite demanding, the response rates are very satisfactory, in particular among EARTO members. This speaks to the close and trustful relationship between EARTO and its members. All the major European RTOs are included in the sample, as well as a large number of small organisations. The quality and length of the responses provided to the open text questions also demonstrate the engagement of RTOs in this study and the effort dedicated to provide the best possible inputs.

However, the sample is very heterogeneous and skewed, reflecting the diversity of RTOs number and sizes per country. A small number of RTOs account for a large share of the number of employees and revenues. The five largest RTOs in the sample represent about 52% of the total number of employees (hence they weight more in terms of headcounts than the 113 other RTOs in the sample). The Lorenz curves below show that 10% of the largest RTOs represent 70% of employees (Figure 3) and 80% of total revenues.

Figure 3. Lorenz curve of the sample distribution by number of employees



What is more, the size of an RTO does not only reflect their organic growth (determined by the country/industry size, its performance, etc.) but also in some cases the consolidation strategy at national level. RISE, for instance, is the result of the merger of a number of the biggest Swedish RTOs into a single institutional group which started in 2016, while each of the Norwegian RTOs that are part of FFA are all separate legal entities and therefore responded at the level of individual institutes. Although these consolidations represent far more than a communication or response strategy (RISE institutes are forming one integrated strategy and operational entity), this creates some discrepancy in the unit of analysis (country, organisation, operational centres). Similarly, Fraunhofer includes 75 research institutes, which account together for only one response, many of them being bigger than many small individual RTOs accounting for one response each.

Partly as a consequence of this, the distribution of responses by country is also very skewed, with three countries (Spain, Poland and Norway) accounting for almost 60% of the total sample (59 responses out of 113) while they represent only 11% of employees, indicating that all of them are small or medium sized organisations (Table 3)

Table 3. Number of survey responses by country / territory and aggregated number of employees in 2019-20

Country / Territory (1)	Number of responses	Aggregated number of employees	Country / Territory (2)	Number of responses	Aggregated number of employees
Spain	31	5%	Luxembourg	2	<1%
Poland	23	3%	Slovenia	2	1%
Norway	13	3%	United Kingdom	2	1%
France	8	14%	Australia	1	5%
Denmark	4	2%	Brazil	1	<1%
Portugal	4	1%	Canada	1	3%
Austria	3	1%	Cyprus	1	<1%
Belgium	3	2%	Ireland	1	<1%
Germany	3	20%	Korea	1	14%
Finland	2	3%	Sweden	1	2%
Italy	2	2%	Chinese Taipei	1	5%
Japan	2	7%	Netherlands	1	3%
Lithuania	2	<1%	**Grand Total**	**113**	**100%**

Note by Turkey
The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Turkey recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Turkey shall preserve its position concerning the "Cyprus issue".
Note by all the European Union Member
States of the OECD and the European Union The Republic of Cyprus is recognised by all members of the United Nations with the exception of Turkey. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

In order to mitigate the biases of this skewed distribution, the analysis is mainly based on dispersion statistics (quartiles), rather than averages. Furthermore, all indicators are analysed for the total sample and by size groups from 'very small' to 'very large' RTOs, including respectively the RTOs whose income in 2019 ranged respectively from Euro 10 to 50 mln and above 500 mln (Table 4). This allows for the testing of the effect of the size on response patterns. When significant differences are identified, they are signalled in the analysis.

Table 4. RTO size categories (in Million Euro)

Size category	Income	Number of RTOs
Very large	Above 500	10
Large	100 to 500	17
Medium	50 to 100	9
Small	10 to 50	37
Very small	Below 10	59
TOTAL		132

Note: for some specific questions, an additional 'top 4 RTOs' category is used, accounting for the four biggest RTOs.

Specific analysis of the responses of Spanish, Polish, Norwegian and French RTO were also performed to check that their responses were not too identical.

Another issue relates to the evolution of the sample over the period, with new RTOs being created (or starting reporting data) during the period. Finally, a few

of the largest RTOs have provided data only for the latest period, hence creating some significant break in the series of data.

2.6 Structure of the report

The next chapter (Chapter 3) presents the analysis of the data collected through the template. This section provides some useful background information that supports the following analyses based on opinions provided in the survey. The report then generally follows the structure of the online survey. Chapters 4 to 7 successively cover RTOs' missions (Chapter 4), activities and outputs (Chapter 5), internal organisations and external collaborations (Chapter 6), and funding (Chapter 7). In each of these, the last section provides a more a qualitative analysis based on interviews, allowing a more dynamic analysis, focusing on current trends, and related challenges and opportunities.[ii] A last chapter draw policy implications.

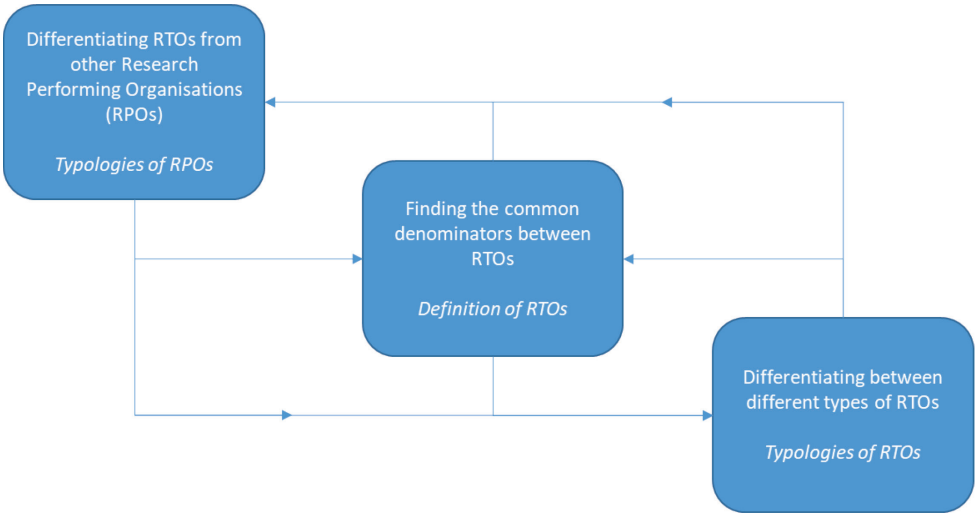
Chapter 3. The RTO landscape

3.1 Defining and categorising RTOs

The population of RTOs is characterised by its porous boundaries and high internal heterogeneity. Firstly, it proves difficult to position RTOs and distinguish them from other Research Performing Organisations (RPOs) in crowded research and innovation systems. Secondly, identifying RTOs is all the more difficult since they widely differ in terms of activity portfolio, scale and scope, organisational structure, degree of strategic autonomy, business model, surrounding national legal framework and national innovation system, etc. All these elements affect the roles/function of the RTO in light of other key players and their mandates. Although this diversity can be seen as a strength, and evidence of their 'plasticity' and responsiveness to various contexts and demands, it is also a limitation: indeed, besides the large ones, the bulk of RTOs lack recognition from policy makers and partners that do not always grasp them as 'actionable' actors, with specific capabilities and needs.

This problem is of course not new: efforts have been dedicated to better understand what make RTOs at the same time unique vis-à-vis the outside and diverse inside. Past works can be classified in three categories, with different purposes: typologies of RPOs including RTOs; definitions of RTOs; typologies of RTOs (Figure 4). While distinct, these efforts are highly interdependent and all provide some inputs to solve the RTO 'puzzle': categorising RTOs as one distinct category of RPOs require some understanding of what they are, hence coming close to a definition; working on a commonly acceptable definition requires a good knowledge of what are the different types of RTOs that must fit in the definition.

Figure 4. Interactions between definitional and typological works related to RTOs



Providing a definition and typology of RTOs was not the objective of this study. However, understanding these organisations in their specificity and diversity is a necessary step when analysing the data collected and studying their role and evolutions in a changing context.

Differentiating RTOs from other research performing organisations

In many studies and reports, RTOs are often included into the wider Research Performing Organisations sector. Previous attempts to 'map' the landscape of these organisations have generally led to identifying RTOs as a sub-category: for instance, Sanz Menandez *et al.* (2011) distinguish between four types of Public Research Organisations (PROs):

- *Traditional mission-oriented centres* (MOCs), owned and sometimes run by national or sub-national public authorities, undertake research in specific topics or sectors in order to provide knowledge and technological capabilities to support policy-making.
- *Public research centres and councils* (PRCs) perform (and in some cases fund) basic and applied research in several fields; these overarching institutions tend to be of considerable size in several countries representing a significant share of the national R&D capabilities.
- *The Independent Research Institutes (IRIs)* perform both basic and applied research focused on "issues" or "problems" rather than just fields. In many cases IRIs may be termed as "semi-public" as they are founded under different legal forms and work at the boundaries between public and private, but develop their activities with substantial public support and/or participation of public representatives in their governance.
- Finally, *Research Technology Organisations* (RTOs) are defined as organisations mainly dedicated to the development and transfer of science and technology to the private sector and society, with generally rather loose links to governments.[iii] By distinction with other research organisations, mainly driven by the advancement of science, RTOs are in general created explicitly to provide scientific and technology solutions for the society and the economy in their respective fields of expertise.

Arnold *et al.* (2010b) distinguish Scientific research institutes (doing fundamental or applied science with a very high proportion of core funding in their income), Government laboratories (which focus on producing public goods to meet knowledge needs of the state or wider society in key 'public mission' areas such as nuclear, defence, seas and oceans) and RTOs (that aim to tackle the needs of industry for knowledge and a range of knowledge-related services).

Herding cats: the challenge of defining RTOs

The multifaceted nature of RTOs naturally leads to a rather generic definition. EARTO defines RTOs as '*organisations whose core mission is to harness science and technology in the service of innovation for public bodies and industry, to improve the quality of life and build economic competitiveness*' (EARTO, 2015). The UK Association of Independent Research and Technology Organisations (AIRTO) describes its members as '*market-led, problem oriented, businesses and organisations serving all facets of technology transfer and innovation, and who secure their own ongoing existence and growth through success in this market place*' (cited in Arnold *et al.*, 2010a). One additional difficulty being that the definitions are often provided by associations

of RTOs, which membership, for historical and contingent reasons or else, can sometime include 'borderline' cases.

Other definitions, more restrictive and normative, hence maybe less suited for such a diverse community, included for instance the following: '*RTOs are organisations with significant core government funding (25% or greater) which supply services to firms individually or collectively in support of scientific and technological innovation and which devote much of their capability (50% or more of their labour) to remaining integrated with the science base*' (cited in EARTO, 2007). The heterogeneity of RTOs does not lend itself well to stringent conditions such as a share of basic funding of total income. Such definition would for instance *de facto* exclude most Norwegian research institutes, wose basic funding ranges between 5% to 25%.[iv]

All things considered, and following numerous interactions with RTOs, EARTO's definition remains valid and operational. This study proposes some adjustments to acknowledge (i) the way RTOs increasingly co-create various types of innovation; (ii) the interdisciplinary and intersectoral aspects of their knowledge base; (iii) the role of RTO's in supporting sustainability transitions; (iv) the balance and synergies between the different activities in their portfolio.

Along these lines, the following working definition is proposed in this study:

> ***"Research and Technology Organisations (RTOs) are non-profit organisations whose core mission is to produce, combine and bridge various types of knowledge, skills and infrastructures to deliver a range of research and development activities in collaboration with public and industrial partners of all sizes. These activities aim to result in technological and social innovations and system solutions that contribute to and mutually reinforce their economic, societal and policy impacts."***

Differentiating between RTOs

RTOs lend themselves better to typologies than definitions. One simple way to differentiate between different types of RTOs is to position them along two main dimensions: their legal status (axis public – private) and their position in the innovation chain (axis science – market innovation). On one end of this bi-dimensional spectrum, some public RTOs have significant 'upstream' research activities. On the other end, some have a private status and significant funding coming from shorter term services to industry. In between these two extremes, a range of organisations exist with different missions, mixes of activities to accomplish this mission, and income structures to fund these activities in a sustainable way.

The present study proposes a first tentative typology of RTOs that factor in notably four dimensions: their balance in activity portfolio, their scope of activities; their level of integration; their position in the innovation chain. These dimensions are not systematically crossed since it would result in too many categories, many of them being marginal or irrelevant. To a great extent this typology reflects the various forms of integration and linkages between different sectors, technologies and applications. Based on interviews and data analysis, four types are distinguished:

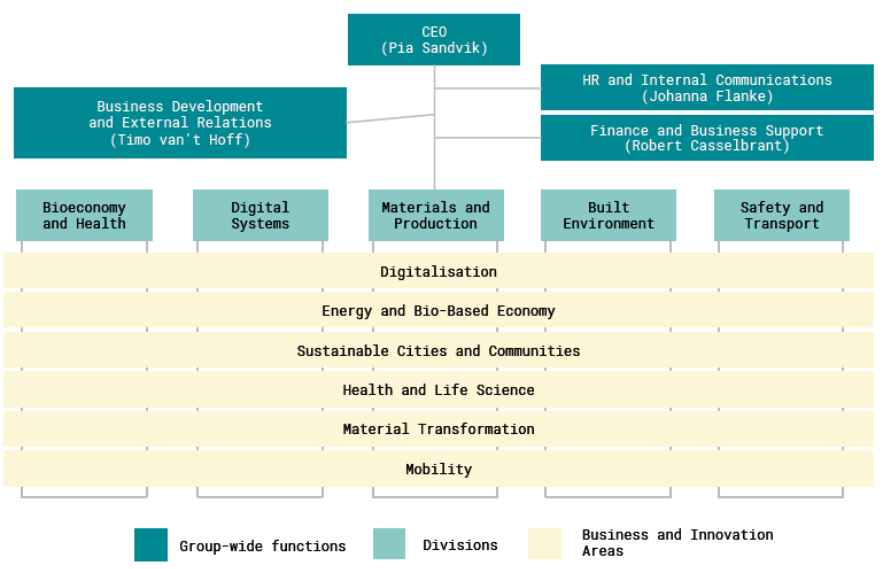
- *Network-based RTOs*: these RTOs are rather decentralised groups of units/centres enjoying a high degree of strategic autonomy from the 'headquarters'. The centres are generally specialised in certain sectors, markets and/or technologies. The 'headquarters' promote collaboration between the individual entities and standardise/mutualise certain support functions (e.g. HR, IP management). Łukasiewicz Research Network (32 institutes) is an example of this type of RTOs.
- *Application sector-focused RTOs*: these RTOs offer a wide range of services, from applied research to problem-solving interventions and technical training to an application sector. Most of them are small, but some can reach a medium size in some large high-tech industries (automobile, industry, health, etc.) and if they succeed in internationalising their activities.
- *Technology-focused RTOs*: these RTOs build on strong research and technology capabilities, as well as applied infrastructures and equipment in one specific technological area. They usually cover a large portion of the innovation cycle (i.e. from low to high Technology readiness levels (TRLs) like the sector-focused RTOs. Their specialisation is at the same time their comparative advantage and their limitation. Their sustainable growth requires efforts to internationalise their activities, which might call for the development of networks of large specialised RTOs, for instance on a regional scale. IMEC and INL are typical examples of this category.
- *Medium to large integrated RTOs*: achieving successfully this model, which combines scale and integration, is challenging. It could be the result of the successful attempts of some of the Network-based RTOs to reinforce their strategic and functional integration, going beyond the historical entities and sites to organise the activities around, for instance, cross-sectoral and interdisciplinary missions and challenges. RISE in Sweden (see Box 1) might be one of the closest form of this type of RTOs. It can also be the result of organic growth as for example with Jožef Stefan Institute (JSI) in Slovenia[v]. This category refers also to entities with broadened R&D domains covering large range of TRLs and operating several research sites internally connected.

Box 1. From a fragmented to an integrated RTO sector: the case of RISE in Sweden

From the 1960s to the 1990s, the sector institute sector in Sweden grew from a handful of research institutes to just over 30 institutes, rather small and closely linked to various industrial and materials sectors. From the mid-1980s onwards, public authorities took action to strengthen the entire sector which was becoming increasingly weak as the academic sector´s research grew. Actions ranged from reorganisation (the 'four-leaf clover' whereby institutes in related sectors and/or with complementary technologies were gathered in four groups) to gathering State-ownership in these institutes under a single umbrella (RISE).

Since then, RISE (now about 3000 employees) operates as one single multi-site institute, organised into five divisions and six business and innovation areas, without reference to the original founding members. While the staff is allocated to the five divisions, the 6 business and innovation areas allow to combine expertise and work across all divisions and operations in order to be able to respond to long-term and complex challenges through interdisciplinary innovation.

Figure 5. Overall organisation of RISE



In addition to the five divisions and six business and innovation areas, RISE also gathers 16 group-wide research areas. Initiatives linked to these areas are often supported from the strategic competence funds, which are funds provided from the Swedish government to support RISE national mission. RISE has also identified reinforcement areas in which knowledge development responds to changing societal challenges and needs. Two of the reinforcement areas, applied AI and Cyber security, became RISE **centres** in 2021. The centres will ensure additional long-term focus and facilitate the acceleration of applied research to strengthen Swedish competiveness within the field.

Source: RISE website

These categories should of course be considered as generic types with some RTOs possibly fitting into several categories. Furthermore, the heterogeneity of RTOs can also be internal: some of the centres/institutes of the Network-based RTOs can be sector- application- or technology-focused. Finally, some organisation are 'borderline RTOs' in the sense that they are closer to other

types of research performing organisations as defined in 3.1.1. This is the case of the RTOs which dominantly work at low TRL level and are therefore close to 'scientific research institutes' or 'government laboratories'. Several of these can nonetheless be found in RTO associations such as FFA in Norway.

This typology can however be a useful starting point to better grasp these actors and assess their specific roles in supporting sustainability transitions.

Characterising RTOs

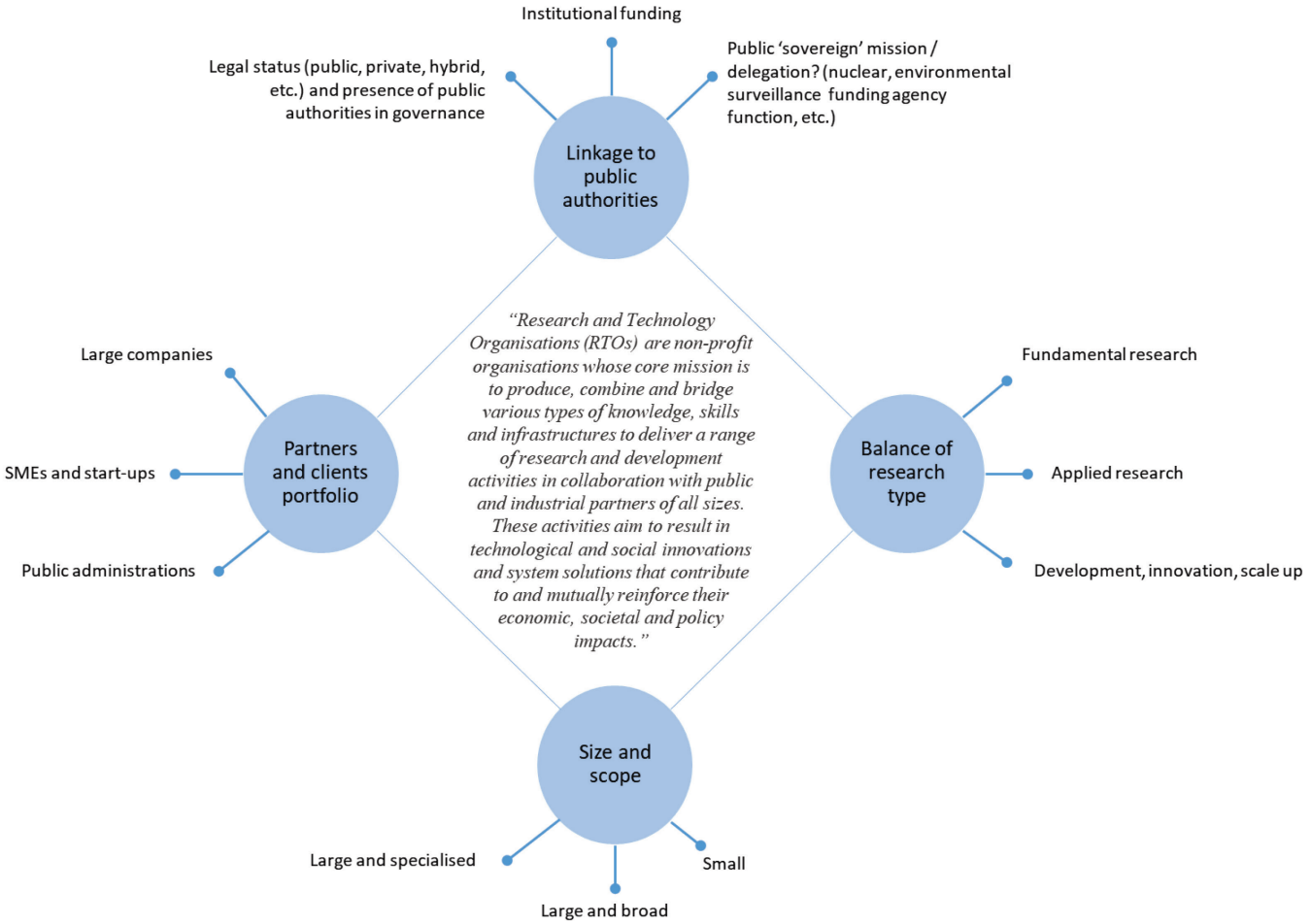
Discussions with RTOs in the context of this study as in previous attempts to define these organisations proved that it is difficult to achieve consensus on this matter due to the high number of specific cases. A relevant typology of RTOs that encompasses them all would include so many types that it would in the end defy the initial purpose of providing an easy understanding of what RTOs are.

Another option would be to define RTOs as sets of characteristics accounting for variations around a common core definition. Such 'scorecard' approach could be an interesting way to prolong the debate on the typology of RTOs:

- a first step would be to come to an agreement on a finite set of non-overlapping key characteristics that allows to differentiate RTOs;
- a second step would be to ask RTOs to self-define themselves in this space of characteristics;
- a third step would be to find a graphic way to present these sets of characteristics and making sense of them, including by using clustering techniques.

In the end, this endeavour should be a way to better understand the specific strengths and opportunities but also weaknesses and vulnerabilities of these organisations, as defined by their specific features. A first attempt, including only basic characteristics, is presented in Figure 6. Other interesting characteristics to be added could be notably the type of impact, the level of integration as specified in 3.1.3 and the type of infrastructure they develop and exploit.

Figure 6. Toward a 'scorecard typology' of RTOs



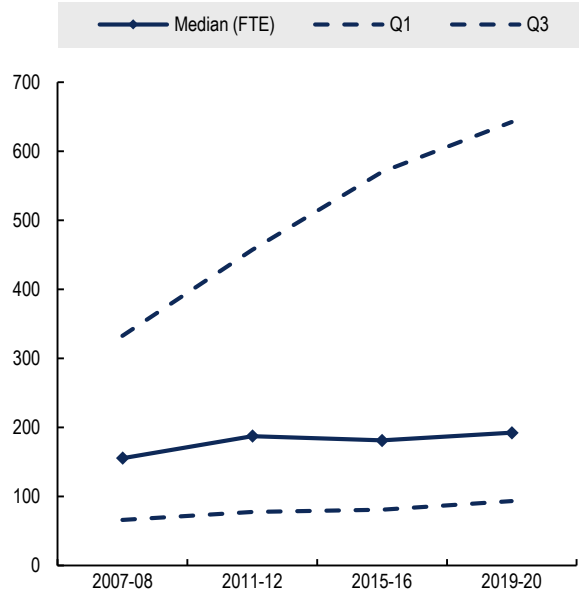
3.2 Basic characteristics of RTOs

This section presents some descriptive analysis of data collected via the template. It is based on a sample of 131 organisations.

Size of RTOs

The median number of employees has increased from 155 to 192 employees in Full-time equivalent (FTE) between 2007 and 2020 (Figure 7). The largest RTOs are accounting for a growing share of the total number of employees, as shown by the steep increase of Q3, while the share of the smallest RTOs that cumulatively represent 25% of employees (Q1) remains relatively stable.

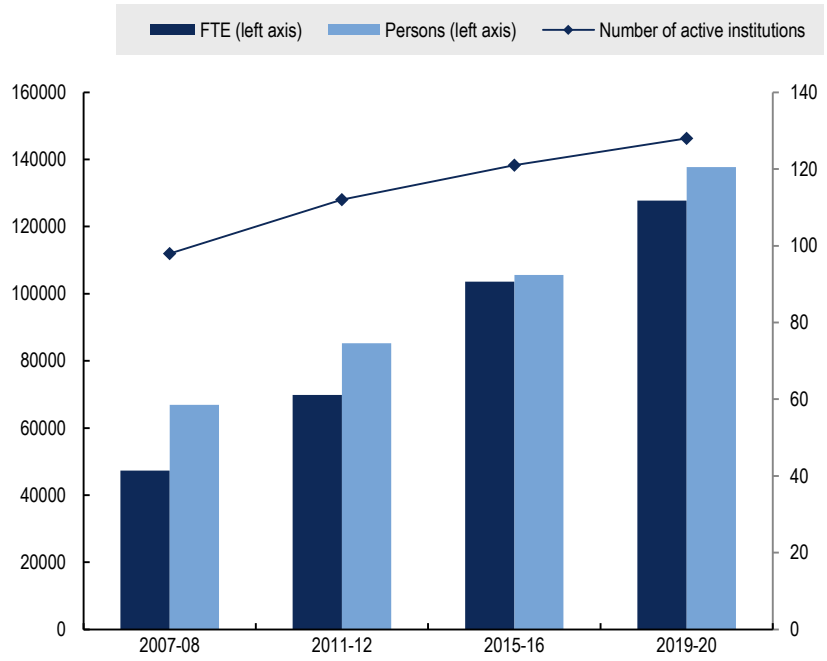
Figure 7. Median number of employees (FTE) in RTOs



Note: in this graph and following ones Q1 and Q3 refers respectively to the first and third quartile.

The total number of employees (heads) has more than doubled in ten years (from 66 855 to 137 723 heads) (Figure 8). While the number of institutions has increased, the number of employees grew even more rapidly. This implies that that the average number of employees per RTOs has increased significantly over the period (from 682 employees to 1075).

Figure 8. Total number of employees (FTE) in RTOs



The median number of employees has grown in RTOs of all size categories and in particular medium size ones (Table 5).

Table 5. Median number of employees by RTO size categories

	2007-08	2011-12	2015-16	2019-20	Increase 2007-2020
Very small	80	83.5	91	96.5	21%
Small	182	214	199	221	21%
Medium	431	528	615.5	650	51%
Large	1212	1578.5	1466.5	1480.5	22%
Very large	6026.5	6173.5	5785	6784	13%

The median number of R&D personnel has also significantly increased (Figure 9 and Figure 10). On average the number of R&D personnel rose from 348 in 2007-08 to 757 employees in 2019-20. Their share in the total number of employees (Figure 7) is almost stable since 2011-12, between 68% and 70% during the period. The distribution of R&D personnel by RTO size shows the same evolution pattern than the one of the total number of employees (higher growth of the largest RTOs).

Figure 9. Median number of R&D personnel

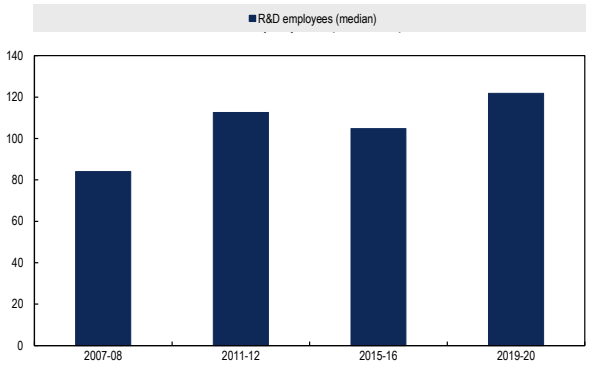
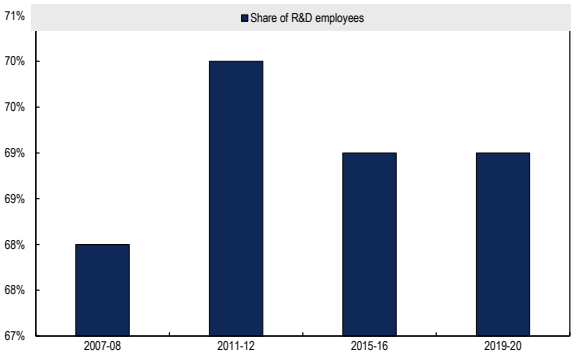


Figure 10. Share of R&D personnel



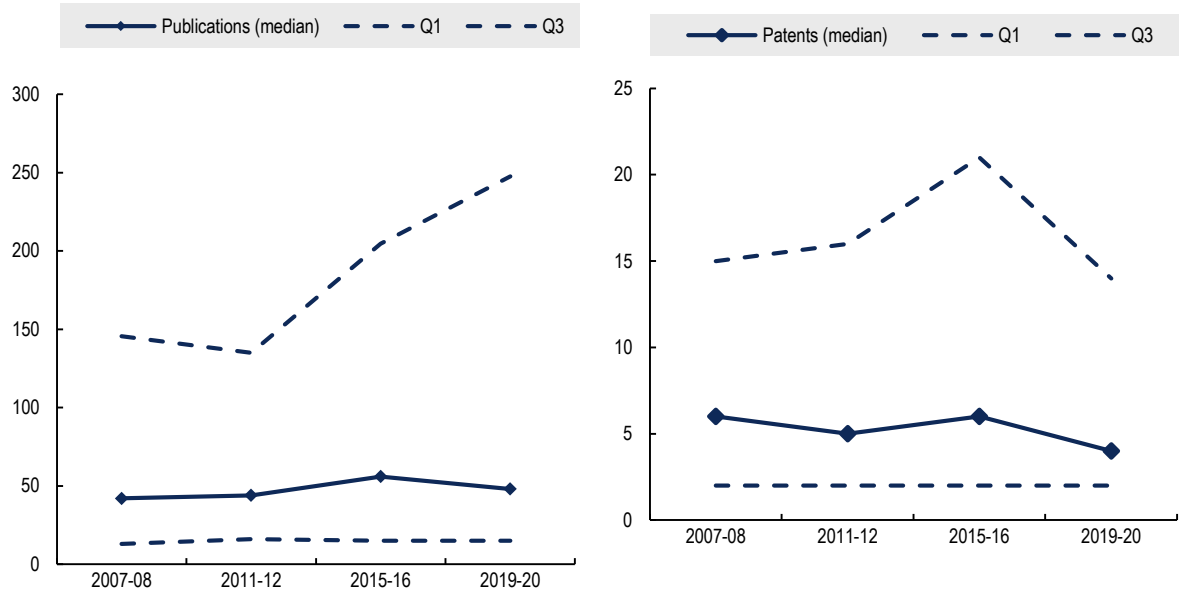
Main outputs of RTOs

The median number of publications is rather stable, slightly decreasing in the last period, but the dispersion within the sample is increasing very significantly (Figure 11). The analysis by group size confirms the strongest increase of the number of publications of the Very large[vi] RTOs (in particular until 2015-16).

The median number of patents is decreasing since 2011-12, including for the RTOs that are more active in patenting.

The number of spin-offs has slightly increased but remains at low level (Q2=2). However, comparison based on this indicator should be taken with caution since only a limited number of the Large and Very large RTOs do create spin-offs. Some RTOs are not allowed or strategically decided not to create spin-offs in order to focus their efforts on existing companies. On the other end of the spectrum, other RTOs have created entities dedicated to creating companies based on the results of their research activities (see for instance Tecnalia Ventures in Spain).[vii]

Figure 11. Median outputs, by type of outputs



Consistent trends by size categories are difficult to clearly assess, not least because publications and patents strongly vary by sectors and fields. Patent applications have decreased in recent years for Very large RTOs, while they have increased significantly for Large RTOs. They have remained at low level and rather stable for Very small to Medium RTOs. As for publications, they have increased significantly from 2007 to 2016 and slightly decreased for Very large, Large and Medium RTOs. They have remained rather stable from 2011 to 2020 for Very small and Small RTOs.

The average number of patents has increased but less rapidly than the number of R&D employees (Table 5), which indicates a decreasing ratio of patents per R&D employee. This trend can be related either to a decrease of patent productivity of researchers and/or a shift of RTOs towards other outputs or other means to protect IP (including secrets). The average number of publication per R&D employee has remained rather stable during the period.

Table 6. Characteristics of output distribution

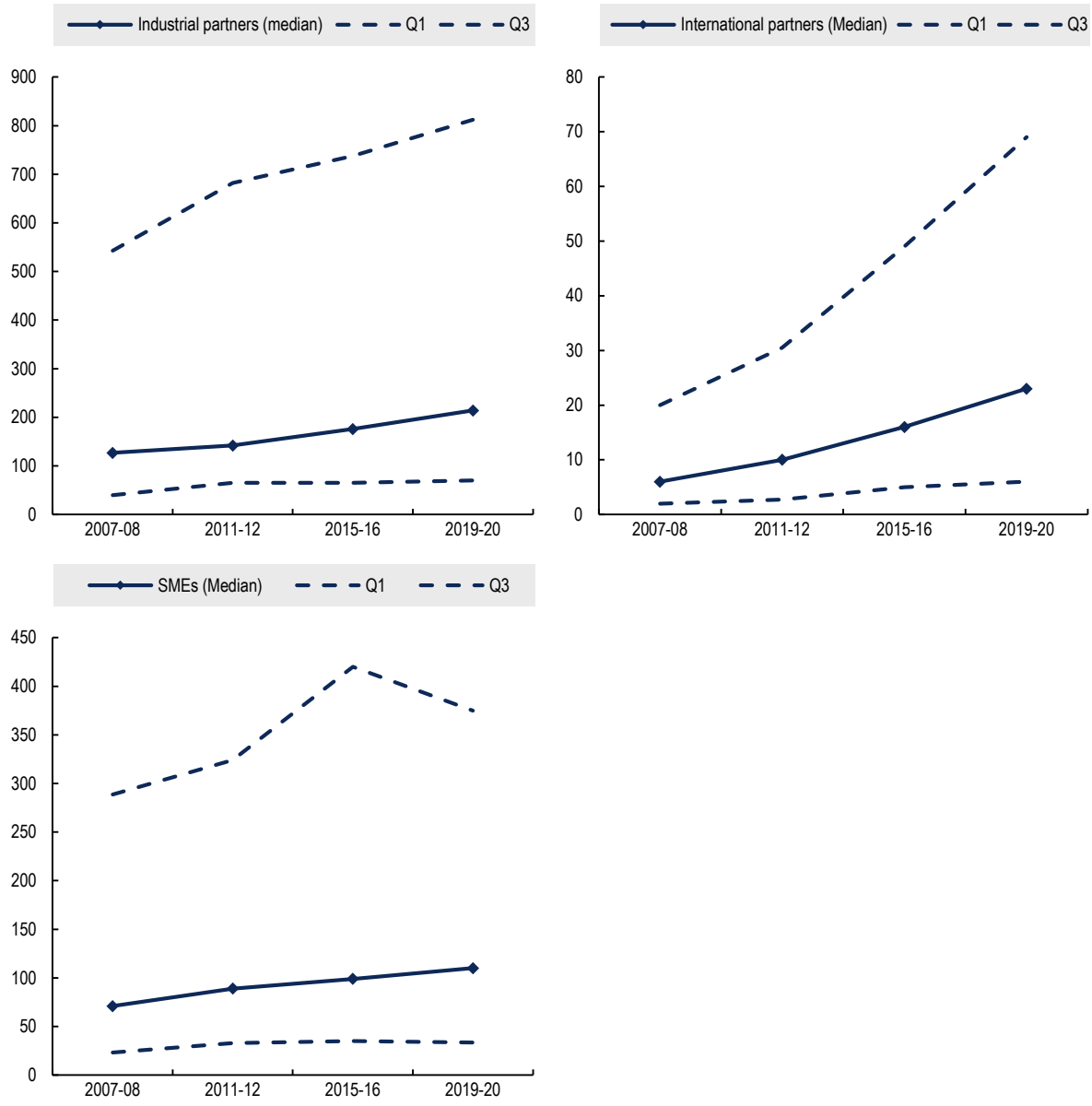
		Minimum		Average		Maximum	
		2007-08	2019-20	2007-08	2019-20	2007-08	2019-20
Publications	Number of publications	1	1	262	454	3484	8294
	Publication/R&D employees	0.021	0.027	0.54	0.55	2.3	6.57
Patents	Number of patents	1	1	53	125	858	7543
	Patent/R&D employees	0.0039	0.0017	0.063	0.043	0.3	0.58
Spin-offs	Number of spin-offs	1	1	3.5	4.4	25	35
	Spin-offs/R&D employees	0.001	0.0003	0.115	0.01	0.1	0.15

Note: RTOs that did not produce some outputs during the period are excluded from the data in this table

Main industrial partners of RTOs

The number of RTOs' industrial clients has increased dramatically during the period. The increase of the third quartile is particularly pronounced, which indicates that the number of RTOs having high number of clients is increasing rapidly. Among industrial partners, the same trend is observed more specifically for international partners and SMEs.

Figure 12. Median number of partners, by type of partners



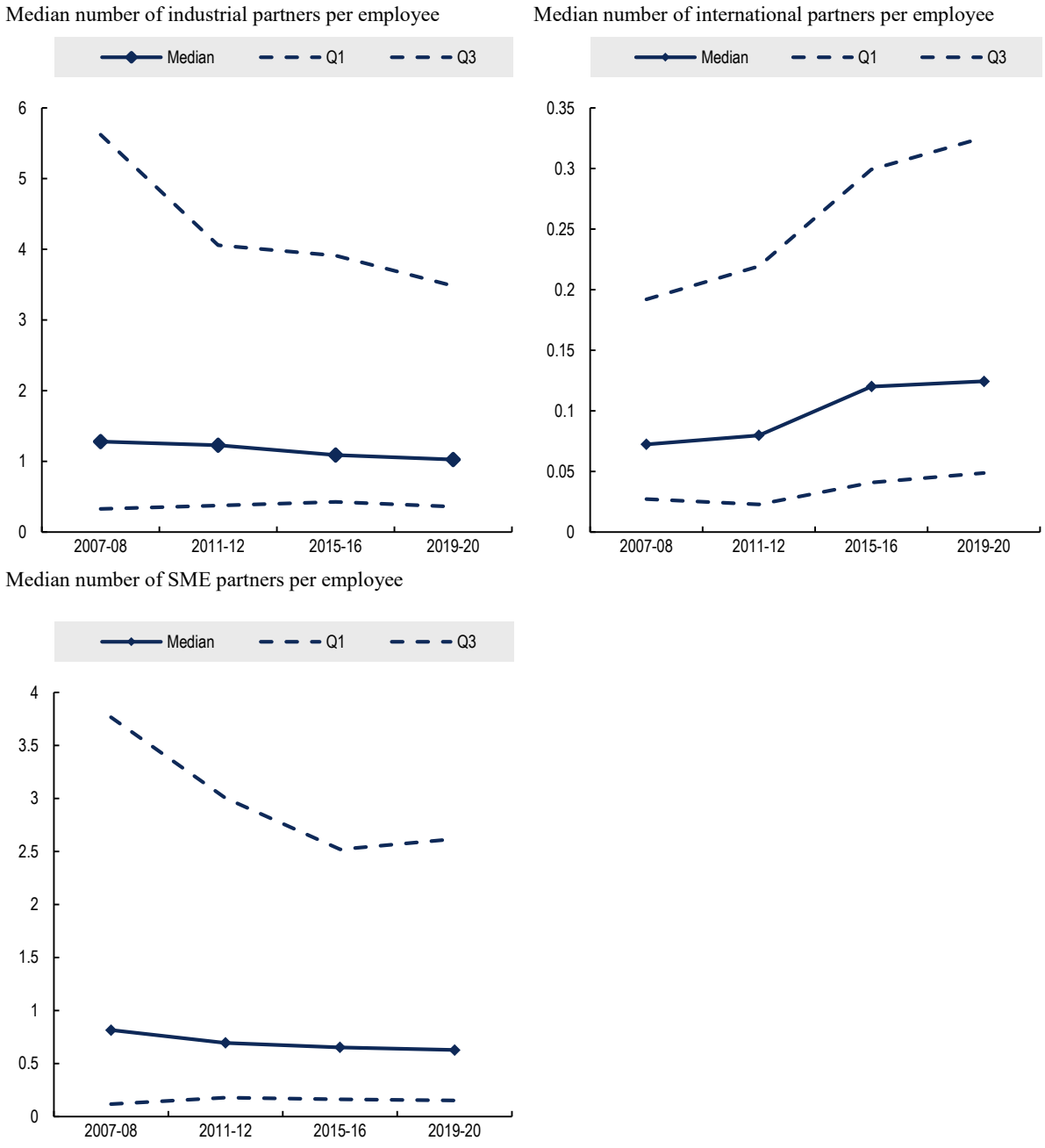
Note: Industrial partners represent all type of partners (business companies only). International partners and SMEs are subcategories of industrial partners.

The increase in the number of industrial clients and SMEs are mainly related to the growth of RTOs, as shown by the evolution of the number of partners per employee,

which remain rather stable or can be even decreasing (e.g. the number of SME partners in the last period).

The evolution pattern is very different for the number of international partners, reflecting a trend of rapid internationalisation of RTOs (Figure 13).

Figure 13. Median number of partners per employee (FTE), by type of client

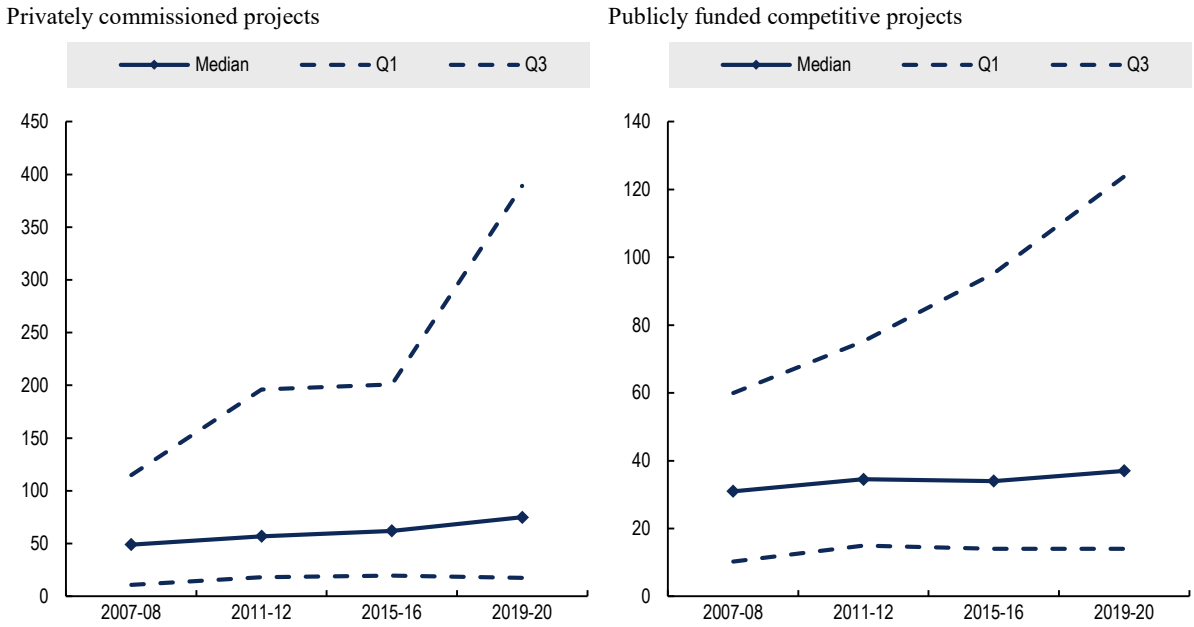


Number of projects of RTOs

The median number of privately commissioned projects is far greater than the number of publicly funded ones. Both types of projects are increasing in number, but the

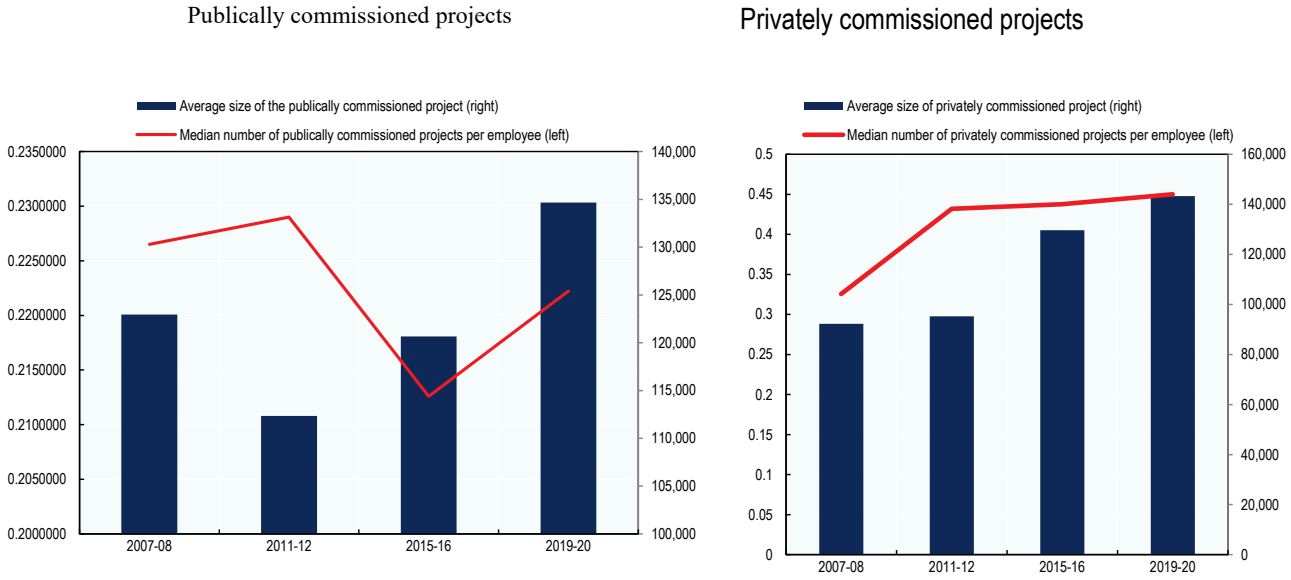
distribution is getting more dispersed, with the largest RTOs having a number of projects (private and public) growing faster than the smaller and median ones (Figure 14). This is particularly true for privately commissioned projects.[viii]

Figure 14. Median number of project, by type of funding



The data provided on the amount of income by sources allows for the calculation of the average project size. The average size of publicly funded competitive projects steadily increased from 112,000 to 134,000 euros since 2011-12 following a sharp decrease from 2007-08 to 2011-12, possibly related to the effect of the 2008 financial crisis (Figure 15). Interviews tend to suggest that many RTOs have compensated the decline in publicly funded projects by seeking more contracts and cooperative projects with industry. The average size of privately commissioned projects increased sharply from 92,000 to 143,000 over the period. Although the study period cover the year 2019-20, the effect of the COVID-19 crisis is only partially captured in the collected data. The same set of data collected by EARTO among its members in 2022 will provide very useful information in that regards.

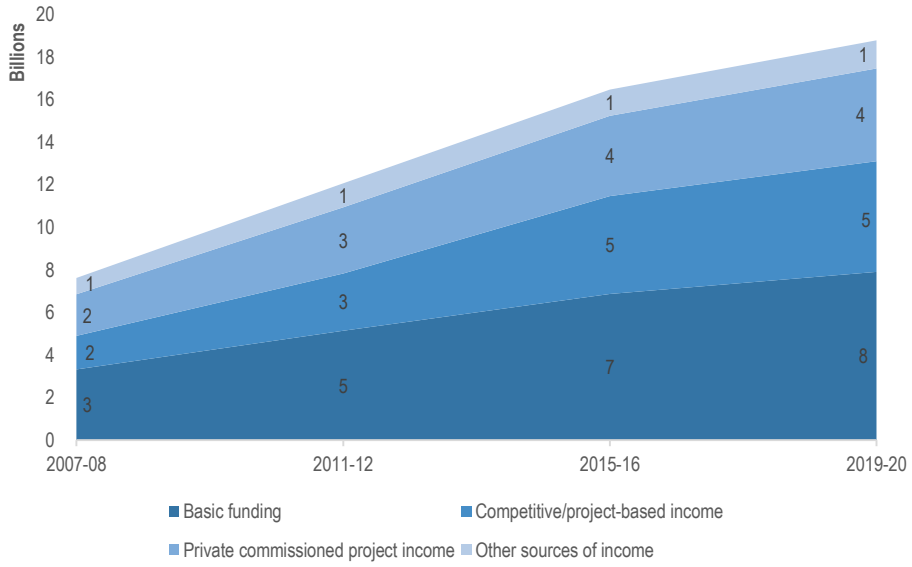
Figure 15. Number of private and public projects per employee FTE (left axis) and the average size of the project (right axis)



Income of RTOs

Reflecting their growth during the period, the budget of the sampled RTOs has increased very significantly from 7.6 to 18.7 billion euros from 2007-08 to 2019-20. The three main sources of income have more than doubled throughout the period (Figure 16).

Figure 16. Structure of RTOs budget, by type of funding (in billion Euro)



In total (all RTOs included), basic funding represents the larger share of RTOs' total income, around 43% across the period. The share of income originating from public

competitive programmes has increased significantly from 21% to 28% and the share of income from privately commissioned projects has slightly decreased from 26% to 23%.

The distinction between European and non-European RTOs shows a greater share of public funding (basic and competitive funding) for non-European RTOs (Figure 17 and Figure 18).

Figure 17. Evolution of the structure of budget of European RTOs, by type of funding

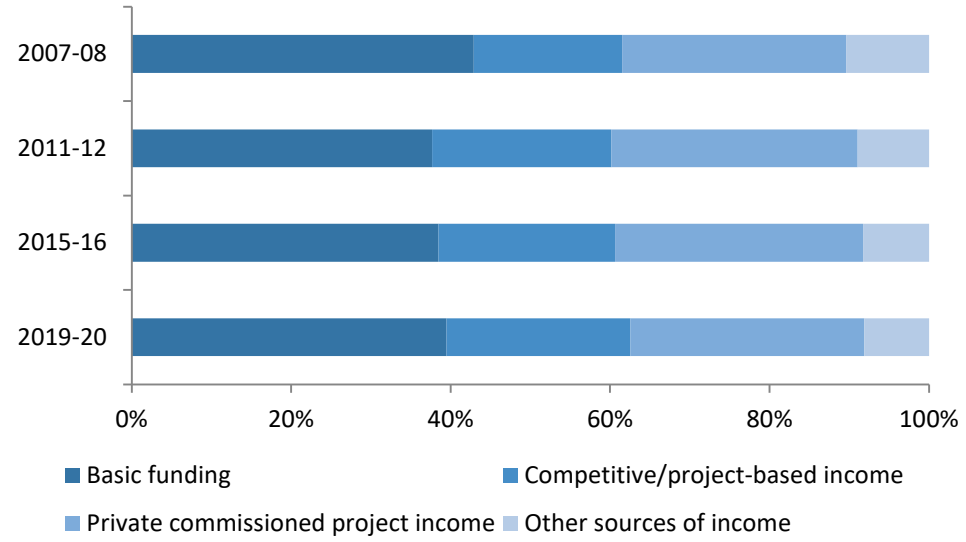
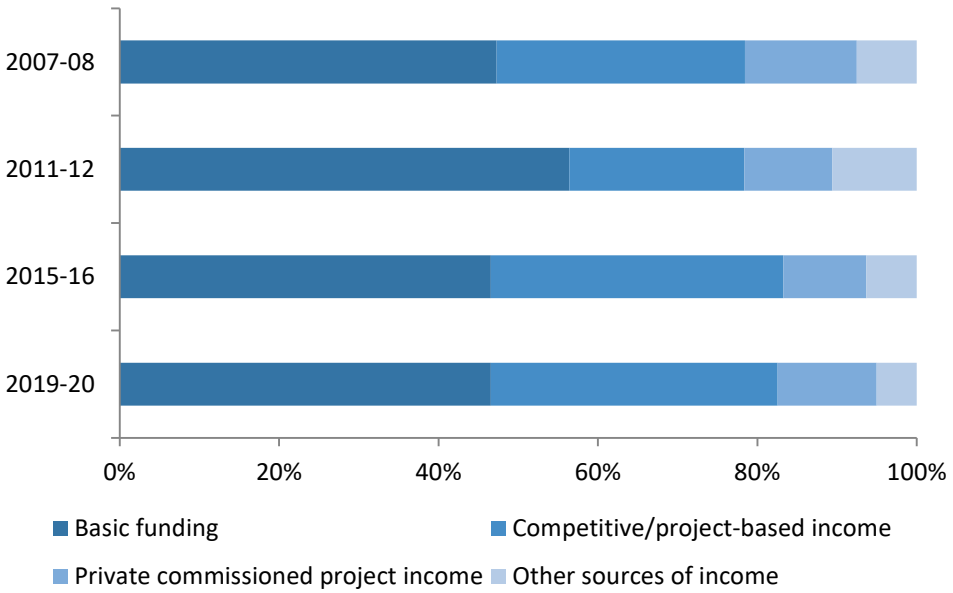


Figure 18. Evolution of the structure of budget of non-European RTOs, by type of funding



The share of basic funding is related to the size of RTOs. It increases significantly with the size of RTOs, from 18% for Very small to 45% of total income for Very large RTOs.

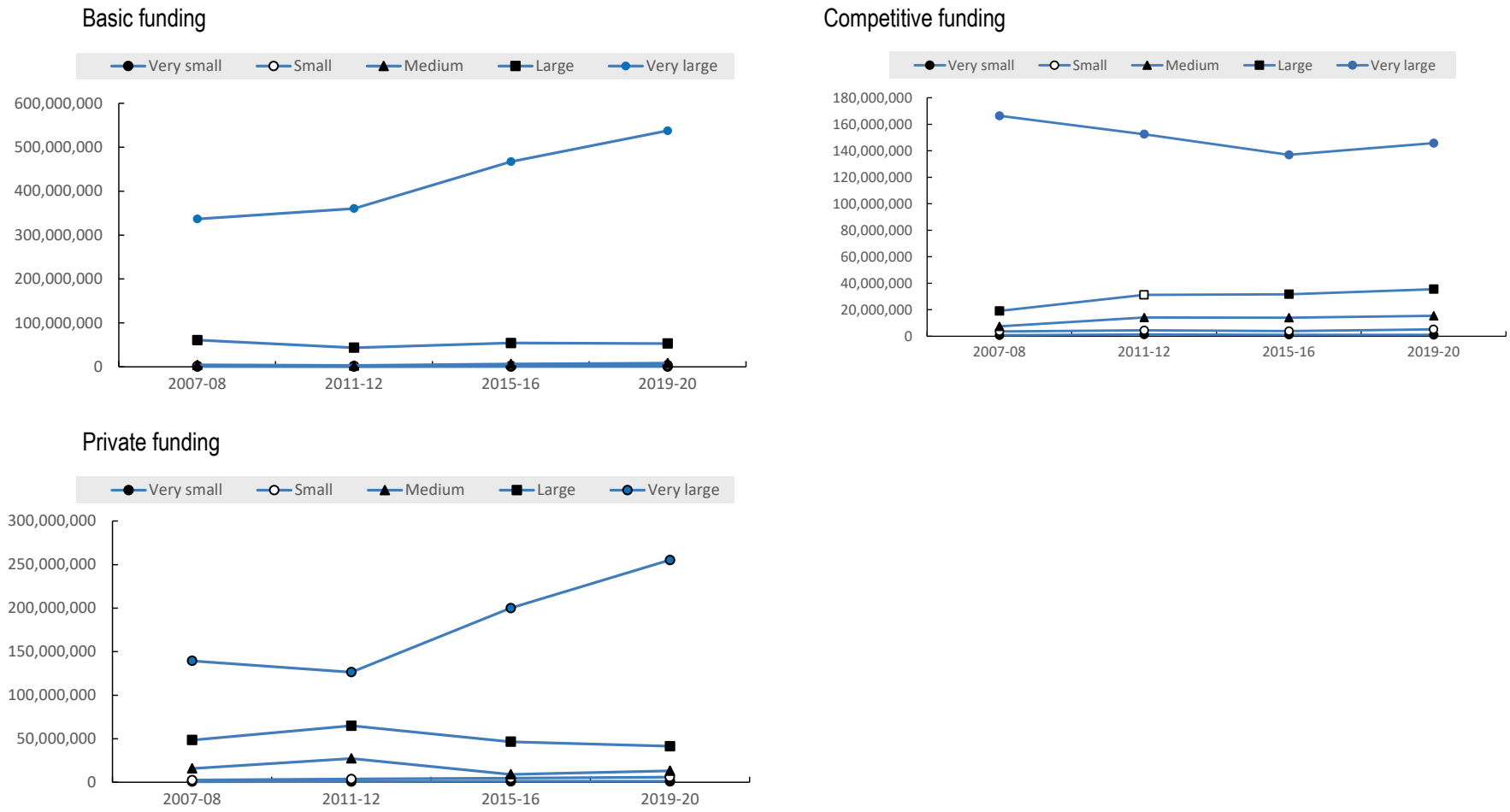
The share of competitive/project-based income is somewhat more homogenous and less related to RTOs' size. Although it is less clear than for basic funding, private funding is following an opposite pattern, i.e. decreasing with RTOs' size (Table 7).

Table 7. Structure of RTOs budget, by type of funding and size group (2019-20)

	Basic funding	Competitive	Private	Other	Total
Very small	18%	30%	32%	20%	100%
Small	22%	33%	37%	8%	100%
Medium	30%	31%	34%	5%	100%
Large	35%	24%	30%	11%	100%
Very large	45%	29%	20%	6%	100%

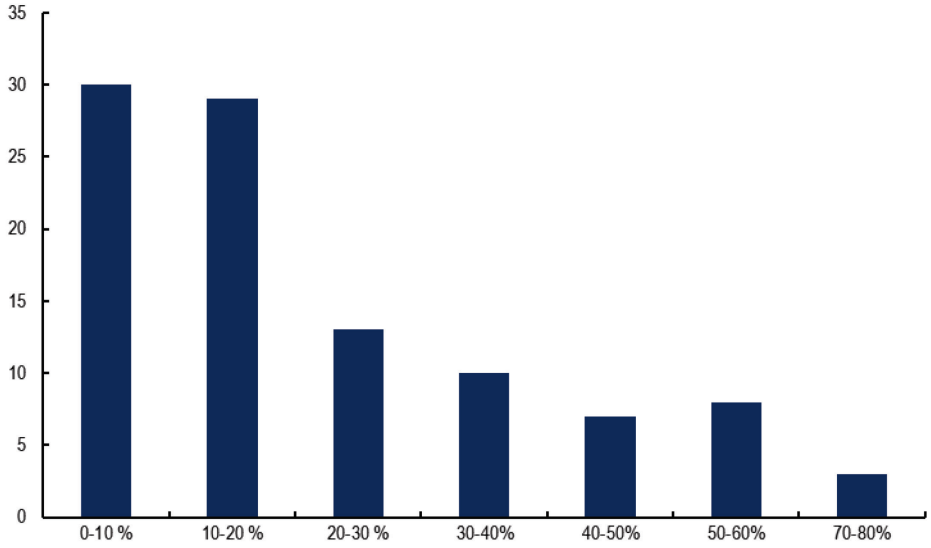
The basic funding and private funding of the largest RTO have increased very significantly, while it has remained rather stable for other RTOs of smaller sizes. An inverse pattern is observed for competitive funding, which has decreased for the Very large RTOs and increased or remained stable for the others (Figure 19).

Figure 19. Evolution of the median RTO income, by type of funding and size group (in Euro)



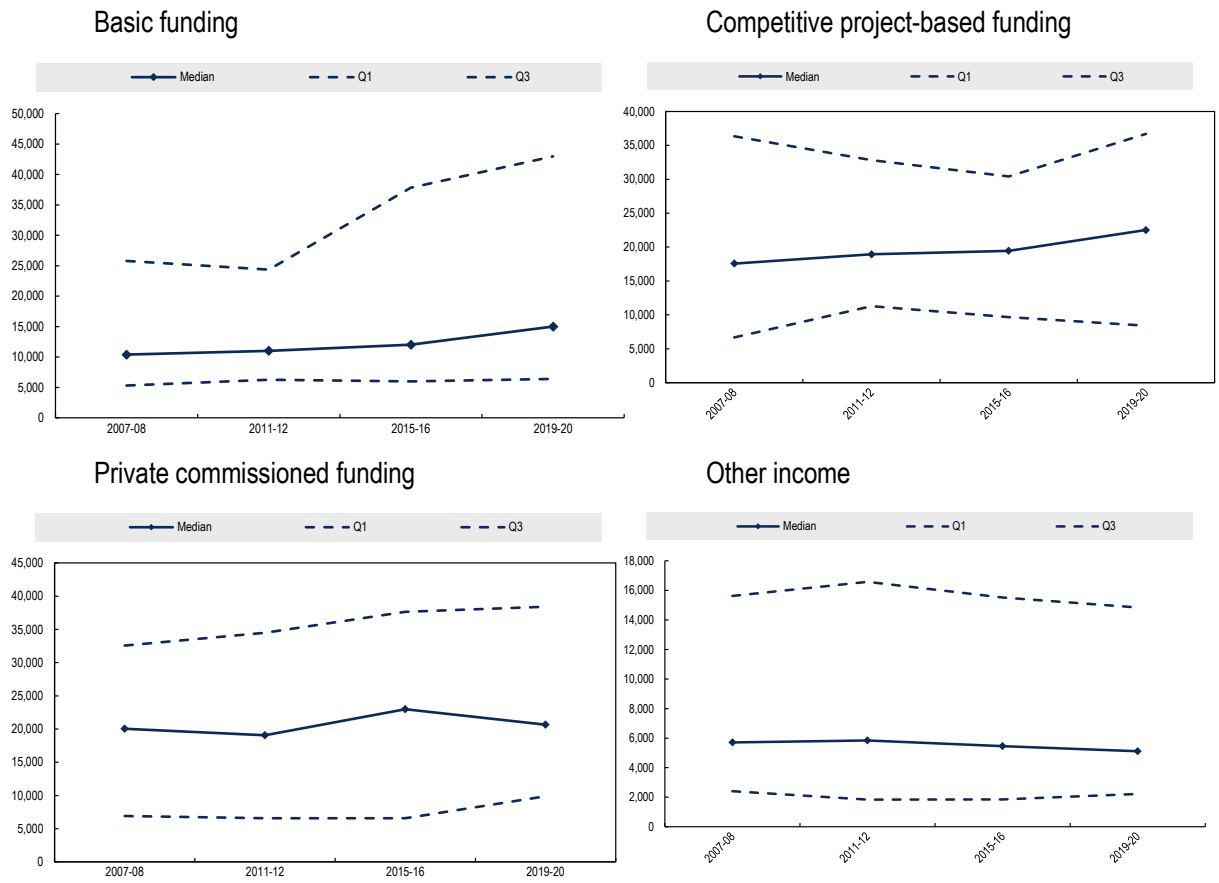
Basic funding represents less than 20% of their total income for 60 RTOs about half RTOs in the sample (Figure 20).

Figure 20. Number of RTOs by share of basic funding (2019-20)



The amount of funding per employee has increased significantly for all types of funding (but 'other income'), and this growth was particularly pronounced for basic funding of the largest RTOs (Figure 21).

Figure 21. Median funding per employee (FTE) and 1st and 3rd quartiles of income distribution

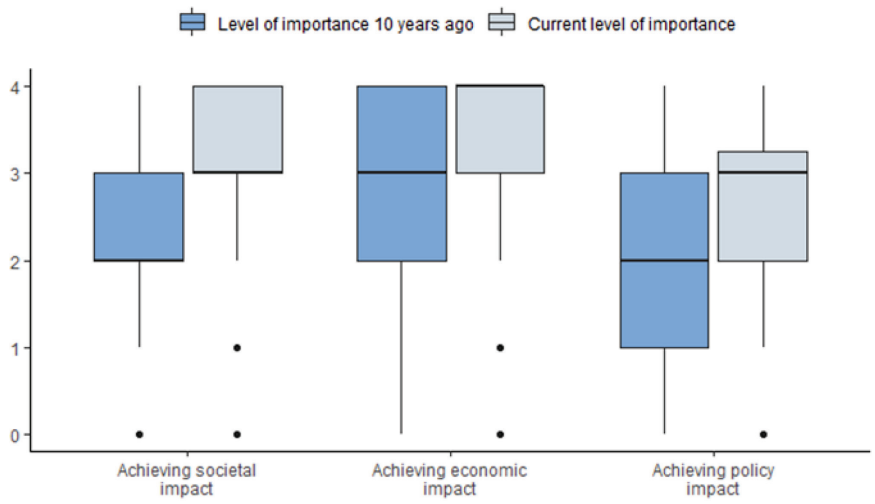


Chapter 4. The missions of RTOs

4.1 Main mission objectives

Survey respondents were invited to indicate the level of priority of three mission objectives, reflecting respectively their relative focus on achieving economic, policy and societal impacts, and how these have evolved in the last 10 years. Achieving economic impact was the main priority of RTOs ten years ago, and its level of importance in RTOs' mission has increased since then (Figure 22). It is therefore still considered as the primary objective of RTOs. The objective of achieving societal impact experienced the greatest increase, but still remains below the economic impact objective. Achieving policy impact is the least important of the three objectives and shows the greatest diversity of responses (with some convergence toward greater importance over the last ten years).

Figure 22. Level of priority of RTOs' mission objectives, by mission objectives



(0 Not important; 1 Slightly important; 2 Moderately important; 3 Important; 4 Very important)

The analysis of median level of importance by size group does not reveal any size effect, apart from a somewhat smaller importance of impact for small institutes. The increase in the level of societal and policy impacts in the missions of the largest RTOs is higher than in more modest size organisations.

4.2 Evolution of RTOs' missions

Stable formal missions, evolving de facto missions

The interviews confirm the analysis of the survey responses and, more generally, the general understanding of what RTOs' mission is. The mission of a large majority of RTOs remains to support the growth of business companies through the provision of technology-based product and service solutions. This type of mission, which can take different forms depending on the national and sectoral contexts, was the genesis of most RTOs and remains their *raison d'être*. The review of official missions clearly supports

this statement.[ix] In some countries such as Norway, the RTOs have been sometimes described as functioning as "the R&I departments" for the industry and public sectors, to the extent there has been debates on a potential overreliance (and associated lack of commitment in R&D) of Norwegian companies vis-à-vis institutes. While this could be true in some instances, it contrasts with the vast majority of cases where RTOs are not service providers for industry, delivering ready for use knowledge and solutions, but partners in co-development processes, hence requiring involvement and capacity also from firms. One important success criterion is the combination of professional quality and proximity to users. Furthermore, the collaboration with a range of users means that the researcher's skills are continuously developed and prevents lock-in of knowledge.

Several RTOs have attempted to capture the microeconomic impact of RTOs on firms' output, with the additional objective to further develop the methodology and validate it more widely across various types of research organisations (See Box 2).

Box 2 Assessing the economic impact of RTOs

TNO launched a study in 2019 to estimate its economic impact on firms' productivity. The results of this study show that firms that use TNO services have 14-17 percent higher value added in the next year, compared to similar firms that did not use TNO services. The study corrected for selection bias of firms that use TNO services, by applying the propensity score matching method that ensures that firms in the treatment group and control group are comparable. For each firm in the treatment group, a counterfactual with a similar probability to use TNO services is selected in the control group. Results are in line with existing research assessing the role and relevance of RTOs. The study concluded that the impact of TNO is significantly positive on firm output.

Fraunhofer conducted several studies to assess its micro and macroeconomic impacts. Using panel data until 2014, one them found that for every euro of public funding spent on the Fraunhofer Gesellschaft, three to four euros were received back on the national, state, and municipal level. Within the same study, also firm-level effects were estimated showing that compared to companies that do not cooperate with Fraunhofer, the companies that do are more likely to launch new products with a probability that is 10.2 percentage points higher. In the case of completely new product categories, this effect is even more pronounced at 13.2%. Another study in 2019 concluded that a one percent increase in the size of the contracts with Fraunhofer leads to an increase in growth rate of sales by 1.3 percentage points, and to an increase in the growth rate of productivity by 0.8 percentage points in the short-run. The study also provided evidence of long-run effects accumulating to 18% growth in sales and 12% growth in productivity over the course of 15 years. In a recent study updating the macroeconomic analysis with data until 2017, the economy-wide GDP effects of Fraunhofer's activities exceeded its budget by a factor of 21.

IDEA performed an economic assessment study based on the activities of nine RTOs during 2015-2016. The study showed that for each 1 job created in those RTOs, 4 jobs were created elsewhere in Europe and for each €1 invested in these RTOs in the form of basic grants, €3 returns flew back to governments.

A Danish study published in 2021 provides a review of about 40 studies and articles addressing RTOs' effects on firms' performance. The presentation of the results is structured along on RTOs' effect on i/ firms' economic performance; ii) firms' innovative performance and iii) firms' collaborative performance. While there are significant difference depending on the size of the companies, the study concludes that firms that collaborate with an RTO become more economic performant, more innovation active and have increased networking capabilities.

Source: TNO (2019), Grant et al. (2022), Fraunhofer ISI (2018), Comin *et al.*, (2019) ; IDEA (2018), Van Criekingen et al. (2021)

There is a strong consensus among RTOs that their respective official missions have not changed in the last 10 years. This is confirmed by a review of official mission statements provided by respondents. At most, the wording has been modernised, the initial generic statements have been made slightly more specific and precise, and some key words have appeared.[x] Significant changes in the mission formulation are very rare and, when they do occur, are associated with changes in government policy and occur most often in RTOs that have strong governance and financial linkages with public authorities. Other significant evolutions of some RTOs' official missions are related to structural changes (notably merger or association/dissociation from universities) and, less frequently, change in management leadership.

However, while the majority of survey respondents and interviewees declare that their organisations' official missions remain unchanged, there are significant evolutions to

the objectives and activities of their organisations. These changes of RTOs' *de facto* missions are gradual and as such have not triggered a rethinking and reformulation of the official mission. Change is more often apparent in RTOs' mid-term strategic plans and communication materials, where the contribution to societal issues is increasingly prominent. Thus, mission statements *per se* may not necessarily be the most obvious or best place to look to understand how these organisations are undertaking and configuring their activities.

These gradual mission changes are mostly related to evolutions of the demand from their clients and needs from the society in general, often mediated or amplified by policy and regulatory changes that necessitate RTOs' shift in activities. The missions of the large national institutes with public missions in areas such as energy and health where the state is still (in most countries and despite waves of privatisations) an important player have changed with the evolution of governments' policies in these areas (notably for instance regarding nuclear or renewables energy).

An interesting configuration is one where the evolution of RTOs' mission was the result of a more collective and negotiated process with the public authorities that fund them and/or participate in their governance structure. Some countries have specific channels or initiatives to collectively discuss the evolution of RTOs and possibly reposition them in the innovation system. In Canada for instance, the 'NRC Dialogue' was a year-long internal assessment that resulted in a significant shift of the organisation in 2017/2018 in various respects (e.g. renewed focus on research excellence, stronger emphasis on operating in an open and collaborative manner, with new funding and authorities, new International Strategy etc.). In Norway, RCN manages the relationships with the institutes to which it provides basic funding and often negotiates with them issues related to their individual performance and directions (for instance specialisation). In Korea, the National Research Council of Science & Technology (NST) that manages 25 research institutes[xi] has in recent years launched an initiative to revise their individual missions. Performance-contracts and strategic and financial 'pacts' like in Austria are also a way to engage in cyclical strategic discussions between RTOs, individually or as a sector, and policy makers.

Contributing to solving societal challenges

Beside the gradual evolution of activities, a more recent trend affects all RTOs: the need to contribute to solving mounting societal challenges, in particular global warming, environmental problems, health issues, and the digitalisation imperative. The COVID-19 pandemic has accelerated this shift. It has triggered a rethinking of their role beside services to industry and provided numerous demonstrations of their capacity to quickly mobilise to contribute to solving societal problems. One interviewee mentioned that the COVID crisis has improved the awareness among public authorities that RTOs could be effective 'policy instruments'.[xii] The large initiatives launched to reduce the negative economic impacts of the crisis by creating new opportunities in sustainable activities (e.g. in Europe the NextGenerationEU Recovery Plan and the associated Green Deal or in the US the American Rescue Plan) have accelerated this shift.

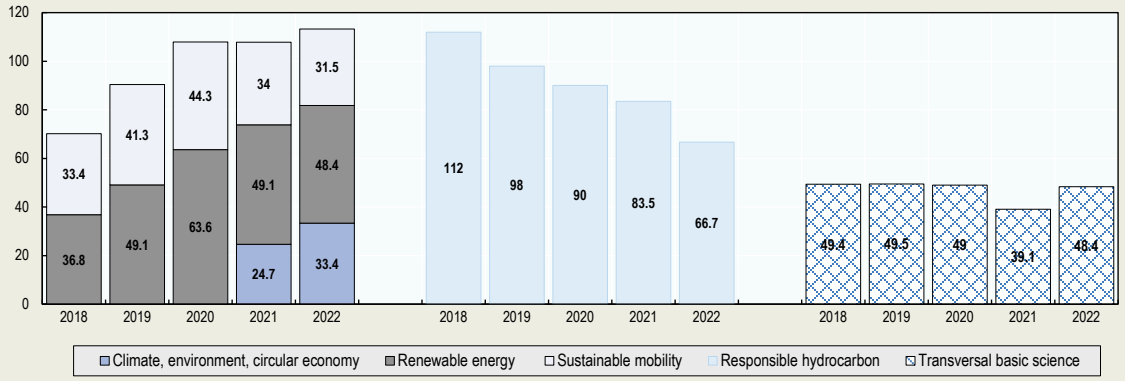
Examples of RTOs' transitions are plenty. Necessary changes in all aspects of the organisation are especially striking for those that were more closely associated to the 'old paradigm' (see Box 3).

Box 3. IFP Énergies Nouvelles' paradigmatic transition

IFP Energies nouvelles (IFPEN), which primary mission was to support the oil, gas and automobile industries is now a major research, innovation and training player in the fields of energy, transport and the environment. Its current mission is to *"provide solutions to take up the challenges facing society and industry in terms of energy and the climate, promoting the ecological transition towards sustainable mobility and the emergence of low-carbon and cost-effective energy mix*. Its strategy is structured along four priorities: climate, environment and circular economy – renewable energies – sustainable mobility – responsible Oil and Gas. These four strategic priorities rely on a transversal fundamental research basis.

Activities related to the new energy technologies account today for 71% of its operational expenses, a remarkable shift undertaken in a challenging context of significant reduction of its state allocation (from 53% of total income in 2010 to 44% in 2019). In 2022, responsible O&G represents 29% of the overall budget (vs. 62% in 2018), while climate, environment, sustainable energy and mobility account for 50% and transversal basic research for 21% (see Figure 23), underlying the shift of IFPEN's activities towards ecological transition.

Figure 23. Evolution of IFPEN's Budget, 2018-2022



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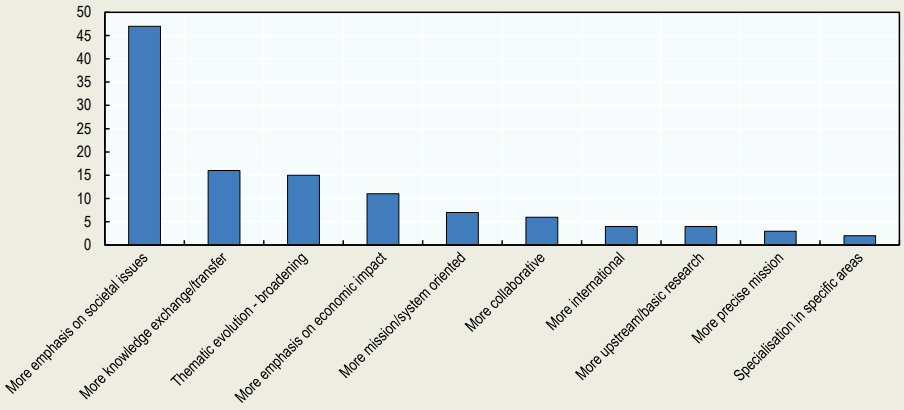
Source: IFPEN

As RTOs are hybrid organisations in many regards (public-private, science and industrial development, policy and services, etc.), this evolution stems both from pressure from governments to deliver on these objectives (attached to basic funding and especially competitive and strategic funding) as well as new opportunities from industry and the public sector clients.

Box 4. Analysis of online survey's open-text responses – mission evolution

A majority of the open-text responses to the question on the mission evolution starts with the statement that the official mission has not evolved or only marginally. The systematic analysis of these responses clearly shows the importance of the mission shift – or rather extension since delivering economic impact remains the primary objective in most cases – towards addressing societal impacts. While some mentioned that they have tried to address societal challenges since their establishment, some explained how they started from strictly economic and business objectives and integrated them over the years with other societal and policy objectives related to, for instance, territorial development and reduction of environmental impacts. Many have followed the changes in their client industries' demand for knowledge and innovation and the trends in research and innovation competitive funding.

Figure 24. Type of mission evolution



Source: OECD-EARTO survey – Rating questions *Note* : Multiple responses allowed

More generally, the responses show that the pressure on RTOs to deliver results and impacts has increased significantly. This explains in particular the greater focus on knowledge exchange and technology transfer based on their research activities.

Many RTOs report also various types of broadening of their mission (towards a wider range and types of clients, industries, segments of the value chain, etc.). Broadening of the set of industries covered by the RTOs. The increased levels of expertise, experience and technical capabilities accumulated by RTOs over the years have enabled them to increase the number of industrial sectors they collaborate with. Furthermore, the synergies between the activities carried out for these different industries have themselves generated opportunities for new activities. For instance one RTO mentioned that the convergence of expertise and knowledge in digital and health technologies help deliver new medicine solutions.

This evolution has important implications on the role RTOs can play in innovation systems to respond to these demands. RTOs that work in the area of circular economy or smart cities underline that these activities have led them to become less 'techno-centric'. More generally, societal challenges often have a systemic nature that requires not only a broader range of competencies but also the adoption of a different perspective, more holistic, *i.e.* involving different sectors and disciplines at the same time rather than responding to their respective needs and demands. These RTOs are playing a role that is in the process of being defined; interviewees describe this emerging role variously as: 'system intermediaries', 'orchestrators', 'transition architects', 'innovation system hub', 'virtual OEM', 'system platforms', 'system translator', etc.

In addition to providing 'deep' knowledge and expertise, this new role also entails bringing together different actors (including universities, industry, intermediaries, ministries, and agencies at different levels of government, regulators, etc.) in large and complex initiatives. This calls for new capabilities, in addition to new forms of technological knowledge and expertise. For instance, in the context of a project initiated as part of the Next Generation Fund, companies or public sector organisations can ask RTOs to develop their initial idea, to make it more ambitious, transformational, and help them enlist different actors, in close interaction with public authorities at different levels of government.

The role of RTOs is to support the development of both 'systems innovations' and 'innovation systems'. While these two interrelated imperatives are often conflated in policy debate, it is important to emphasise that they require different capabilities and imply different roles. System innovations imply the combination of complementary knowledge, expertise, and technology to develop new solutions. This calls for some actors with wide scientific and technological coverage to be able to work at the interface between various disciplines and sectors. Innovation systems draw on the convening capacity of RTOs (rather than 'convening power', which remains the quasi-monopoly of policy makers via their funding and authority) to create bridges between different actors. This role can be defined as one of 'facilitator of collective action', including tasks that go beyond coordination (which professional consultancies can perform). In Europe, participation in large European funded projects, from FP6's Integrated Projects to the various European Partnerships, have been instrumental in helping European RTOs to further develop these capabilities (including organising proper collaboration framework conditions between different type of partners with IP, confidentiality[xiii]).

Intervening at system level in a specific area (i.e. encompassing a portfolio of technologies and activities needed to address a complex challenge) is out of reach of most companies. Even keeping abreast of developments in the system, which include a range of public and private actors, is often difficult to companies under strong competitive pressure. This requires a long-term investment and a breadth of expertise (scientific, technological, economic but also with regards to policies and regulations). Against this backdrop, RTOs are important partners that bridge the companies to this wider strategic scale and scope.

Several RTOs already play advisory or coordinating roles to support mission-oriented policies in Austria (AIT, Joaennum), Germany (Fraunhofer) and Sweden (RISE). Some of them, like in Canada (NRC) and Australia (CSIRO), are even themselves the leaders of the mission-oriented policy initiatives, a way to both better integrate their activities around missions and better orientate and coordinate the various actors of their respective national innovation system.

Box 5. RTOs as system integrators in Finland and Sweden

Systemic policy approaches are all forms of public intervention that support not only individual actors and projects but also the broader groupings (e.g. national or local innovation systems, networks and clusters, various types of ecosystems) in which they are embedded and they interact to foster collective action. Mission-oriented policies and other types of so-called transformative policies are among the systemic policies that have aroused most interest in recent years. Nordic countries are among those that have implemented several of these policies. The key role played by RTOs in these initiatives is acknowledged by a variety of sources.

Sweden is one of the most advanced countries in terms of STI systemic policy. Its innovation agency, Vinnova, defines itself as the Swedish Governmental Agency for Innovation Systems and implements several systemic instruments such as Vision-Driven Health and the Strategic Innovation Programmes. It is in this context that the role of Swedish RTOs as system integrator should be considered, both as a cause and consequence of this trend. This role of RTOs, and of RISE in particular, is formally acknowledged in the Research and Innovation Bill, i.e. the STI action plan that defines the main thrusts of the STI policy for the next four years: "The need for system solutions where many actors collaborate is large and RTOs have a significant role to play in this (…). The ability to bring together different actors around common problem formulations is important for developing solutions to societal challenges. RISE is successful in holding together and coordinating complex projects both nationally and within the EU based on its interdisciplinary competence and neutral position in the Swedish innovation system". An evaluation of the Strategic Innovation Programmes provides even stronger evidence of this role played by RTOs. The report indicates that these initiatives have had significant systematic impacts, by gradually achieving a national joining of forces and mobilisation, both across traditional sectoral boundaries and along value chains. The programmes have also contributed to renewal by involving actors that have not previously participated in R&I initiatives. RTOs have significantly contributed to this "by fulfilling a system integrating function, especially with regard to industry."

Finland also adopts a systemic policy making approach, notably using ecosystems to allow coordination of a wide set of actors around commonly defined vision and roadmaps. Business Finland implements different systemic instruments, notably the Growth Engines. A recent impact study analysed in details several Finnish ecosystems using network graphs and showed the role that VTT played in several of them as connectors between different actors. VTT was even one of the key actor in 2015-16 to think and help design the national ecosystem approach with public authorities. While VTT in not the only actor to play this role (some universities and large companies also are also network 'nodes'), it is non equivocally the one that ensure this bridging function in the greatest number of ecosystems and appear more central in ecosystem network graphs. VTT also leads and formally acts as formal coordinator of several of these ecosystems (such as Smart Otaniemi in smart energy solutions or BATCircle in battery materials and component development). VTT has created a position of 'Co-creation managers' who are in charge of specific eco-systems.

Source: Interviews; Åström and Arnold (2019), Government of Sweden (2020); Zegel et al. (2021)

In the midst of this gradual 'mission shift', RTOs must still contend with the need to achieve consistency between their economic and societal components in their mission, as the latter gain prominence. So far, RTOs do not report any incompatibility or need to undertake significant trade-offs. However, this shift and subsequent need for consistency might ultimately require structural reorganisation and operational process change at some level.

The strengths and limitations of RTOs to contribute to sustainability transitions

When it comes to dealing with system innovation, timeframes and sizes matter.

With regards to timeframes, sustainability transitions are long term process. They require actions to be taken in the short term to initiate processes and allow new behaviours, but technologies with more long-term effective deployment are also necessary to face current technological or material bottlenecks or implement new product or service generations replacing transient ones. Some RTOs can tackle this wide timescale of deployment, sometimes ranging ten to thirty years, thanks to their ability to deliver technology to their partners of high maturity level and develop more disruptive and long-term solutions. RTO also often complement their scientific and technological expertise with market and technical-economic competences which allow them to act not only as technology providers, but also to consider the opportunities and limitations, as well as the conditions, for a given technology to actually contribute to policy objectives. This is particularly important in global transitions where the scale of the challenges require an integrated approach to understand the evolution of complex systems.

Size, critical mass and scope can be achieve through the mobilisation of large RTOs or through network-based strategies.

Large RTOs and well-integrated networks of smaller RTOs have several features that make them well equipped to deal with complex and systemic issues:

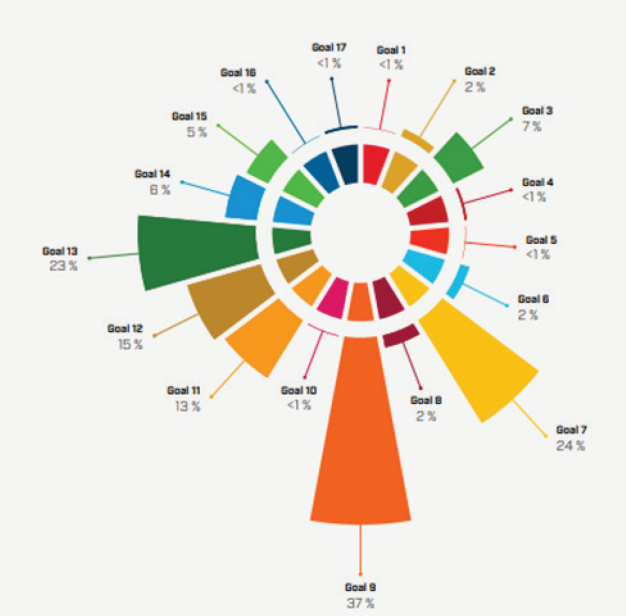
- They include the units related to the different disciplines and sectors relevant to a given societal challenge. RTOs need to be capable of articulating different knowledge components, as discipline and sector boundaries become increasingly blurred. The central functions (performed by large RTOs' headquarters) can be helpful to coordinate, and in some cases incentivise, the contributions from different parts of the organisation.
- They have the analytical and strategic capabilities that are needed for understanding ongoing and future system-wide transformations, and translating these into opportunities for the RTO. In recent years, some RTOs have established dedicated units for modelling system trends, public policy departments, or established links with social science research groups in universities. More generally, RTOs emphasise the role they play in connecting SMEs to ongoing and future system change and helping them seize related opportunities (hence the term of 'system translator').
- They can not only identify related opportunities but also influence them. Several interviewees mention the growing need to be involved in policy debates, both to be more visible and also to influence these debates and help shape the environment and 'boundary conditions' in which they operate. Few RTOs have this capacity fully developed yet, but several of them mention that this is an area that they plan to strengthen.

Box 6. SINTEF commitment and monitoring framework on the UN 2030 Agenda

The mission of SINTEF - Norway's largest RTO - is "Technology for a better society" since the 1990s. While having a positive impact on society has therefore been an integrated part of SINTEF's mission for decades, there has been in the 10 years a gradual increase in society's focus on societal challenges, and much attention has been put on SDG goals from governments. This trend has been one of the key drivers for SINTEF making the Sustainable Development Goals (SDGs) formative for SINTEF since 2019 when it adopted its corporate strategy guided by the UN 2030 Agenda. As a research institute, SINTEF is involved in many value chains, industries and areas of expertise – with an emphasis on sectors where technological solutions play an important role. This breadth means that SINTEF aims to deliver on the entire sustainability agenda and have committed to all 17 SDGs.

A condition to fulfil these objectives is that the institute is able to monitor its investments and the resulting progress made in this framework. For that purpose, SINTEF regularly assesses how its portfolio of research projects and start-up companies contributes to the various SDGs, as published in its annual sustainability report. The whole report is structured along the SDGs, presenting the main financial investment, activities and results (for instance the number of start-ups) for each goal. This is a way to be more transparent, to prioritise and better integrate consistent initiatives but also provide internal incentives for actions towards SDGs at all levels of the organisation.

Figure 25. Share of SINTEF gross turnover per Sustainable Development Goal



Source: SINTEF (2021); Larrue, (2021b)

Despite these strengths, large RTOs are also at a disadvantage, as contending uncertain societal challenges requires a high degree of flexibility and agility, which generally decrease inversely to organisational size. As it was put by one RTO during the OECD-EARTO intermediary workshop, '*RTOs have to be big and small at the same time*'. Several RTOs are currently trying to mitigate this disadvantage by adopting

organisational structures that combine the advantage of scale and scope, the technological depth, and the capacity to recombine the necessary elements of knowledge and expertise as needed (see Section 6.3).

Smaller RTOs contend with uncertain societal challenges by acquiring new research and innovation competencies relevant to new types of applications, new industry processes, and new emerging technologies in order to support sectors to shift toward sustainability. However, interviewees and respondents from these kinds of RTOs mentioned that they also increasingly feel the need to better understand and master changes at a more systemic level, as they find it difficult to separate their specific interventions from the broader system in which they are embedded. To better navigate uncertainty, smaller RTOs are making changing to their hiring practices, including by hiring managers with social science backgrounds, explicitly seeking previous experience in large projects, experience in interacting with/ developing public policy in strategic areas. Some small RTOs raise the challenge they face to integrate bigger projects with multi-stakeholder teams (e.g. larger projects in the context of various national mission-oriented policy initiatives, EU funded programmes Partnerships, etc.). Another option for small RTOs is to reach critical mass and scope by building networks to be attractive to collaboration. Depending on the strategic and institutional context, this 'Network-based RTOs' strategy (see the RTOs' typology in 3.2.3) can be a more dynamic and flexible model. Merging or forming a network can therefore in some instances be alternative solutions.

Box 7. The networks of RTOs in Norway and in Spanish regions

In Norway, significant structural changes have occurred in the RTO sector in recent years (merger between RTOs and between RTOs and universities), to such an extent that institutes are now favouring 'softer' approaches (OECD, 2022). Four institutes (IFE, NILU, NIVA and NGI) have recently interrupted a restructuring process towards one large RTO and are now considering adopting a network model.

Another interesting example of network in Norway is the FRAM - High North Research Centre for Climate and the Environment in Tromso. It consists of researchers from 21 members (RTOs, universities, companies and government bodies) who collaborate for developing larger national and international projects and programs. The Norwegian ministry of Climate and Environment contributes to the FRAM Centre with a yearly program funding of 5 Mill. Euros.

Also, the Gemini Collaboration is a strategic research collaboration between parallel research groups at SINTEF, NTNU and the University of Oslo. The aim is to develop large-scale technical centres that produce higher quality results collectively than the individual groups would achieve independently. The first four Gemini centres started their collaboration in 2003. Since then the number of partners has increased to more than 20. Centres are designated for terms of three-years after which they must apply for re-designation. Many centres have now entered their third term. The main objectives of these partnerships are:

- Achieving effective and long-term co-operation by means of mutual commitment.
- Better utilisation of laboratory facilities and joint equipment upgrades.
- A movement away from individual collaboration towards the development of larger, robust research centres.
- A comprehensively planned interplay between basic and applied research.
- Greater universal exposure in relation to clients and students.

Spanish RTOs have experienced some concentration, usually at regional level (Basque Country, Catalonia, Navarra or Valencia), either at the initiative of RTOs themselves or of the regional administrations. These structural changes responded to several objectives, both internal (reducing overlaps between RTOs and improving efficiency and effectiveness, increasing capacities and critical mass) and external (promoting a single-entry point to RTOs from public administrators, leveraging international relevance).

Two main approaches can be identified:

- Merging several RTOs into a new bigger organisation, focusing on the critical mass and positioning of the newly created RTO.
- Creating a RTOs network, with some transversal competences (common branding, promotion of cooperation, matching of commercial opportunities within the network), while individual RTOs kept their identity and independence.

In the early 2000s, in the Basque Country 8 RTOs merged into a newly created RTO (Tecnalia), finalised in 2011. Tecnalia became the biggest Spanish RTO, with currently an annual turnover of around 160M€ and employing over 1.500 people. There was also the creation of an RTO network (IK4) that provides common services to 9 Basque RTOs, which cooperate on common projects and follow specific common protocols.

In 2014, Catalonia promoted the integration of around 20 RTOs into a new organisation (Eurecat). Although this process was not completed (some RTOs in Catalonia finally opted out), Eurecat is now the largest private RTO in the Mediterranean area and the second largest Spanish RTO, employing over 700 people and having an annual turnover of about 55M€

The public administration of Valencia decided to strengthen the already existing regional RTOs association (REDIT) and make it its main contact point to implement the regional innovation

policy. In this case, the existing RTOs were already organised around REDIT, and the regional authority just took benefit of the existence of this association.

Navarra created ADITECH in 2016, a network with the mission to coordinate the whole set of research organisations in the regions (RTOs, but also universities, public research centres, and R&D enterprise units). ADITECH coordinate RTOs and leverage their relations with other science, technology and innovation agents.

Other regions have decided to create or promote different associations following the example of Navarra or Valencia. This is the case in Galicia (ATIGA), Andalusia (ACENTA) or Castilla y León. Furthermore, the Basque Country has recently created BRTA, a public network that coordinates all kind of STI organisations in the Basque Country (from RTOs to public research-oriented organisations), and also provides common services to RTOs.

Source: FEDIT (2021); FFA; SINTEF website (https://www.sintef.no/en/sintef-group/gemini-collaboration/)

RTOs' role to develop and support large technology infrastructures (TIs),[xiv] demonstration and scale up initiatives is another important contribution to addressing societal challenges.

Technology infrastructure are mostly managed and hosted mainly by RTOs and, to a lesser extent, Technical Universities (TUs). The role of TIs is particularly important to deliver the twin green and digital transitions (Viscido *et al*., 2021). RTOs are well suited for this role since developing and maintaining TIs require interdisciplinary competences and complex technological know-how and experts to operate them (ibid.). As TIs are mobilised to investigate and demonstrate solutions to systemic challenges, they also increasingly encompass not only physical and digital aspects, but also the economic, regulatory and ethical aspects (see Box 8).

Box 8. RTOs' support scale-up and demonstration – the case of AIT's City Intelligence Lab

The City Intelligence Lab (CIL) is an interactive platform developed by the Centre for Energy of the AIT Austrian Institute of Technology in 2019. It aims to explore new forms and technologies for the future urban planning practice, following the approach of co-creative development. The CIL develops and make use of cutting-edge digital technology and innovative approaches, in particular big data and artificial intelligence (AI)-powered urban planning tools. Using augmented reality, real-time analyses and simulations can be experienced in 3D on an interactive platform.

The CIL makes it possible to bring together the ideas of developers, investors and urban planners more quickly and cost-effectively and to ensure the sustainability of cities. With the help of digital technologies CIL is able to make complex correlations tangible and residents can be directly involved in the planning process. The platform allows city planners, public authorities and various types of stakeholders (e.g. citizen, real estate developers) to run complex simulations (policies, planning and climate scenarios, etc.) and see how these changes affect jobs, transport or, for instance, pollution.

CIL is not only an international laboratory, but also a decision platform, to develop answers to the core challenges of climate change in an urban context. Its interactive urban design model couples generative building generation, deep learning accelerated impact assessment in real-time with augmented reality.

The CIL is not only computer based – users can meet physically in CIL's facilities. These facilities include interactive projection walls and augmented reality platform that create an environment for collaborative planning and the co-creation of urban planning workflows and processes.

Its AI-based interactive planning platform InFraRED ("Intelligent Framework for Resilient Design") aims to make environmental simulations accessible to a wide range of stakeholders. It uses deep learning models to predict simulation results, allowing users to reduce the time and costs of running complex environmental simulations such as wind simulations that are normally based on time-consuming computational fluid dynamics.

The CIL at the Centre for Energy expands AIT's competences in the area of Digital Resilient Cities. This research area connects know-how in urban planning with state-of-the-art solutions for city management and planning. 60 percent of the projects are international, the team is active in more than 20 countries. The CIL was also an essential part of the i-Lab at the heart of the Austria Pavilion at Expo Dubai 2020: As part of the world exhibition, the experts of the CIL presented its approach to data-driven and evidence-based urban planning and held presentations on the topic of "Sustainable Future Urban Planning" to show how cities can be planned under the aspects of climate change, energy and mobility.

The Lab is governed by a Board composed of representatives of the private sector, academia, and municipal sector. The Board reviews and contributes to the Lab's agenda.

Source: AIT

Chapter 5. The activities and outputs of RTOs

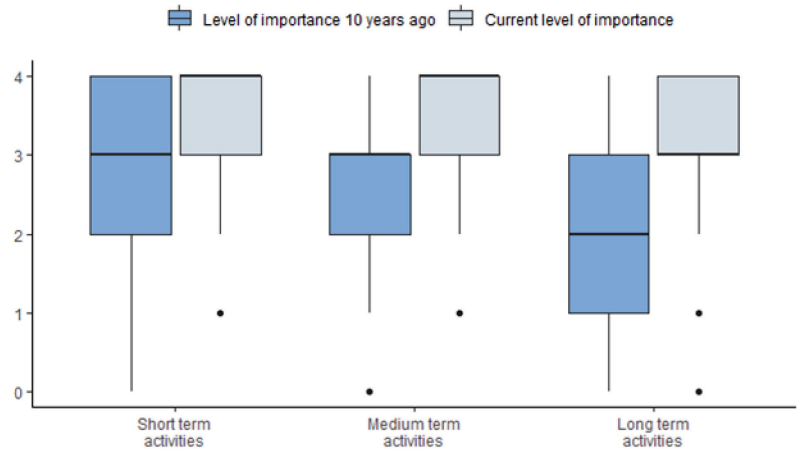
5.1 RTOs portfolio of activities

Respondents were invited to assess the level of importance of the different types of activities they perform, identified by their respective timeframes, ten years ago and currently. Since these activities are very diverse, they were grouped for this exercise into three main types according to their strategic timeframe: short-term, mid-term and long-term. These categories broadly correspond to the three main components of the portfolio of activities of RTOs as described by Arnold *et al.* (2010):

- In the long-term, RTOs perform exploratory research and development to develop an area of capability or a technology platform;
- In the short-term, RTOs conduct more routine exploitation of the knowledge, including via consulting and the provision of various services to industry and public administration;
- In between these two time horizons, they take charge of work to refine and exploit their knowledge base, often in collaborative projects with industry.

Figure 26 shows that RTOs perform all three groups of activities, which are considered as at least moderately important by a great majority of respondents 10 years ago and at least important by all RTOs in current days. A significant evolution relates to the fact that all group of activities have become more important, which indicates the growth of these organisations' activity portfolios, in relation to the widening of their mission discussed in the previous section. While the most important activities were the ones with a shorter time horizon 10 years ago (52% rates short term activities as currently very important), midterm activities are now considered as important as short term activities, and long term activities are catching up with these two types of activities (strongest increase of the three types).

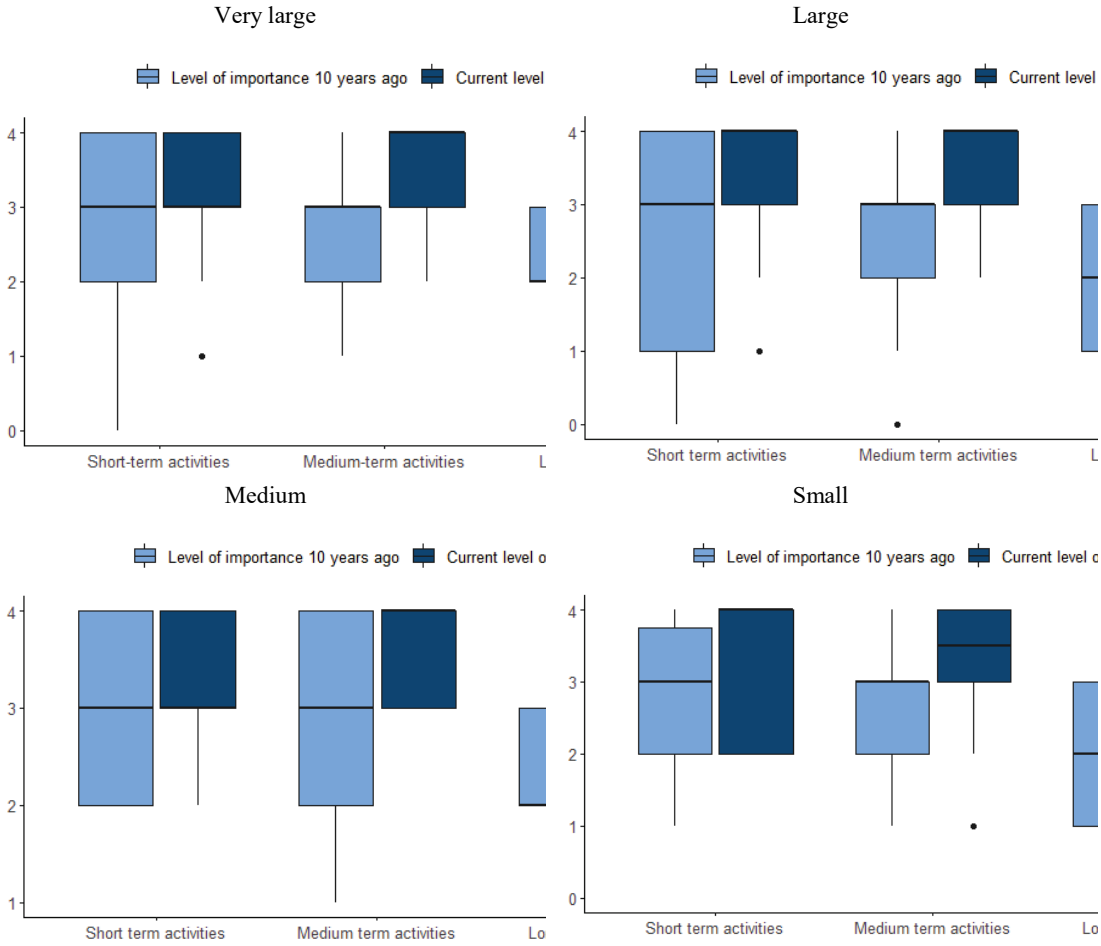
Figure 26. Level of priority of RTOs' main activities, by type of activities



Source: OECD-EARTO survey – rating questions
Note: 0 Not important; 1 slightly important; 2 moderately important; 3 Important; 4 Very important

Larger RTOs (and in particular those that pertain to the Very large RTOs category) report higher (and increasing) level of importance of long-term activities (Figure 27).

Figure 27. Level of priority of RTOs' main activities, by type of activities and size group



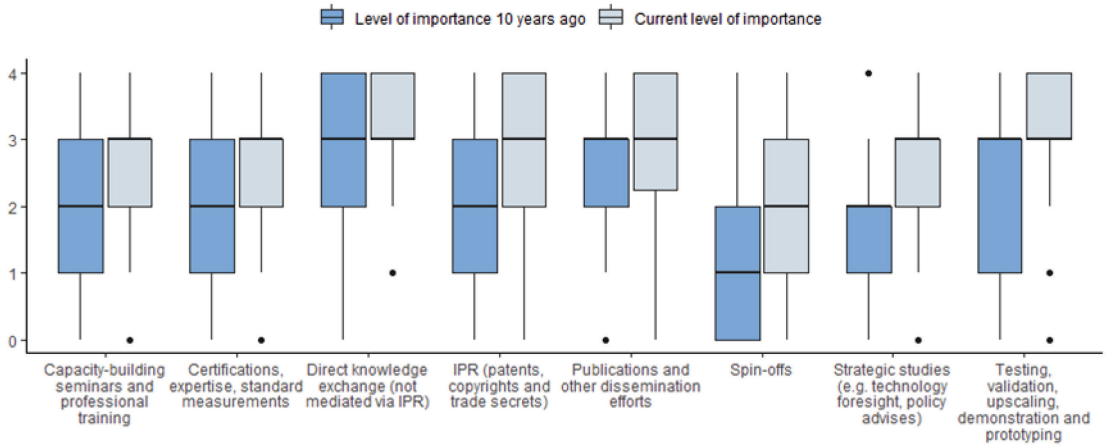
5.2 RTOs' main outputs

This question relates to the change in the level of importance of different types of outputs. The most important outputs in RTOs' portfolio are direct knowledge exchanges, IPR, publications and testing. Least important is spin-offs, which is consistent with the collected data on the number of spin-offs per RTO (Figure 28). As previously mentioned, not all RTOs are using spin-offs to transfer and exploit research results.

Over the last 10 years, all outputs have become more important (at least Q1 and Q3 have shifted upwards, if not the median). The outputs which importance has increased the most are capacity building, certifications, IPR, spin offs and strategic studies. Direct knowledge exchange, testing and publications, already at high level ten years ago have increased more modestly.

The outputs that exhibit the largest dispersion of current level of importance are IPR, publications, and spin-offs.

Figure 28. Level of importance of RTOs' outputs in their portfolio



(0 Not important; 1 Slightly important; 2 Moderately important; 3 Important; 4 Very important)

5.3 Evolution of RTOs' activities and outputs

While the official missions of RTOs have remained stable (see Section 4.2), the underpinning activities and the outputs of these activities have changed significantly.

RTOs' 'growth trajectories'

The balance between the different groups of activities, as well as the content and objectives of each of these activities, is evolving. The first driver of these changes is the 'natural' widening and deepening of RTOs' activities, most often through organic growth and in some cases through mergers and acquisitions of other organisations with complementary assets (technological competencies, infrastructures, client bases, etc.).

The wide diversity of RTOs make it difficult to identify common trends. The evolution of their portfolio of activities can be better characterised in terms of various 'trajectories' of RTOs, which differ according to their initial conditions and the pressure and opportunities for change exerted by their immediate environment:

- In many cases, the RTOs that were created to attend to the need of a specific sector accumulated knowledge, expertise and networks that allowed them to expand to adjacent sectors, or activities related to upstream or downstream the value chains.
- Several RTOs started their activity based on the exploitation of a specific applied research area or technology, and based on this pillar expanded the range of applications derived from these activities. Some acquired new technological competencies but managed them carefully as to not dilute their specificity and comparative advantage in crowded and competitive national landscapes.
- The management and exploitation of large technology infrastructures and equipment was a core activity (and comparative advantage with regard to universities operating in the same area) of some RTOs specialised in a sector or technology area. This activity, which requires significant public support, evolved with policy priorities. One common pattern is the increasing openness of these infrastructures to make them available to a broader range of users, including SMEs and other research organisations. This trend relates to a change that influences the whole portfolio of RTOs activities, i.e. the pressure to improve their financial sustainability (funding for the maintenance of these infrastructure after their creation being often too scarce) and strengthen their impact.
- For historical reasons, a few RTOs initially focused on upstream research activities, with a large share of public funding. The increasing pressure to deliver impactful results and secure external revenues has led them to move downstream and strengthen their transfer and services to industry.

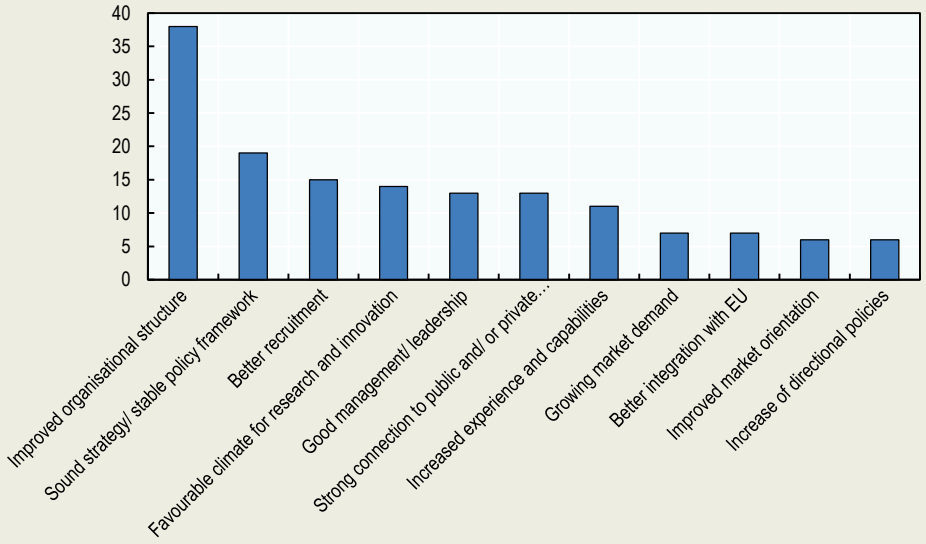
The broadening of the scope of RTOs also relates to the type of services provided to their clients: from technology-based services, several of them attended to a gradually increasing range of demands from clients, notably in the area of education (e.g. hosting industry PhDs), skill development (training services) and support to start-ups. In most cases these new activities remains closely connected to their research and technology services. This is important for RTOs in order to remain consistent with their mission (rather than by prospects of new sources of income) and to avoid overlap with other organisations specialised in these activities (notably universities, transfer organisations, consulting companies).

One key issue concerns the ability of RTOs to develop new activities. Working with start-ups is an option but these new firms typically have limited capital and thus face difficulties in investing in R&D with the RTO without any form of subsidisation. A few RTOs also mentioned that they themselves deliberately used start-ups to develop markets for their more exploratory/radical knowledge and innovation activities in emerging areas where there was no industrial partners yet. Some of these start-ups have grown, made a new sustainable business out the radical innovation and became partners. This is a way to support almost ‘from scratch’ the emergence of a new ecosystem. However, this strategy is long and risky and is therefore an option only for large RTOs with sufficient basic funding. The French CEA is one of these large RTOs that has been able to develop such approach.

Box 9. Analysis of online survey's open-text responses – factors influencing RTOs' impact and delivery on their missions

The survey asked respondents to provide information about factors that have positively influenced their ability to deliver on their missions and have impact. It was possible to provide multiple answers.

Figure 29. Positive factors influencing RTOs' impact



Source: OECD-EARTO survey – Rating questions
Note : Multiple responses allowed

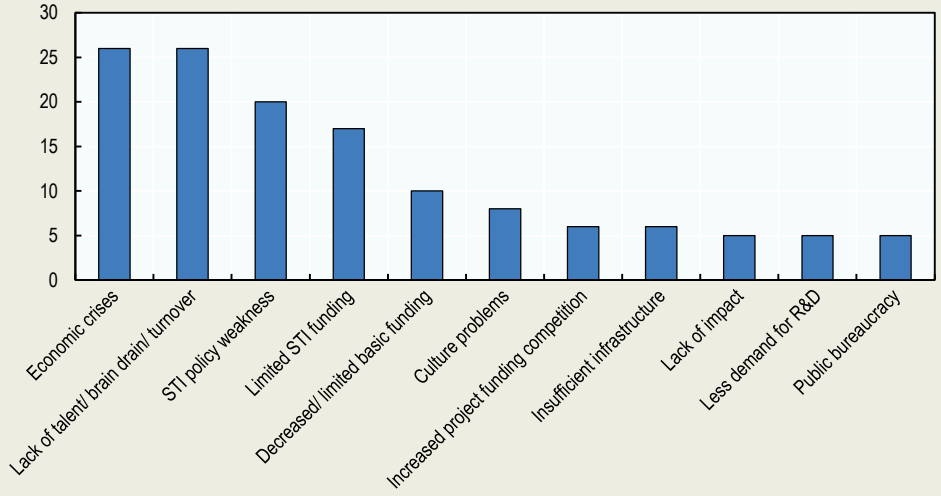
The most salient positive influence respondents reported was 'improved organisational structure'. This factor encompasses a few kind of scenarios, such as better integration of research domains and/or reorganisation of research groups, more closely linking business cases to research, better defining operational lines in relation to overarching strategy, or structuring technical areas in such a way that they address common objectives from different angles, achieving complementarity. Clearly, having the right kind of institutional strategy and focusing attention on fine-tuning organisational structure have allowed RTOs to optimise their operation and positioning. Respondents also emphasised the importance of having a stable political framework, so that governance could be managed without the influence of 'politicised short-termism', or to have a strategy that ensured explicit alignment with state objectives, so that areas of work are more clearly defined in relation to needs set at the political level for the sake of clarity and continuity. Respondents also stressed the importance of having diverse capabilities, multidisciplinary talent, improving the level of expertise in staff, welcoming a 'generational shift' in the employee population, and using recruitment effectively both to broaden the kinds of professional profiles as well as the nationalities present in the RTO, (to include both local and international talent and, in turn, leveraging their respective professional networks well).

Other notable positive factors include a favourable climate for research and innovation, generally meaning the confluence of both political and market focus on the kinds of R&D the RTO was well positioned to deliver on; good leadership and management; strong connections to public and private actors; increased experience and; growing market demand (and also situation where market demand is growing in sophistication, due to more professional buyers of research services); better integration with the EU (through increased participation in EU programs);

improved market orientation (closer collaboration with industries and/ or better tracking of industrial trends and needs); and increase in directional policies.

Conversely, survey respondents also reported on negative factors influencing the ability to deliver on their mission and achieve impact, as outlined below in Figure 30.

Figure 30. Negative factors influencing RTOs' impact



Source: OECD-EARTO survey – Rating questions
Note : Multiple responses allowed

The top two most salient factors were the impact of economic crises, such as the 2008 crash and the current COVD-19 pandemic, and the lack of talent/ 'brain-drain'. For the former, this covered issues related to decreasing innovation investment by most local companies, slowing economic growth, and limiting the creation of new services and technological capabilities. For the latter, this covered scenarios such as inadequate talent attraction, retention, the lack of availability of specialists, and the natural attrition of the workforce that is not being replaced, often because the contracts of younger employees are not renewed due to budget constraints and/ or it is difficult to re-train newer employees to assume new roles. One respondent said "*A decreasing staff, a high average age of the personnel, an insufficient replacement of the turn-over, and a lack of new resources bringing in new skills and capabilities, impact us negatively, in particular regarding our ability to achieve new research perspectives*." The third most reported factor was STI policy weaknesses, coming to encompass issues related to the lack of political commitment to R&D, the instability and variability of policy, or even a lack of a comprehensive understanding of RTOs in the broader innovation ecosystem. One respondent put it best, "*the national policymaker has very scarce comprehension of the role of RTOs because for them the national innovation system is very simple: on one side there are private entities like industry and on the other side public entities like universities: others aren't considered*."

Other notable negative factors tended to constellate around the issue of limited STI funding and increased project funding competition, as well as culture problems (such as reluctance to collaborate/ inertia to change), insufficient infrastructure (or inability to upgrade when necessary), and the impact of difficult public bureaucracy.

Strategic management of RTOs' activities and outputs

In several cases, this incremental broadening of RTOs' activity portfolios was the result of purposeful, proactive initiatives. Some RTOs could broader their portfolio by launching new initiatives to respond to nascent, emergent needs. Small to medium size RTOs have strong autonomy and flexibility, the combination of which gives senior management scope for new entrepreneurial endeavours. For example, some RTOs are developing new business models and launching innovative initiatives such as incubators, accelerators, hubs, and platforms (related to Industry 4.0, for instance). For this entrepreneurialism to succeed, it needs not only effective strategy and management but also available funds and/or the ability to access public support (via basic funding or large competitive projects).

Although incremental, the evolutions of RTOs' activity portfolios require the careful management and balancing of different interdependent activities, in particular the development of long term competencies (which notably requires the development of research activities and infrastructure to remain at the frontier of the technological offer) and the capacity to respond to shorter term demands from industry. Competitive projects, most often run in cooperation with public and private partners for duration of 2 to 4 years, and have an important role to tie the activities of the portfolio together.

As one interviewee expressed it, '*if there is not enough R&D, the mission becomes empty. If we put too much focus on short term services to industry, we can enjoy some years of growth based on growing contracts from companies but we can rapidly run out of resources for supporting companies' new needs. On the contrary, if we put too much emphasis on research, we slowly lose touch with industry and our impact decreases'*. Too much focus on commercial prospects might even lead RTOs to compete with the very companies they initially intended to support...

Striking and maintaining a sustainable balance is a matter of strategy and good management in organisations which, like other research-based institutions, leave a significant autonomy to centres/units and even researchers. It is also of course very dependent on the evolution of their funding structure, especially the shares of basic, competitive and industry funding.

The ability to closely connect the different activities along the research and innovation chain has become even more important as RTOs are increasingly engaged in addressing ambitious societal challenges. This is a characteristic where large RTOs or close networks of RTOs can provide a holistic approach ranging from fundamental research to mature technology, and combine various disciplines, including in social science, and skills. Addressing a wide range of activities within the same organisation, or between partners in close collaboration, could be instrumental to successfully deploy relevant disruptive innovations in areas such as for instance, quantum computing. The need for this connection between activities at different TRLs has also implications in terms of integration of funding schemes across the entire innovation chain.

Chapter 6. The internal organisation and external collaboration of RTOs

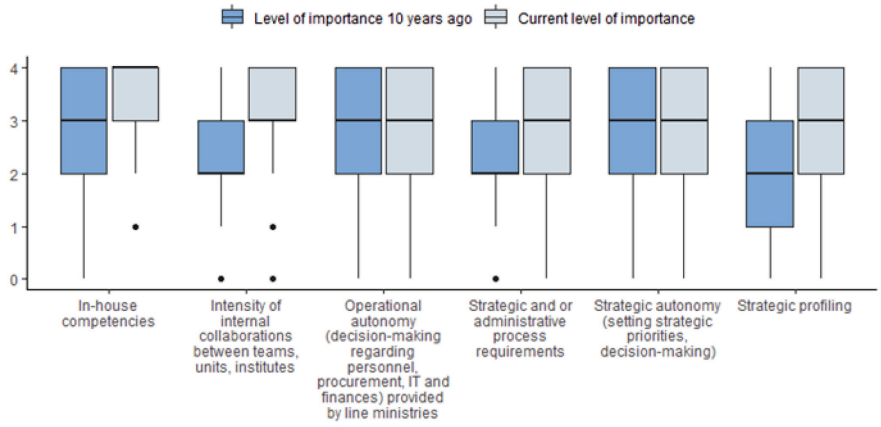
6.1 Internal features of RTOs mission delivery model

Respondents were asked to assess the level of importance of selected internal features of RTOs' mission delivery model. In-house competencies are given the highest level of importance ('very important'). Internal collaborations among research teams/units come second but have experienced the highest increase over the last 10 years (Figure 31).

RTOs enjoyed high level of operational and strategic autonomy ten years ago and still do. Strategic profiling of RTOs has also increased but remains at lower level than the other features. The importance of internal process requirements and processes have also slightly increased.

The largest dispersion of responses is observed for operational autonomy, strategic autonomy, and internal process requirements.

Figure 31. Level of importance of different internal features



(0 Not important; 1 Slightly important; 2 Moderately important; 3 Important; 4 Very important)

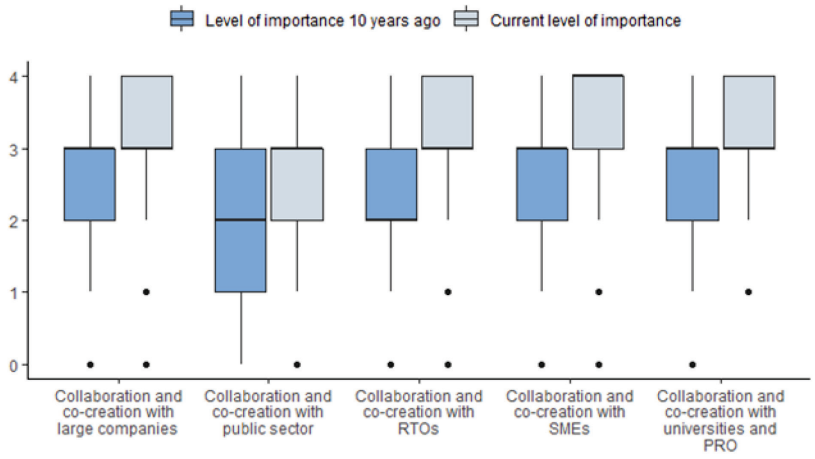
6.2 Co-creation or collaboration activities between RTOs and with other organisations

This question invited RTOs to assess the level of importance of different types of co-creation or collaboration partners among their different partners, and the impact of these changes on mission delivery.

All RTOs have increased their collaboration with all types of partners over the last ten years (although to a lesser extent in the case of universities and non-RTO research organisations) (Figure 32).The main RTOs' partners are SMEs (51% of RTOs rate them as very important partners) and large companies (47% of RTOs rate them as very important partners).

Collaborations with public sector organisations showed the greatest dispersion of responses ten years ago, from very low importance (3% of RTOs) to very high importance (23% of RTOs). However, it has now somewhat converged towards 'moderately important' and 'important'.

Figure 32. Level of importance of RTOs' collaborations with different types of partners



(0 Not important; 1 Slightly important; 2 Moderately important; 3 Important; 4 Very important)

While they increasingly compete in competitive research funding, RTOs also often maintain strong collaborations with universities. These include for instance shared positions between HEIs and RIs, different types of alliances and partnerships, RTOs-industry hosted PhD programs, regional innovation platforms, ecosystem-based support (which include support to networking and possibly strategic plan co-creation), shared infrastructure, joint projects, dedicated funding to strengthen knowledge exchange in HEIs and RIs, and faculty positions to RTOs & industry.

The Jožef Stefan Institute (JSI) in Slovenia for instance is closely connected with the Slovenian universities, where many scientists started their career at the Institute. When appointed to teaching posts, they retained their research positions at the Institute. Since 1985 more than 1800 postgraduate students have gained their MSc. and Ph.D. degrees at the Institute.

An important aspect of RTOs mission delivery is the relationships with their partners. The nature of these relationships is changing as RTOs increasingly co-create outputs with their partners, far from a mere role of service providers. As shown in other OECD studies (Kreiling and Paunov, 2021), these co-creation practices are powerful mechanism to generate innovation. They actively involve actors in the innovation process from the very beginning and combine their diverse expertise to facilitate the transfer of tacit knowledge, hence the growing importance of direct knowledge exchange emphasised previously.

Relationships between different RTOs can be very important when it comes to tackling complex societal challenges. Some countries with institutionalised network of RTOs such as Korea have set up mechanisms to increase the cooperation between these organisations with different knowledge, skills and networks (see Box 10).

Box 10. NST Convergence programme to support collaboration between RTOs and between RTOs and other research institutions

Korea's National Research Council of Science and Technology (NST) has operated its Convergence Programme since 2014 with an aim to foster open innovation ecosystem primarily among its government research institutes (GRIs). It operates four sub-programmes, which by design promote collaboration between RTOs and RTOs with knowledge institutes such as HEIs:

- Convergence Research Centre (CRC) – 'On-site' research collaboration project between GRIs. On-site method indicates that the lead organisation (usually GRIs) provides research facility that brings together researchers from other participating institutions.
- Creative Allied Project (CAP) – Initiative research for concept development that can potentially be developed into large-scale national projects.
- Advanced Convergence Research Project (CPS) – Specific support to verification or feasibility test of already developed research ideas prior to the initiation of convergence research project.
- Convergence Cluster (CCL) – Support for networking events to foster the culture of open research among GRIs. This programme intends to incentivise researchers to collaborate with those outside their organisations.

So far NST has supported financially 63 new initiatives (4 CRCs, 9 CAPs, 15 CPSs and 35 CLSs) in 2022. The sub-programs that involve longer term and challenge-based research benefit from bigger and longer-term funding. Research consortia in future-leading type CRC can receive about KRW 4-8 billion annually for 6 years and projects under CAP challenge-and-creative type receive KRW 2 billion annually per project for 5 years. These two programmes adopt state-gate funding mechanism where the funded projects need to pass external peer evaluation managed by NST after the first 3 and 2 years respectively to proceed to the next stage of 3 years. GRIs participating in the CRC and CAP sub-programmes are required to contribute matching budgets of more than 30% of the entire cost. The participating GRIs procure funding from either the basic funding or their own income. CAP projects defined as 'challenging and creative' are exempt from budget contribution requirement for the first 2 years. So are the CPS projects for the whole project duration. The other 2 sub-programmes, CPS and CCL, grant funding for 2 years due to their shorter term nature and more specific targets.

NST operates the Convergence Research Committee which advises the whole programme and selects the main topics. The Committee consists of ST experts from industries, HEIs, GRIs, the press and from other social and economic disciplines.

The Programme overall has contributed to an increase in joint research performance (publication increase from 110 in 2017 to 543 in 2021; patent from 46 to 188) and provided concrete solutions to societal issues such as establishing a pilot facility for carbon reduction technology. According to a survey carried out by NST, the GRIs who participated in the Convergence Programme have been satisfied by the programme. A majority of CRC participants assess it as 'positive', and benefited from 'easier communication', 'increase focus on tasks' and 'peer-learning process.

Source:NRC

6.3 Evolution of internal organisation and external collaboration of RTOs

There is a large degree of consensus among survey respondents and interviewees on the growing need for RTOs to strengthen (i) their strategic consistency to be able to create critical mass on some selected priorities; (ii) their transversality to promote interdisciplinary and intersectoral collaborations, within each RTO and between RTOs and partners. As previously mentioned, these needs stem from the imperative to tackle 'wicked' societal challenges that are more complex, uncertain and, more generally, systemic. This is for instance the case of issues related to the energy transition, which requires strong knowledge and expertise related not only to relevant technologies, but also to behaviours, regulations, infrastructures, etc. Technology convergence in some areas adds to this trend.

This is the case for instance of the IoT that requires mastery of both hardware and software components.

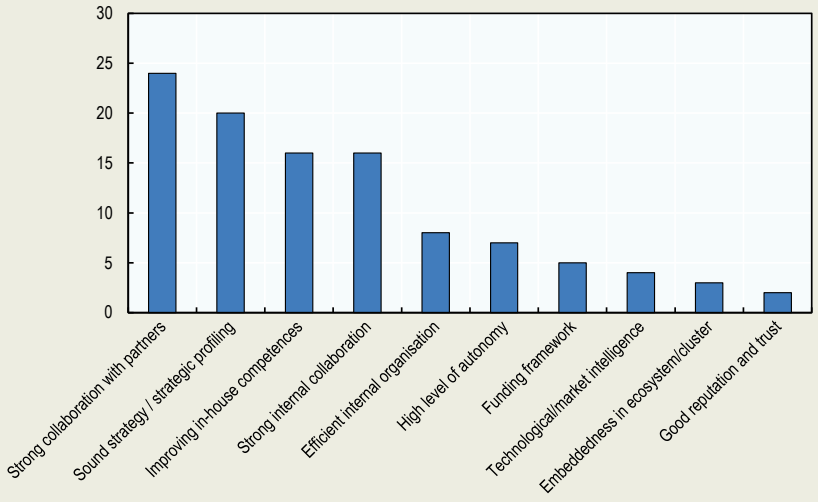
Both survey responses and interviews tend to confirm that RTOs are actively responding to these needs via a significant increase of collaboration between units and teams within each RTO. However, better integrating sets of often historically independent entities proves challenging and requires efforts to change the structures, the processes, the incentive system and, not least, the mind-sets.

Collaboration has increased within networks and associations of RTOs, or more generally between independent institutes, based on MOUs and more often in the context of *ad hoc* publicly-supported collaborative projects of larger size.

Box 11. Analysis of online survey's open-text responses – RTOs' internal features influencing their mission delivery

The survey asked the respondents to provide additional information on the factors that have most impacted their ability to deliver their missions. In line with the findings above, the most pronounced feature is the RTO's ability to form strong collaborative relationship with partners, including the private companies (both large and SMEs), public sector, and PROs. Several responses pointed to the fact that the increased level of cooperation with private sector industries has given more directionality to the RTOs' R&D activities and increased the relevance of their outputs. Secondly, the sound organisational strategy and strategic profiling of RTOs were proven to be effective in raising their profile. Factors such as 'improving in-house competences' and 'strong internal collaboration' were reported to have positively influenced the RTO's capabilities. With the establishment of the new strategic plan, the organisation has positioned itself to provide a multidisciplinary approach by bringing in the breath of capabilities of multiple research centres. At the same time, its earned reputation as a collaborator further allowed them to work with external partners, which helped complement the in-house competences.

Figure 33. Internal feature influencing positively their mission delivery



Source: OECD-EARTO survey – Rating questions
Note : Multiple responses allowed

The most notable factor internal features hindering the RTOs' abilities to deliver their missions is their lack of autonomy vis-à-vis the public authorities. According to the responses, this affects the RTOs both directly and indirectly. The former concerns their operational autonomy whereby in a certain case the "*increase in reporting duties to regional agencies changed the ways the projects are executed and justified" or the organisation needs "authorisation from the state government to hire new employees*" which can at times directly affect the in-house competences. The impact may be also indirectly made where the RTOs' missions and activities are tied to national policies and priorities that are often slow to change, therefore the RTOs might miss the collaboration opportunities with private entities.

Changing the organisational structure of RTOs

This trend has led to the significant restructuring of some national RTO landscapes. For instance in Sweden the previously independent institutes merged into one integrated organisation, RISE. In Poland, the Lukasiewicz Research Network connects 32 institutes.[15] In Belgium, IMEC (semi-conductors) acquired iMinds (software, artificial intelligence and ICT) in 2016.

However, achieving the necessary scale, scope, and integration should not be achieved at the expense of the capacity of RTOs' centres, units, and staff to generate new ideas and projects. Neither should it diminish the 'depth' of the knowledge and expertise of RTOs in any of the specific disciplines and sectors they cover. Many RTOs, in particular the larger ones, are therefore trying to find a way to balance top-down strategic integration and bottom-up initiatives, scope and depth of technological capabilities, and scale and agility.

Several RTOs strive to solve this challenge through changes in the organisation structure and processes (see Box 11). A matrix organisation, which might seem *a priori* relevant to allow for multiple combinations of technologies and applications, is often considered too rigid and heavy, and personnel resists them (due to multiple reporting obligations and a dilution of responsibilities and leadership). A few RTOs mentioned that they have tried a matrix structure in the past and came back to a flat structure with departments/centres representing a mix of technologies and business sectors/markets. The management of systemic projects is ensured by flexible teams and an improved account management system.[16] An organisation along challenge areas has also been adopted in some RTOs. Several RTOs combine both options with business/technology departments and 'virtual' challenge programs or clusters. The latter draw on the staff and equipment of different parts of the organisation as necessary, and can be recombined when new priorities arise. While this can be done through projects, the virtual entities are more institutionalised, have longer term dedicated staff (for instance a programme coordinator and a deputy) and funding, and can encompass a portfolio of projects related to a challenge. Knowledge can therefore be more easily accumulated and exploited than it can in the case of individual projects, after the completion of which teams are dismantled.

Box 12. Examples of new organisational structures of RTOs to promote internal strategic consistency and collaboration

The Portuguese RTO INESC TEC is constituted of 13 centres, with additional virtual 'layers' to increase consistency and promote exchanges:

- Five TEC4 thematic units (related to challenges and/or markets: energy, health, agro-food, sea, industry) are responsible for gathering resources from different centres to conduct activities in specific cross-sectoral/interdisciplinary areas. Each TEC4 unit is staffed with one coordinator and one business developer. In addition, the 'TEC Partnerships' unit is used to explore and nurture areas that are only emergent but could become TEC4 units in the future
- Four research clusters bring together scientists from the different centres in the associated areas (computer science, Networked intelligent systems, Power and energy, Industrial and systems engineering).

CSIRO, an Australian RTO of 5,500 employees, 55 sites, 11 business units and many research centres has organised its activities along 6 challenges and 12 missions. The challenges are cross-cutting themes: Food Security and Quality, Health and Wellbeing, Resilient and Valuable Environments, Sustainable Energy and Resources, Future Industries, A Secure Australia and Region. These challenges were identified through internal analysis of trends, engagement with industry, government and academia, and a review of Australian and international priorities. Below the challenges, 12 missions (Antimicrobial Resistance, AquaWatch Australia, Climate Resilient Enterprises, Critical energy metals, Hydrogen Industry ...) aim to focus resources from across the organisation and partners towards key priorities. Each of the centre is asked to define its 'mission pathway', hence its potential contribution to the missions relevant to its research area. The RTO used to have Flagship Programmes, seen as prefiguration of missions, but less challenge-oriented and more science-pushed.

The International Iberian Nanotechnology Laboratory (INL), an Intergovernmental Organization promoted by the Governments of Spain and Portugal, reorganised its former research departments into 6 thematic clusters (which are a mix of science, technology and market-oriented areas) focused on identified societal challenges (Precise Personalised HealthTech, Future Food value chains, Clean Energy, Sustainable Environment, Digitalization and Advanced Materials and Computing) and, under these, 25 research and engineering groups. These clusters are flexible, in which groups organically join one or more clusters and discuss opportunities to collaborate, share know-how, and pursue jointly the missions of the clusters, which were developed in a bottom-up approach. Overall coordination is ensured by the Research, Technology, and Innovation Office. The cluster members meet bi-weekly. The Cluster coordinators, three which progressively move from deputy-, to main-, to past-coordinator, are appointed by the Director General of INL.

The Lukasiewicz Research Network has established four Research Groups in line with societal challenges: Health, Clean and smart mobility, Sustainable Economy and Energy, and Digital Transformation. These Groups gather researchers and specialists from 32 institutes. Each group is managed by a Board composed of the Group coordinator and the members from the institutes which are active in the thematic scope of the Group (each Group has from 8 to 24 members). The main goals of the Groups are to strengthen knowledge transfer among members, improve communication and establish platforms for the generation of ideas for future interdisciplinary projects. The member of the Groups are also engaged in the "Łukasiewicz Challenges". This is a new initiative whereby any enterprise just by filling an online form can describe a technological problem that can be solved by implementing a research and development project. Within 15 working days, Łukasiewicz provides free of charge a selection of alternative project proposals for taking up the challenge and recommends teams of experts and equipment facilities to solve the problem. Moreover, as part of the "Łukasiewicz's Challenges", it is possible to identify a potential source of research funding from domestic and foreign sources and Łukasiewicz's

experts also support the preparation of applications in identified calls. The Łukasiewicz's Challenges system is also the simplest form of ordering a service (e.g. ordering certification or testing in accordance with standards) or inquiries about product availability in all Łukasiewicz Institutes at the same time. Then, thanks to the Łukasiewicz's Challenges, it will be offered to the entrepreneur within 5 working days.

In Norway, SINTEFs organisational model in the past 10 years has gone from 9 research institutes to 6, with a focus on creating cross-fertilisation and interdisciplinary units with the ability to respond to the ever more complex challenges facing their partners, clients and society. An example is the 2018 merging of the social science institute into the more technical and sectoral institutes, as well as the introduction of the "SINTEF Group strategic initiatives" in 2019. The latter are cross-departmental internal projects in which SINTEF invest basic funding with the aim of generating knowledge and competency in areas where they see a growing market potential.

Source: Interviews; Various websites; FFA, SINTEF.

Changing the incentive systems within RTOs

The advantage of 'virtual challenge' entities is that they require only limited changes to the structure of the RTO, although they must still contend with the challenges to change practices and mind-sets. Several RTOs are using different processes for that purpose. For instance, every year INESC TEC launches an internal call for proposal to fund collaborative projects involving several centres. INL launches internal calls open to all research groups for frontier research project and projects with industry. These prizes allocate seed funding to a small-scale consortium to nurture and test new ideas and new collaborations. These calls are open but are aligned with the four general goals of the RTO and include different INL groups and clusters.

Box 13. VTT challenge-based organisation

From a technology-driven organisation and a complex matrix structure technology/industry, VTT gradually reorganised its activities around 7 systemic and technological challenges and 3 business areas (of about 100 to 200 researchers each). While technology is still at the core of the organisation's activities, VTT is now steered by the purposes of the activities, their expected impacts, rather by the technological dynamics themselves. It is also a way to provides more holistic solutions to the challenges and better demonstrate and communicate on what the institute aims to deliver. The accounting and staff management is structured along the business areas. However the most important incentives are set at the level of the whole organisation rather than at the level of individual business areas in order to foster cohesion of the institute and intersectoral and multi-disciplinary collaborations.

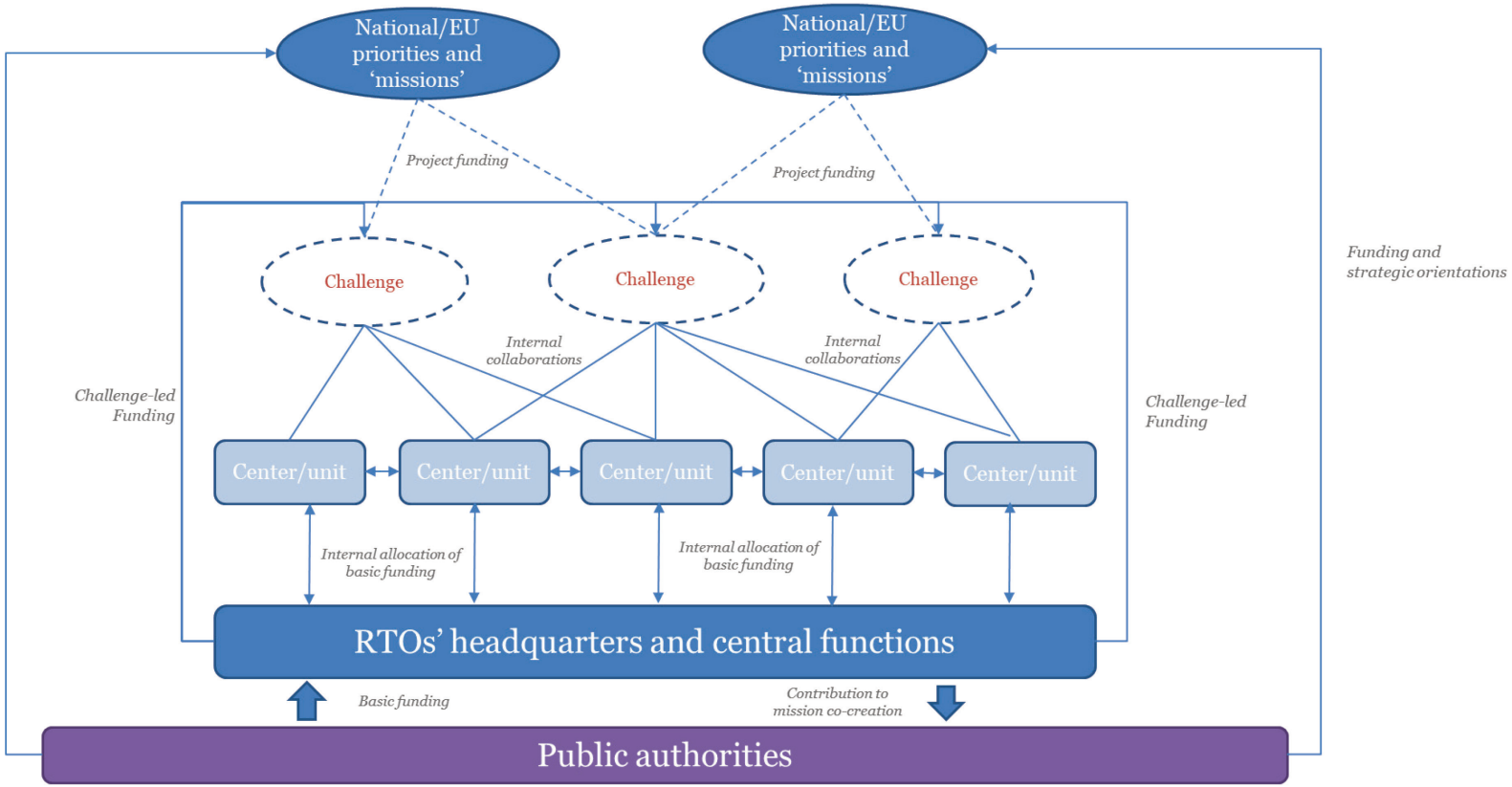
Figure 34. VTT's systemic and technological challenges

Source: VTT

Another way to promote collaborations within RTOs consists in changing evaluation criteria at organisational and individual levels. However, the need for intra-RTO collaboration seems to have not yet significantly influenced the structure of incentives within RTOs. Only a few RTOs declared that they evaluate their centre/unit managers not only on the basis of their team's performance but also on the level of collaboration with other entities within the RTO. The internal KPIs used to allocate the basic funds among the different units/centres of an RTO can also take into account the level of collaboration between centres.

Figure 35 presents some aspects of the organisational models discussed in this section: a challenge-based virtual structure, with internal calls for incentivising organisation-wide efforts toward these solving these challenges.

Figure 35. Schematic diagram of a challenge-based organisational structure of RTOs



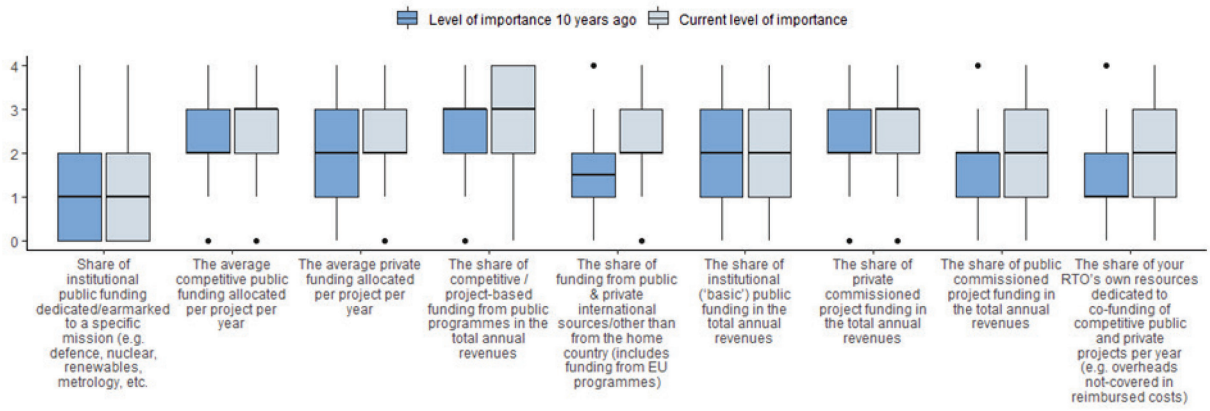
Chapter 7. The funding structure and modalities of RTOs

7.1 Funding structure

This question concerned the change in the level of importance of selected features of RTOs' funding structure. The share of competitive projects is considered the feature of their funding structure that has the highest importance.[17] The highest increase in importance over the last ten years relates to the share of co-funding by RTOs with their own internal resources when participating in competitive research programmes (Figure 36).

The lowest importance (and stable at this low level) is assessed for the component of basic funding that is earmarked for specific missions. A minority of RTOs' principals make strategic use of the basic funding of RTOs (i.e. providing part of the basic funding against some specific projects/programmes).

Figure 36. Level of importance of RTOs' funding features



(0 Not important; 1 Slightly important; 2 Moderately important; 3 Important; 4 Very important)

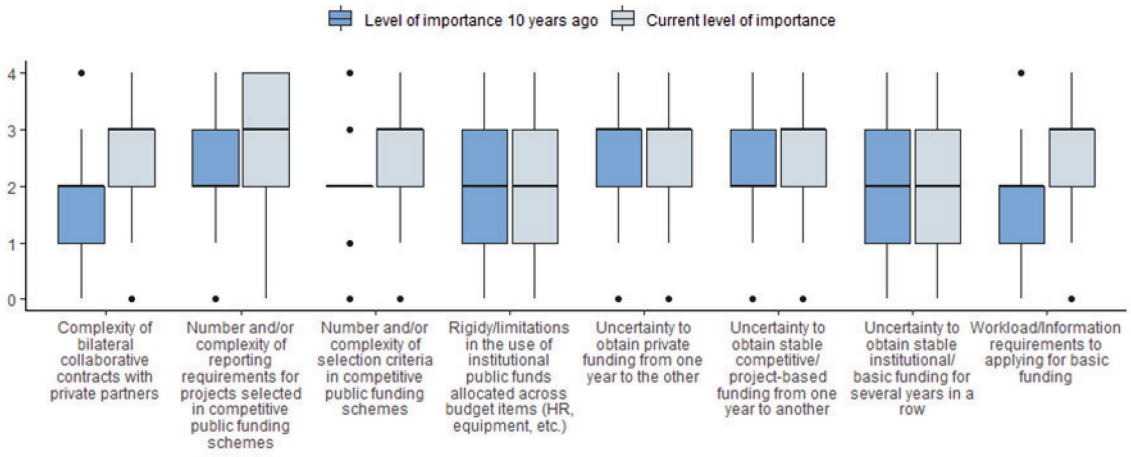
7.2 Funding modalities

This question relates to the change in the level of importance of several characteristics of RTOs' funding models, and the impact of these changes on their mission delivery.

The reporting requirements for projects funded via competitive public programmes have experienced the highest increase in importance, followed closely by workload related to basic funding application (but it is not considered as very rigid), the complexity of bilateral collaborative contracts and the range/complexity of selection criteria (Figure 37).

The level of uncertainty has increased for project-based funding, but has remained stable for private and basic funding. It is currently considered slightly lower for basic funding.

Figure 37. Level of importance of RTOs' funding modalities



(0 Not important; 1 Slightly important; 2 Moderately important; 3 Important; 4 Very important)

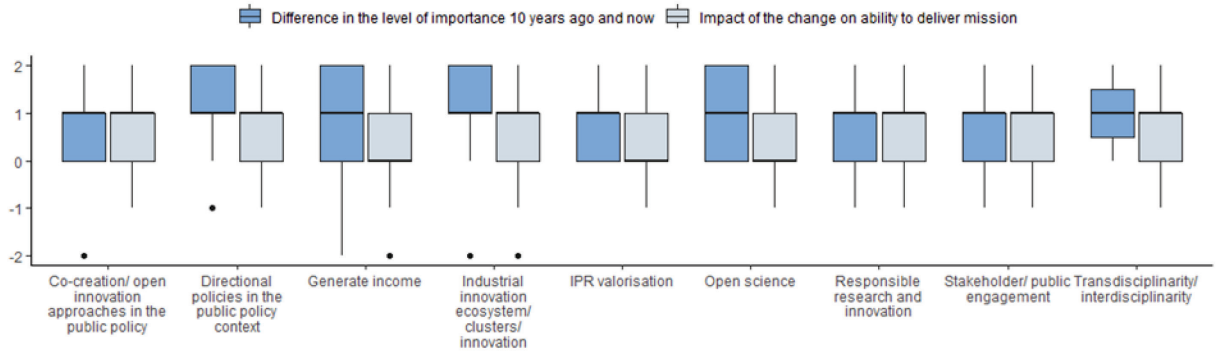
7.3 Policy context

This last closed-ended question is on the level of importance of several features of RTOs' direct policy context and the impact of these changes on mission delivery.

The highest increase in importance over the last ten years was reported for directional ('mission-oriented') policies and policies to support industrial ecosystems (Figure 38).

Currently, the highest impact of these changes on mission delivery was for directional policies, industrial ecosystems, Responsible Research & Innovation (RRI), stakeholder engagement and interdisciplinary research. The lowest impact relates to pressure and incentives to generate income, IPR, and open science.

Figure 38. Impact of the changes of RTOs' policy context on mission delivery



(-2 Highly negative impact; -1 Rather negative impact; 0 No impact; +1 Rather positive impact; +2 Highly positive impact)

7.4 Evolution of RTOs' funding

A variety of funding models

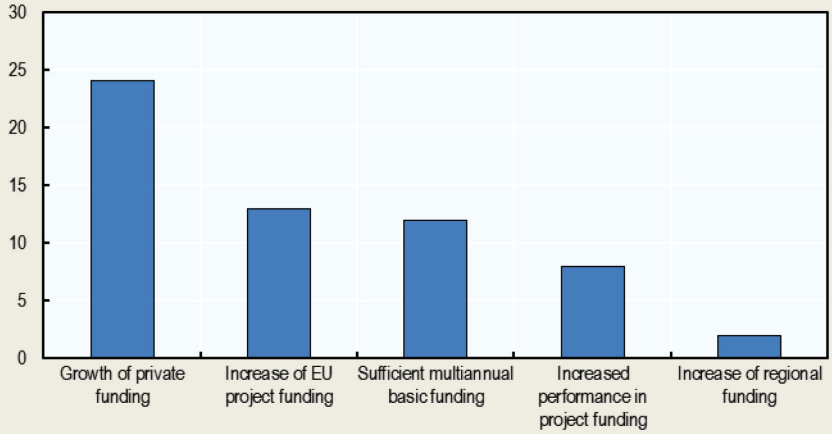
The funding structure of RTOs greatly differs among RTOs as well as between units/centres within RTOs. While the 'ideal' RTO model is presented as one wherein there is equal funding share of basic, competitive, and commissioned funding, in reality many permutations exist. This diversity of funding models depends on:

- National factors – countries have different public funding 'traditions', notably with regard to the provision of basic funding. Industry structures also greatly differ according to countries. Countries and sectors with only few medium and large companies are less amenable to award contracts for research and innovation services.
- The position of RTOs in the innovation cycle – RTOs in lower TRLs generally have a higher share of basic funding (and public funding in general)
- RTO's focus areas and outputs – for instance the RTOs or centres providing support to policy – sometimes referred to as 'paper institutes' as opposed to 'technological institutes' – benefit from less industry funding.
- Other specific cases such as the operation of large technology infrastructures or agency functions[18] also explain variations in the funding model.

Box 14. Analysis of online survey's open-text responses – funding structure and modalities

Concerning the open-ended responses about the funding of RTOs, the answers to the questions on funding structure and funding modality respectively were gathered together for better significance (Figure 39). Among the factors positively influencing the mission delivery, the growth of private funding has been reported to have generated the biggest impact. For some RTOs, the share of private commissioned projects is made a centrepiece of their funding models. Such high level of income from the industry is not a feature found in all RTOs since as previously noted, the funding structure and modalities vary across the organisations. Also deemed importance are the increase of EU project funding and sufficient multi-annual basic funding. As regards the basic funding, according to one response, the share of basic funding is "essential (for the RTOs) to have the economic capacity to undertake projects funded under the EU Framework Programmes (currently Horizon 2020 and Horizon Europe)", and the tendency to require institutional co-funding may be "a challenge for the RTOs with relatively low level of basic funding" since they then lack the necessary co-funding capabilities.

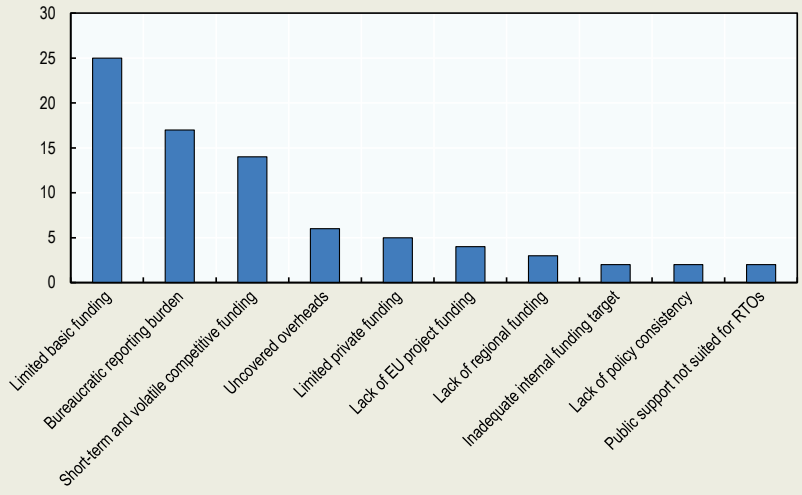
Figure 39. Funding factors influencing positively RTOs' mission delivery



Source: OECD-EARTO survey – Rating questions
Note : Multiple responses allowed

On the flip side, more than one-fourth of the RTOs surveyed noted that the share of basic funding for their organisations is limited. This does not contradict the finding above of some RTOs reportedly benefitting from relatively larger share of basic funding since not only the funding structures vary across organisations but also comparatively younger organisations or those involved in low TRLs tend to witness higher levels of institutional funding. Some responses pointed out that there are "*uncertainties*" tied to obtaining stable institutional funding, and that this may hamper the promotion of "*a coherent and continuous investment in developing new capacities to support the renewal of institutions' offers*". A certain number of RTOs suggested that the bureaucratic reporting burden is high and not reimbursed, and that they are in particular related to the European research funding or regional funding schemes. Moreover, the competitive funding scheme tend to be perceived as being too short-term and volatile, which makes it difficult for RTOs to "*link (their) actions to resources*" and hinders the planning of mid- to long-term programmes.

Figure 40. Funding factors influencing negatively RTOs' mission delivery



Source: OECD-EARTO survey – Rating questions
Note : Multiple responses allowed

Recent funding trends

Despite this diversity, some trends and commonalities can be identified.

Regarding basic funding:

- Most of the basic funding provided to RTOs is conditional on the achievement of performance targets. The number or types of KPIs have not changed significantly in the last 10 years. The targets in some cases were increased as a way to incentivise greater performance;
- Even when the basic funding is associated with a performance-contract, which can include some strategic orientations in addition to the KPIs, the directions provided remain wide and generic, hence leaving significant strategic autonomy to RTOs' boards and leadership. In large RTOs, the internal allocation among the units/centres tend to replicate the same formula, sometimes adding some internal performance indicators (such as the participation in in-house collaborative projects);
- Most of the RTOs interviewed benefit from multi-annual basic funding,[19] which is considered essential to enable them to plan ahead, invest in the development of new capabilities, and undertake mid to long-term initiatives. In some cases, the basic funding is allocated yearly with only indications/forecast for the coming years. In some other cases (Germany, Austria), the multiannual funding is a binding commitment (under the form of a 'pact').
- The strategic earmarking of basic funding is rare. A few RTOs mentioned some funding for multiannual strategic projects, directly negotiated with the public authorities, which can be considered as 'quasi-basic funding';
- Basic funding is awarded competitively to a few RTOs (for instance to INECS-TEC[20] in Portugal, DTI in Denmark and 10% of RTOs' basic funding in Norway).

This can reinforce the competition between RTOs rather than promoting their cooperation.

Regarding competitive (project-based) funding:

- As previously mentioned, there is a trend towards larger projects, more challenge-based/mission-oriented. Since these projects are multi-years and multi-stakeholders, it is not clear whether this translates into more funding for any given project participant;
- The number and range of selection and monitoring criteria is increasing, in particular for EU funding. New indicators related to societal and environmental impact, gender equality, territorial cohesion, ethics, RRI, *etc*.[21] adding some additional administrative burden.
- The limited coverage of indirect costs (calculated as a fixed top-up rate on direct costs) in EU funding and some national funding is considered a significant problem by several RTOs. RTOs have to manage carefully this source of funding (including by refraining from participating in some projects) as it can jeopardise their financial stability and requires significant other revenues to compensate for the uncovered costs. One interviewee qualified EU Framework Programme funding as '*not good for KPIs…*'

Box 15. Opportunities and challenges of mission-oriented policies for RTOs

Although most of the non-institutional funding remains allocated to RTOs through traditional competitive schemes, mission-oriented policies are becoming more prominent in EU and national policy mixes. These policies are defined as co-ordinated packages of policy and regulatory measures tailored specifically to mobilise science, technology and innovation in order to address well-defined objectives related to a societal challenge, in a defined timeframe. These measures possibly span different stages of the innovation cycle from research to demonstration and market deployment, mix supply-push and demand-pull instruments, and cut across various policy fields, sectors and disciplines (Larrue, 2021a).

While interviewees generally welcomed these relevant and better oriented and coordinated initiatives to tackle societal challenges, they also highlighted some potential issues related to this trend:

The number of and funding for open calls is decreasing in countries that engaged proactively in these type of policies while these calls allow them funding of more exploratory research projects which are in turn limited. Furthermore, there is less funding available for projects that do not fit in any 'mission'. Calls become vastly oversubscribed, translating into low success rates, causing frustration and inefficiencies among applicants.

While mission-oriented schemes are in principle associated with larger and more integrated funding, their implementation sometimes involves in reality a several short-term funding, from different sources and actors, with different operational principles (funding rate, timeframe, reporting process, etc.). This make their management more complex and costly and the reporting heavier.

Mission-oriented policies and programmes involve sophisticated multilevel and cross-sectoral governance structures and various layers of consultation to co-develop the mission and subsequent agendas. The transaction costs associated with the most ambitious initiatives of these missions can rapidly become heavy for RTOs which do not have dedicated capacity for such involvement in public policy and stakeholder engagement, especially when their basic funding is limited.

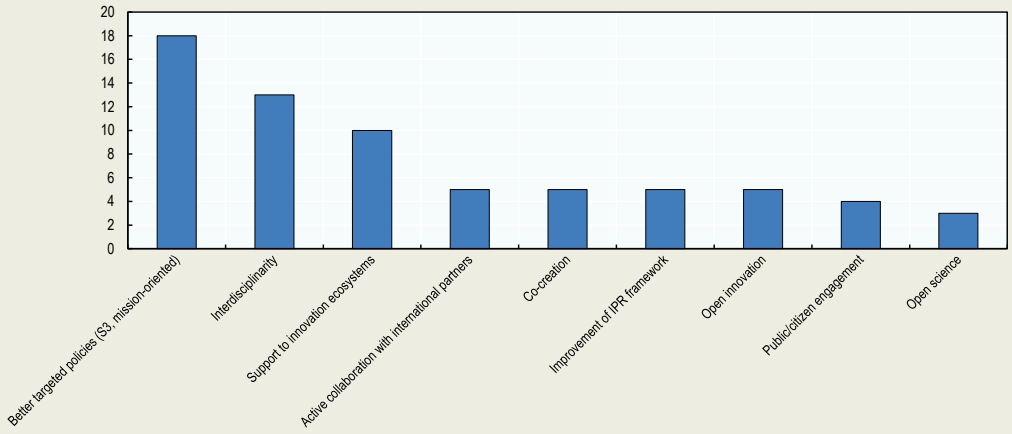
Regarding commissioned public and private funding:

- The historic trend of increasing pressure on RTOs to increase their share of external funding shows no sign of abating;
- The share of commissioned contracts from public authorities is increasing, in relation to strategic work and studies related to societal challenges;
- Recent trends such as open science/open innovation pushed by public authorities can sometimes be detrimental to collaboration with industry which strive to preserve their competitive assets. One interviewee also mentioned that the focus on system transition can also create some distance to industry more immediate needs;
- Several RTOs face a saturation of industry demand for their research and innovation services in their specific working area and country. This means that they have already engaged the companies with which they are most amenable/able to cooperate. In order to increase their share of industry contracts, they, therefore, need to work with SMEs that do not yet innovate (but with sufficient technological content in their activities). Some RTOs have set dedicated specific programs (e.g. to conduct early need diagnostics; to train SME employees) or units (e.g. to serve as 'one-stop-shop' for SMEs). However, supporting the technological upgrading of these SMEs proves to be very challenging and necessitates specific public funding and programs. Vouchers are in place in several countries, but often remain limited in amount and time. While they are useful to solve a specific problem faced by the SME, they are less able to enhance their 'absorption capacity' in a durable way and lead to a more ambitious collaboration with the RTO. One RTO pleaded for a 'collaborative voucher'.

Box 16. Analysis of online survey's open-text responses – policy context

The survey gathered open-text answers regarding the individual RTOs' perception of opportunities and challenges in the overall policy context. Among the positive factors is the better targeted policies (for instance, Smart Specialisation Strategies and adoption of mission-oriented policies) which recorded the highest number of responses (Figure 41). Some of the answers allude to the facts that, in Europe, the Regional Cohesion's RIS3 instrument has "aligned great part of research priorities at the regional level and developed specific instruments that connect the industry to RTOs in certain strategic research areas" and that stronger incentives were created in support of the emerging markets. Strong directionality added to the public policy context in turn feeds into the enhancement of interdisciplinary of RTOs' missions and increased support given to innovation ecosystems which recorded the second and third highest number of answers. The overall policy context that is becoming more transversal requires for an interdisciplinary approach and this is perceived as an advantage of RTOs that generally possess expertise for different R&D areas. Also, one organisation answered that they have profited a great deal from the creation of national innovation hubs which facilitated the exchange of knowledge and practices among innovation actors that also relates to the fostering of open science and open innovation. However, one interesting note on open science was that "*openness*" may result in "*increased workloads*" needed to make information available for other usages if not supported by additional allocation of resources.

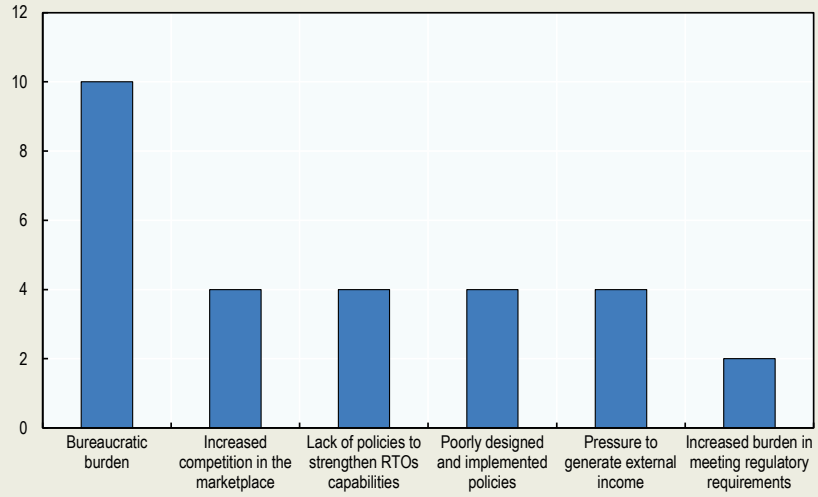
Figure 41. Positive factors in the policy context influencing RTOs' mission delivery



Source: OECD-EARTO survey – Rating questions
Note : Multiple responses allowed

On the contrary, the recent changes in the policy context have posed challenges and brought in additional burden on RTOs. Among the recorded answers, the growing 'bureaucratic burden' was considered particularly high. This is to be differentiated with the aforementioned 'bureaucratic reporting burden' tied to the funding scheme as the answers recorded under this label indicate the increased pressure on overall project management and admiration overload that are in some instances caused by the "*risk aversion of funding organisations*", for instance costs related to the legal support (Example for IP management, legal compliances, etc.). Other factors embedded in the policy context that negatively influenced the RTOs' performances include 'increased competition in the marketplace' and 'lack of policies to strengthen RTOs' capabilities'. The two factors are not entirely separable as evidenced in a few of the responses from RTOs that perceived their stronger engagement with industries as both incentives (therefore opportunities) and pressures. Having better exposure to the industry and market may present opportunities for them to increase their capacities but at the same time may be perceived as direct competition with private actors without adequate policies to strengthen their capabilities.

Figure 42. Funding factors influencing negatively RTOs' mission delivery



Source: OECD-EARTO survey – Rating questions
Note : Multiple responses allowed

The effect of the 2008 and COVID-19 crises

The 2008 and COVID-19 crises have differently affected countries, sectors and organisations. There are therefore significant differences in the way RTOs have lived through these crises.

Two RTOs claimed that the 2008 financial crisis had dramatic effects on their business model due to a drop in industry contracts, then subsequent public funding when the stimulus packages were terminated and the debt crisis took over. As a result, experienced staff was made redundant. In other RTOs, depending on countries and sectors, either the public funding or the industry contracts significantly decreased and led to some shift in the balance between these two sources of funding. However, the 2008 crisis has not hit severely the majority of interviewed RTOs, as R&D remained during this period a priority in many countries and innovative companies – their main clients – weathered this crisis better than other types of businesses

As for more recent crises, the COVID crisis may have had some positive effects on RTOs' activities. Several companies took advantage of the lockdown period to launch small projects and public authorities, during this crisis even more than in 2008, used research and innovation policies as counter-cyclical measures. Furthermore, large RTOs have been able to shift more resources towards areas that benefited from the crisis (health and digitalisation). Finally, most RTOs have quickly and proactively reacted, repurposing funding and infrastructure to deliver solutions to COVID-related issues.

Box 17. Examples of RTOs' rapid mobilisation to address the COVID pandemic

For many years now, CEA has defined key programs to address infectious disease and viruses in collaboration with academic and industrial partners. While the Covid crisis impacted the CEA organisation like many others, it was also an opportunity to provide innovative services and solutions based on the previously developed know-how and technologies. A first example was the design and transfer to industrial partners to quickly manufacture optimized ventilators for hospitals. Beside the work done to prepare quick diagnosis tests and innovative vaccines, such as messenger RNA, CEA research teams have also been able to participate to the evaluation of antiviral cure drug candidates in pre-clinic studies. This campaign led to the demonstration and publication that hydroxychloroquine had no antiviral effect on SARS-CoV2, and that other approaches such as monoclonal antibodies could be investigated.

In three month after the crisis outbreak, Łukasiewicz built from scratch several lines producing medical masks using only technologies developed in the institutes of the network. 4 lines were sold to commercial entities. In addition, Łukasiewicz in cooperation with the Wrocław University of Science and Technology looked for effective therapies among known drugs by intensifying work on SARS-CoV-2 Mpro protease inhibitors. In addition, Łukasiewicz started the production of Ventil devices - setups enabling independent ventilation of two patients with one ventilator. These devices have also successfully passed the medical certification process.

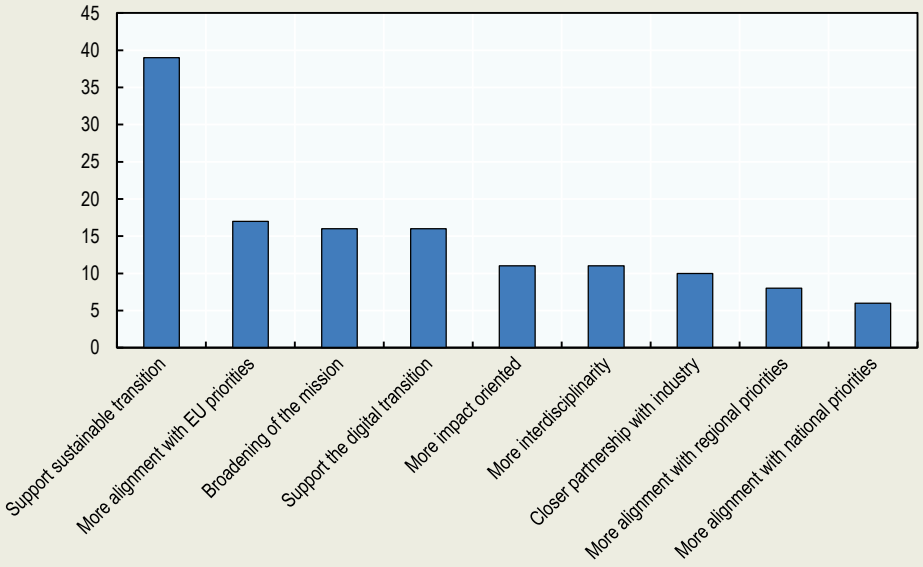
Source: CEA; Łukasiewicz Research Network

In Norway the industry-oriented RTOs were provided with an extraordinary basic funding in 2020 in order to compensate for terminated industry-funded projects, and ensure that they continue their activities, including to address consequences of the crisis.

Box 18. Analysis of online survey's open-text responses – foreseen evolutions of RTOs missions and models

RTOs were asked to specify on the foreseen changes in their missions and roles in the next five years (Figure 43). The most salient change can be labelled as the increased support for sustainability transition followed by closer alignment with the EU priorities, broadening of the missions and support for digital transition. It does not come as a surprise that the RTOs who anticipated a broadened support for sustainability transition alluded to their future contribution to EU programmes for 'twin transitions', namely, green transition and digital transition. In most cases, this requires the RTOs to redefine their missions in a way to broaden the base so that they can serve better the societal and industry needs. According to them, their missions will "*increasingly have to give priority to the major megatrends in areas of sustainability and environment*", and for instance, "*objectives such as digitalisation and decarbonisation*" remain as high priorities. In order to better cater to the newly emerging needs, the RTOs reckoned in some cases that a better (or sharpened) focus on the "*regional impact*" (also recorded as 'more alignment with regional priorities') would be needed.

Figure 43. Foreseen evolutions of RTOs missions



Source: OECD-EARTO survey – Rating questions
Note : Multiple responses allowed

To be more specific, the RTOs were asked what type of changes in their mission delivery model, funding structure/modalities and overall policy context they foresee in the next 5 years. The answers overlap with those to the former question to a certain extent, but grasp the circumstantial differences faced by a variety of RTOs. First, concerning the overall policy context, the respondents shared a mutual understanding that they are asked or are willing to pursue the strategies that are more 'mission-oriented' therefore addressing societal challenges. However, in terms of their funding structures / modalities that could be an enabler but also a hindrance to their delivery of missions, the answers varied. Some RTOs sought for increasing their dependence on the business turnover for greater income and minimising the RTOs' link to public policies that were at times perceived as being too volatile and unstable. Such an understanding was reflected also in another response that "*national basic funding model can help the organisation balance its financial stability*". Others anticipated more independent relationship vis-à-vis the regional authorities in the future and a gradual shift from mostly public to mostly private funding modality which is stated in the mission

statement as well. They understood that "*higher degree of income (can be generated) from IPR exploitation both through licensing and spin-offs*". While this was not a dominant perspective among the RTOs surveyed, some organisations called for a "*healthier*" balance between public and private funding, some pointing to a "*50-50*" divide. As regards the mission delivery model, some RTOs foresee that in large-scale challenges, "*reinforcing (their) capability to identify the new challenges*" and "*setting up necessary consortia via both internal and external collaborations*" will become more important.

Chapter 8. Implications for policy

The fieldwork, analysis and consultations conducted in the context of this study has several policy implications. Public interventions (funding but also related to regulations and framework conditions) should accompany and support the ongoing changes of RTOs – internally but also all together as a specific component of national and EU innovation systems – so that they best contribute to the twin imperatives of strengthening economic competitiveness and tackling societal challenges. Some of these policy messages and recommendation have been advocated by EARTO in recent years. This study allows to i) better substatiate these policy messages with data and sound analytics ii) embed them in a narrative about the evolution of their context and the imperative to implement sustainability transitions.

1. Launching a pilot study with a few countries to measure the specific contributions of RTOs to their national policies, paving the way toward a more systematic recognition of RTOs in national classifications

The COVID crisis has increased the awareness of the specific roles played by RTOs in national policy implementation, beside their traditional function to support businesses and some public service missions delegated to some of them. From beneficiaries of public schemes and funding, they become themselves key 'policy instruments', with a key and distinct role within various ecosystems that are essential to tackle complex economic and societal challenges.

While the diversity of legal status and economic models of RTOs is one of their strengths to respond to different demands in various national contexts, it also hinders the acknowledgement of their unique role. It makes them either invisible or fragmented in national statistics (as business entities, non-profit organisations, government organisations – often as a result of history), and hardly comparable in an international perspective.

The scale of some of the future challenges ahead – and COVID is just one example – creates a need for concertation at international level, which would be facilitated by a clear definition of RTOs as a premise to better and more homogenous statistical classification for RTOs; an important pre-condition for enhanced visibility. This definition would be even more effective if underpinned by a sound classification/typology that reflects the diversity of RTOs roles and missions.

This is an issue that has been tackled with only mixed results in the past due to many challenges. One option would be to start with a pilot project where a set of willing countries would issue a list of national institutions that correspond to the commonly agreed definition of RTOs. While the definition provided in this study cannot be used to derive parameters to automatically select relevant institutions, it could serve as a basis for 'manually' identifying these institutions. In cooperation with national statistical offices from the pilot countries, and possibly with support from relevant European authorities such as Eurostat, meaningful input and output data could be extracted from the subset of selected institutions. This exploratory exercise would provide some first comparable statistics on RTOs and their contributions in innovation system performance could then be identified more precisely.

2. Reviewing and benchmarking RTOs' national basic funding schemes to enable them to best contribute to societal challenges with the adequate time horizons, scale and scope

The study has shown the great diversity of funding models of RTOs, both between and within countries. Within these funding models, the proportion of basic funding is a key parameter that strongly influences the other funding streams (through various types of leverage effects) and therefore greatly determine what the RTO will in the end deliver and to which parts of the society. While the essential character of basic funding is not new, it has become even more so in the context of mounting societal challenges. To be tackled, these require a portfolio of investments with different time horizons, including longer term ones to build capabilities and explore new options, pursue transformative ambitions and a more systemic approach that link different potential solutions and activities (from research to capacity building or standardisation).

A harmonisation of basic funding rates is neither realistic nor desirable, as RTOs' funding models depend on the specific characteristics of the environment (country and area) in which the different RTOs operate. Another option is to engage in discussions with RTOs about their missions, the ways they can achieve it and what are the associated investments (including human capital, technology infrastructure, etc.) and therefore the funding needs. Such discussions could be held in the context of negotiation of performance-contracts that condition the allocation of the basic funding. This would also support the strategic profiling of RTOs and make clearer their expected contribution to national priorities.

3. Enabling the structural changes of RTOs and networks of RTOs

Societal challenges often call for solutions that cut across existing disciplines and sectors and require larger scale and scope. This creates both an opportunity and a challenge for RTOs. On the one hand, RTOs have the technological and networking capabilities to connect different sectors and disciplines to develop new solutions to complex problems. On the other hand, RTOs need to undertake internal changes to strengthen their transversality and promote interdisciplinary and intersectoral collaborations, within, with and between their various partners.

Public authorities can support this process of change at the level of each RTO as well as at the level of the whole national RTO sector:

- Internal changes is the responsibility of each RTO. However, their ability to conduct these changes will depend on their ability to reduce their dependence on shorter term and narrower projects associated to contractual funding. The provision of sufficient basic funding is therefore a key condition of these changes.
- At level of whole national RTO sectors, public authorities can engage in discussion with RTOs on needed structural changes at national level (network of RTOs, mergers), allowing the necessary scale and scope. Some countries such as Korea (Convergence programme) have implemented schemes to support cooperation between RTOs.

4. Improving the specific framework conditions at national and supranational levels to ensure a fair and homogenous treatment of RTOs

Specific reviews of framework conditions at national and EU levels (possibly fed with dedicated studies) should allow a review of the barriers that hinder RTOs in their mission delivery. Depending on countries and areas, these barriers may have to do with their access

to and participation in different international, EU and national funding streams (including cost coverage), the possibility to create and be co-founder of spin-offs, the implications of their legal status on RDI state aid rules (for Europe), etc.

In some countries, RTOs have also been at a disadvantage relatively to universities when cooperating with industry due to different pricing conditions. Some countries (e.g. the Netherlands) have alleviated this issue by ensuring fair competition between RTOs and universities.

5. Ensuring the funding of the experimentation of novel sociotechnical solutions, including through the support to the development and maintenance of technology infrastructures

The systemic solutions to societal challenges most often call for large scale experimentation, where not only new technologies but also new skills, regulations and users' behaviours are put to the test. RTOs can play an important role in these initiatives, not least in developing and maintaining (physical or virtual) technology infrastructures (TIs). In order to support system transitions, TIs should not be understood as only useful to test technological performance but in a broader sense as 'experimentation infrastructures' for sociotechnical solutions, where technologies are tested in their interaction with the communities, organisations as well as policy and regulatory environments in which they are embedded. Such TIs take notably the form of demonstrators, testbeds, piloting facilities and living labs.

The role of technology infrastructures in the demonstration and scale up of new solutions to complex challenges of systemic nature (such as smart cities) is increasingly acknowledged in the literature and among policy makers. However, public policies have not yet taken on-board the need to support specifically technology infrastructures for various reasons (for instance they are seen as too 'close from the market' and are often overshadowed by research infrastructure). More generally, the costly stage of demonstration and scale up – essential for moving from local innovation successes to system transition – are in most countries not well covered by national policy mixes and international programmes (including EU).

Dedicated public support should therefore be implemented at all levels to cover the capital and operating expenditures associated with the development and long term maintenance of TIs.

6. Conducting a reflection on how to strengthen European networks of specialised RTOs with unique expertise and infrastructures in key technology areas to gain scale and increase capabilities

To be competitive, RTOs specialised in key technology areas such as semiconductors or nanotechnologies where international competition is fierce need to reach a critical mass that allows them to invest in the needed capabilities and costly infrastructure (e.g. clean rooms). They therefore need to operate beyond national borders, i.e. at the European level. Formal recognition by the EC (for instance through some 'labelling' process) of these specialised RTOs so that they can reach the required scale would support this process in the European Research Area that, despite progress, remains fragmented. This would also call for member states to promote cross-border collaborations with these RTOs and ensure a level-playing field for RTOs in Europe.

Such initiative would also be a way to strengthen the linkages between STI and industrial strategies, in a context of growing concerns regarding EU strategic autonomy (see for example the US and EU Chip Acts that organise key STI actors like RTOs together to create critical mass in the specific area of microelectronics).

7. Reviewing and improving the various collaborative incentives and funding instruments to support the cooperation between RTOs and universities

The traditional allocation of roles between RTOs and universities based on the level of Technology Readiness Levels (TRLs) has become obsolete in many areas due to the natural evolution of the missions of these institutions and to the complexity of the scientific, technological, and societal challenges with which they contend. Against this backdrop, the priority should not be to distinguish ex ante the roles of RTOs and universities to avoid overlaps but rather to find ways to enhance their collaboration on ambitious projects. The division of roles will naturally emerge within these collaborations and partnerships.

Accordingly, to avoid tension and promote further collaboration, policies on insurance fair pricing competition could be further look at and incentives could be developed. Particularly interesting are the longer term initiatives that are institutionalised and embedded in a co-developed strategic framework. This is the case of various types of innovation platform schemes, such as collaborative labs and various centres of competence/excellence, and of 'ecosystem-based initiatives' in which different actors in priority areas are incentivised and supported to collectively develop and implement common strategic agendas (such as for instance the SIPs in Sweden – see Box 5 and UK Catapults). Such initiatives also promote further collaboration with industry.

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Annex A. List of needed changes in the next five years according to survey respondents

The last online survey open-text questions asked respondents to present the internal and/or external changes that would be needed to ensure that their RTO best deliver on their mission in the next 5 years. The table below presents their synthesised responses, anonymised and edited for clarity and length.

Category of change	Desired change
Political/ policy	• Consolidate a national industry net on emerging sectors such as circular economy, bio-economy, green transformation, etc. • Reorient the innovation system so that it takes into account RTOs' conditions and needs (not just universities). • Ensure that governments have 'balanced portfolios' when managing/ governing public (competitive) funding schemes to cover both short and long term change. • Implement pre-commercial procurement and public procurement of innovative solutions efficiently. • Improve awareness at the political level on the fundamental importance of low TRL / blue sky R&D. • Spur value chain change and re-organisation, so that industries revolutionise (one RTO cannot do this alone, for example, in the case of the plastic industry). • Devote resources from national and European recovery plans to boost research towards climate-neutrality by 2050. National R&D projects should be initiated to implementation of European Green Deal, including establishment of R&D&I infrastructure for pilot and demonstration projects. Active national engagement in a change of funding, activities and policies will be needed. • Translate the European Industrial strategy for the Member States, to ensure that RTOs can cooperate. Emphasise and fund applied research facilities, technology infrastructure. • Continue national support instruments to help institutes participate in EU projects. • Consider changing some countries' legislation regarding the legalities of whether an RTO can be a co-founder of a company, meaning that currently the establishment of spin-off from the institute is not possible and only a spin-out model allows to transfer the institutes' technology to a new company established by our researchers.
Competitive funding	• Change the rules of the framework programmes so that participation in EU projects do not lead to economic loss for institutes (due to the situation where research staff register hours on a number of projects in parallel, meaning that it is difficult to cover all real costs through the EU funding). • Increase expenditure on research and development with easier access to EU framework programs (no territorial restrictions in obtaining competition funds). • Define a specific role for RTOs in funding schemes, so they do not have to battle with other knowledge institutions for a place. • Reduce EU and national funding agencies' bureaucracy and increase transparency and make sure information about new programs is made available early. • Continue to work on open science, internationalisation, and other policy and horizontal considerations defined by the European Commission in Horizon Europe.
Basic funding	An increase in basic funding could: • Help RTOs fund change and open new arenas internally to support the need for sustainability and new jobs. • Enable RTOs to be more targeted towards segments such as founders, embryonic business start-ups and smaller entrepreneurial businesses – as these segments do not have the funds and conduct research in areas that the market currently does not demand (being proactive/front-runners). • Deepen the specialisation of the RTOs and strengthen their links with the industry. It should be subject to indicators (tech transfer, private contracts, etc.) and evaluation, but in a time period longer than one year to allow stability and planning of resources. • Better support the transversal activities of the organisation (business development, networking activities, internal and external communication of the organization, strategic and management report, training activities). • Help RTOs to focus more on innovative and system-level R&D.
Internal capabilities	• Improve strategic recruitment, to improve staff's orientation to business and fight workforce attrition. • Focus on continuous training of staff, developing people with diversity and inclusion in mind and providing clear career paths for both technical and non-technical staff. • Increase of adaptability to new conditions, including easier and faster ways to hire new permanent or temporary researchers, and faster ways to purchase goods and services needed for projects. • Recruit potent T-shape business and technology leaders all over the world and create impact teams around them. • Strengthen technological capabilities internally with greater investment in training and IPR. • Build-up of teams of experts capable of flexible and efficient response to market requests as well as founds acquisition. • Consider recruiting for broader competences (policy follow-up, legal, financial, RRI including ethics and data, communication).

Organisational strategy	• Increase the degree of specialisation of centres and compete globally. • Better define the RTO's R&D strategy and link it to the regional industry needs • Improve the commercial strategy to increase the average fee per contract • Better define unexplored strategic lines both in R&D and in the area of technological services that will allow us to reinforce inter-sectorial diversification and increase the number of clients. • Improve clarity in the definition of the centre's strategies, having strategic roadmap for 4 years with a financial plan, and particularising them each year; transparency in the centre's strategies towards the workers, promoting greater involvement of staff in the generation of new projects and businesses. • Better monitor arising trends and technologies in alignment with the needs of the industry and public authorities' roadmaps, to better deploy emerging innovations.
Organisational structure	• Support the defragmentation of research activities by supporting interdepartmental cooperation, merging of research units and improve internal integration. • Make our organisational structures simpler and more agile so that we can stay competitive (money alone is not the only important factor to research success). • Continue with process to make clusters, as the absence of multiple structural layers will enable streamlined communication and reporting processes, making the organisation more adaptable to change. The use of cross-function teams will need high levels of cooperative coordination throughout the organisation. • Continue to develop transdisciplinary research, creating innovation ecosystems and delivering system solutions to enhance co-operation between units. • Better involve/ enlarge social sciences expertise.
Technological infrastructure	• Subsidise the purchase of apparatus, prototype installations, and equipment. • Enable digital innovation tools (IT systems, infrastructure and platforms that enable security, accessibility, integration and collaboration (internally and externally). • Increase investments in equipment and laboratories required in the future, commercial revenue will become increasingly important. • Increase funding for R&D labs and testbeds so that the industry can have access to advanced infrastructure. • Extend specific capabilities in the digital area (both in terms of people and equipment) to better respond to digital transformation needs of our customers. • Encourage active participation in, and access to, research infrastructures to distribute research data. Through participation in national centres of excellence in research and innovation, we can facilitate cutting-edge research and network development.

Source: OECD survey

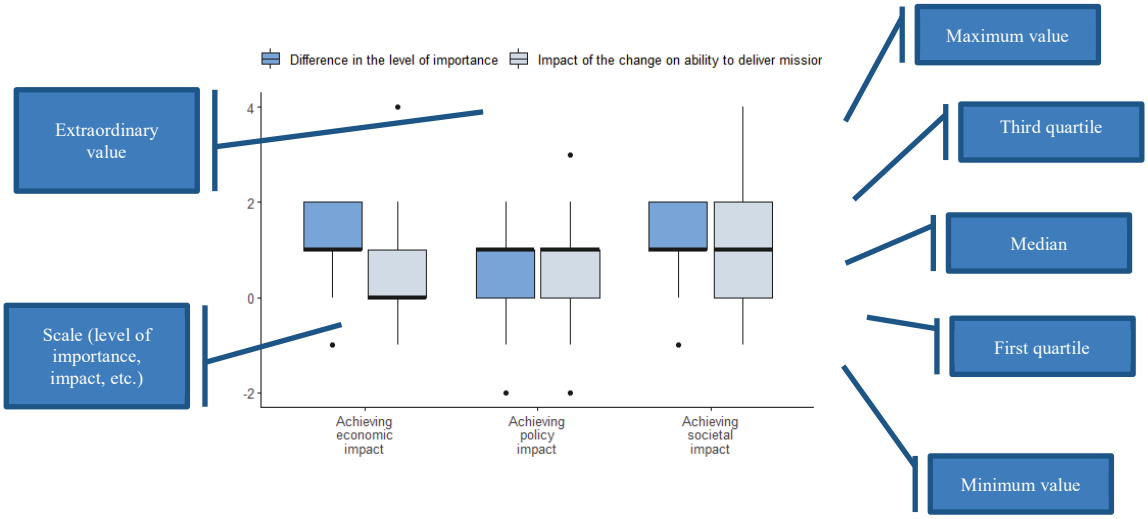
Annex B. List of interviewees to date

	RTO	Country	Names of the interviewees
1.	CSIRO	Australia	Mark Bazzacco, Natasha Dames, Anne-Maree Dowd, Patrick Dias, Yuko Wakamatsu
2.	AIT - Centre for Innovation Systems & Policy	Austria	Matthias Weber
3.	AIT	Austria	Anton Plimon, Katja Lamprecht
4.	IMEC	Belgium	Luc Van den hove, Anne Van den Bosch, Bart Van Bael
5.	NRC	Canada	Mitch Davies, Rebecca Hart, Flavia Leung
6.	DTI	Denmark	Juan Farré, David Tveit, Dorte Dalsgaard
7.	DLR	Germany	Uwe Möller, Hans-Joachim Kroh, Pascal.Breuer
8.	LIST	Luxembourg	Thibaud Latour
9.	Lukaziewicz network	Poland	Marcin Kardas, Marcin Kraska, Piotor Loroch
10.	INESC TEC	Portugal	João Claro, Marta Barbas
11.	INL	Portugal/Spain	Sonia Pazos
12.	LEITAT	Spain	Gerard Musterni Girbau
13.	RISE	Sweden	Pia Sandvik
14.	TNO	The Netherlands	Eric Drop and Marcel van Zandvoort
15.	MTC	UK	Harald Egner, Paul Hadley
16.	TECNALIA	Spain	Elena Schaeidt Ayarza and Angelica Lopez Sobrado
17.	Fraunhofer	Germany	Christopher Frieling and Miriam Leis
18.	Fraunhofer ISI	Germany	Jakob Edler
19.	VTT	Finland	Tuula Hämäläinen Lula Rosso and Antti Vasara
20.	IFPEN	France	Catherine Rivière
21.	CEA	France	Bertrand Bouchet, Benjamin Lucas-Leclin, Valérie Jacot, Laurence Piketty
22.	Tyndall	Ireland	Cormac Harrington, William Scanlon

Annex C. Guidelines for interpreting the box plots

This annex provides some guidelines to make sense of the box plots used to analyse responses to most survey questions.

The box plot presents the key characteristics of a distribution: minimal and maximal values, the quartiles (Q1, Q2, Q3) and some extraordinary values considered as not consistent with the main distribution.



[i] See list of interviewees in annex B.

[ii] The Chapter 3 is based on the data returned by 131 RTOs. The Chapters 4 to 7 build on the survey responses from 113 RTOs and 22 interviews.

[iii] In a more recent paper, the authors use a clustering method that results in four types of PROs : Hybrids ; Research Councils ; Technology and Innovation Centres ; and Government Laboratories (Cruz-Castro *et al.*, 2020).

[iv] Data from the Research Council of Norway.

[v] JSI is the largest RTO in Slovenia, with 1150 employees. It is organised in 30 departments gathered in three fields, physical sciences, chemistry-materials-biotech-environmental-life sciences and ICT-electronics-engineering.

[vi] Capitalised sizes of RTO indicate that the adjectives refer specifically to the size categories presented in table 4.

[vii] Tecnalia Ventures (over 20 employees) has developed a portfolio of 14 spin-off companies with annual turnover of 33.5 million euro and 267 employees (see OECD, 2021).

[viii] The median number of privately commissioned projects of the Very large RTOs has increased from 964 to 2592 (as compared to an increase from 65 to 84 for the medium size RTOs).

[ix] Survey respondents were asked to copy paste the official mission statement of their organisation.

[x] For instance, one RTO changed its mission from 'to transform knowledge into GDP' to "creating growth and improving society".

[xi] NST's does not fund these institutes but steer and manage them through the development of process guidelines and strategic dialogue. Its role is to '*support national research projects and policies and lead the development of the knowledge industry through supporting, fostering and systematically managing Government-funded Research Institutes in the field of science and technology*' (https://www.nst.re.kr/nst_en/).

[xii] In some countries, some large historical RTOs had previously a STI coordinating role, which they lost in the 1990s and 2000s as innovation systems modernised and New Public Management approaches favoured autonomous agencies to drive in a more competition-based way the research and innovation activities. This is what happened for instance in the Netherlands with TNO. It is interesting to note that with the trend towards mission-oriented policies (the Dutch Mission-driven top sectors policy), this trend is now again inverted and TNO's coordination role is strengthening, in the 'orchestrator' type defined in Box 5.

[xiii] See for example the DESCA model of consortium agreement, https://www.desca-agreement.eu/desca-model-consortium-agreement/

[xiv] Technology infrastructures should be distinguished from large scientific research infrastructures. They are (physical or virtual) facilities and equipment such as demonstrators, testbeds, piloting facilities, living labs. They are used to develop, mature, test, demonstrate and upscale technology to advance through industrial research and experimental development activities from proof of concept to technology validation in relevant environment (Viscido et al., 2021).

[15] From 38 institutes in 2019, consolidations reduced the number of institutes to 32 currently. The reorganisation of institutes will continue and it is expected that by the end of 2022 there will be 26 institutes in the Network. There are also plans to include some new research institutes to the Network.

[16] One of them emphasised that the experience of the matrix structure had been instrumental to change the mind-sets internally and reduce sectoral siloes.

[17] Although in average basic funding represents a higher share of RTOs total income (see Section 3.5). 'Importance' has in this section a more strategic meaning.

[18] This is the case for NRC in Canada and CSIRO in Australia.

[19] For instance: AIT (3 years), CSIRO (4 years), DLR (5 years), IMEC (5 years), MTC (5 years), RISE (4 years).
[20] As an 'Associate laboratory'. The RTO receives another basic funding component as 'Interface'.
[21] This is consistent with the results of the OECD study on competitive research funding (OECD, 2018).