Review of impact assessment studies of RTOs

Final Report | October 12 2022

Prepared for:

EARTO
Rue Joseph II, 36-38
B-1000 Brussels

Authors of the report:

Miriam Van Hoed
Valentijn Bilsen
Isabelle De Voldere
Martina Fraioli

Jozef II-straat 40 B1
1000 Brussel

T: +32 2 282 17 10
info@ideaconsult.be

www.ideaconsult.be

Table of contents

List of Figures

List of Tables

INTRODUCTION

EARTO is the European Association of Research and Technology Organisations, promoting RTOs and representing their interest in Europe. The EARTO network counts over 350 RTOs in more than 20 countries. One of the missions of EARTO is to create awareness and evidence on the role RTOs play in the European R&D&I ecosystem. However, the RTO sector is not captured in official OECD or EUROSTAT data and therefore little systematic information about the sector is available. To help fill this gap, EARTO has carried out/commissioned several analyses in the past years. Also several RTOs have impact assessments or evaluations that they use in their communication to national and local policy makers or stakeholders.

EARTO has therefore commissioned this review study, to provide an overview of methods and evidence that will inform RTOs, policy makers and stakeholders on existing evidence and dimensions of impact created by RTOs throughout Europe. The study will also inform on the state-of-the-play, and eventual gaps, regarding methodologies to assess RTOs' impact in the future.

The review study was commissioned to IDEA Consult and was carried out in the first half of 2022.

1 / Scope of the study

1.1. Objectives and structure of the report

With this review study, EARTO aims to gain insights in the methodological state-of-the-art regarding impact assessment of RTOs. The study therefore focuses on a **reasoned comparison of methodologies** that are applied in a range of existing impact assessment studies of RTOs in Europe (**section 2 /**).

At the same time, EARTO seeks to develop a broader context framework for its impact assessments, including a view on the range of results and outcomes in these existing impact studies. To reach this result, the review study also includes a **reasoned comparison of results** (**section 3 /**).

Objectives	Focus
Gain insights in the methodological state-of-the-art and possibilities	Compare the methodologies applied in recent studies
Develop a broader context framework for EARTO's impact assessments	Compare the results obtained in recent studies

The remainder of this **section 1 /** further defines the **analytical framework** and the **scope** of the study. It also outlines the **selection process** for reports included in the review and a general mapping of the selected reports along the dimensions of the analytical framework. The finding of the **in-depth analyses** are elaborated in **sections 2 /** (methodology) **and 3 /** (results). Finally, **section 4 /** concludes with **main findings and lessons learned**.

1.2. Analytical framework

The review analysis is structured along two main dimensions: **economic and societal impact[1].** Within each dimension a range of outcomes can be identified to assess an RTO's impact. The aim is to compare different methods that measure these similar types of outcomes. For instance, one of the main indicators to assess economic impact is the creation of new jobs. The review study compares the methodologies that aim to measure

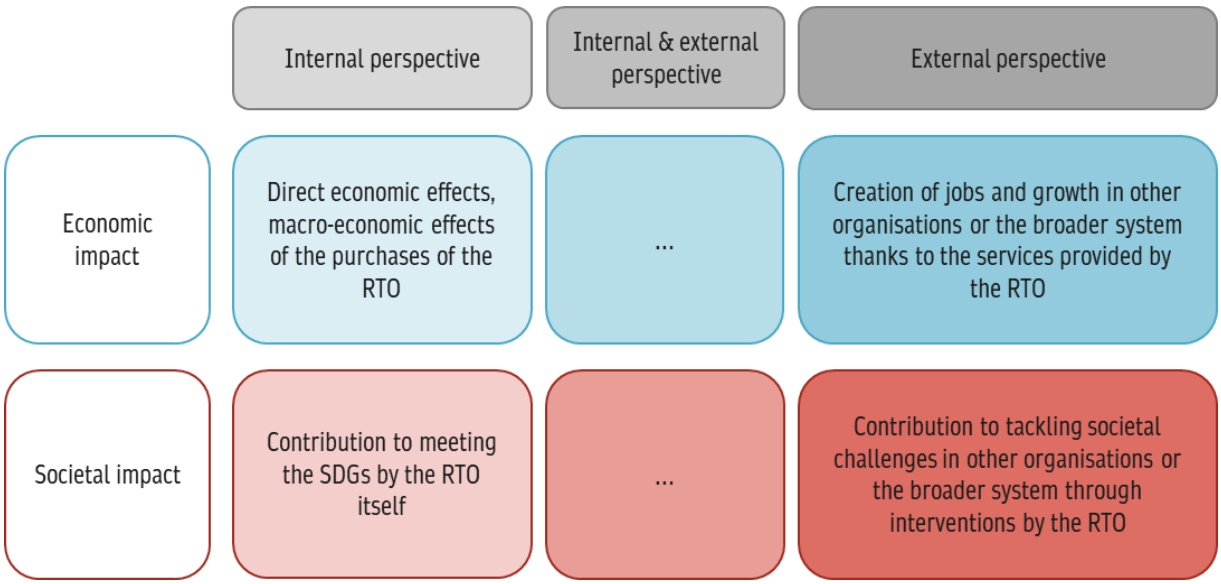
[1] We note that the review of environmental impact methodologies has been incorporated in the review of societal impact methodologies, as environmental challenges have become an integral part of societal challenges.

job creation and provides a structured overview of the strengths and limitations of each methodology, as well as the range of outcomes that is identified in the existing reports.

The traditional approach to impact assessment is to start from an **intervention logic** that connects inputs and activities with a range of outputs, outcomes and impacts, and to develop a methodology to measure these impacts. Moreover, economic impacts can be categorised into **direct, indirect or induced impacts**. Direct impact is for example captured in the employment at the RTO or its direct contribution to value added. Indirect impact is the impact upstream (at the supplier side) or downstream (at the client/user side). Induced impact refers to the effects created in other sectors due to expenditures by amongst others the RTO's employees.

Yet to structure the studies in this review along a common framework for both the economic and societal dimension, we define a slightly different and new approach. Within each impact dimension, we find that studies take either a more **internal or external perspective** (or combine both) when assessing the impact. We define these two categories based on the perspectives taken, i.e. on whether the study focuses on the impact of the RTO as an organisation as such (employing people, purchasing inputs) or whether the study focuses on the impact of the RTO beyond that, based on its specific strengths in transferring technologies and innovation or taking up specific roles in the broader society. The **internal perspective** thus focuses on the activities and governance of the RTO itself, e.g. the economic impact of their purchases in the local economy, the societal impact of their labour policy or management of their infrastructures, etc. For economic impact, it is therefore related to direct impact, but also includes elements of indirect impact upstream. The **external perspective** means that the impact assessment looks at the impact that the services of the RTO create in other organisations – the (direct or indirect) clients – or in the broader system, e.g. to what extent R&D collaboration with the RTO leads to innovation and new market opportunities for companies, or to cost reductions. It is therefore related to the traditional indirect economic impact downstream and induced impact, but can also include elements that capture less quantifiable effects and societal contributions, e.g. how the RTO services lead to greener production processes in companies or to new policy development supporting more sustainable practices. This spectrum of perspectives can be found **in each of the impact dimensions**, as the framework below demonstrates.

Figure 1: Analytical framework for the review study



Source: IDEA Consult

Reports will be discussed along this analytical framework in the following sections. Both quantitative and qualitative methods, and more or less innovative methods, will be mapped to this framework.

1.3. Scope and selection criteria

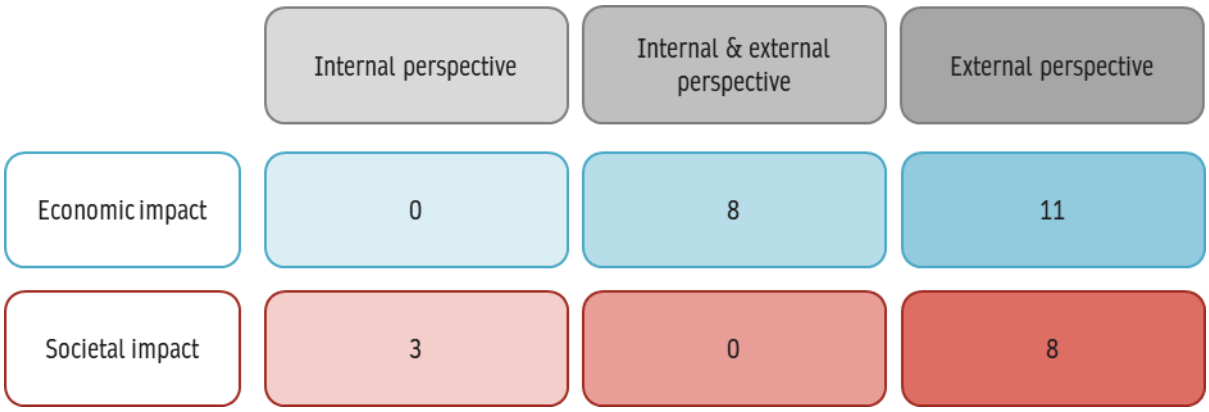
The review study focuses on **recent** reports developed **by or for RTOs** and that measure at least one of the mentioned dimensions of **impact**. The aim was to select reports that together cover a diversity of dimensions and methodologies.

Based on a direct question by EARTO to its members, and a complementary online search by the research team, over 40 reports were identified and screened. Finally, **23 publications were found to be within the scope** of this review study. A few other publications were not fully in scope, but proved relevant for the general scoping and analytical framework and are thus included where relevant to provide a more complete overview of existing material – without being part of the in-depth review analysis. The studies cover evidence for Europe, Belgium, Finland, Germany, the Netherlands, Norway and Spain. Annex A.1 / provides a list of references for the 23 publications in scope and publications used to contextualise results.

Figure 2 maps the studies to the dimensions and perspectives of the analytical framework (cf. Figure 1). From this, it is clear that most studies focus on the external perspective. In the economic impact dimension, several studies combine an internal and external perspective. 7 studies are reviewed both for the economic and societal dimension.

Each section below starts with a more detailed overview of the selected studies, including general characteristics and perspectives taken.

Figure 2: Mapping of the selected studies to the analytical framework



Source: IDEA Consult

2 / A reasoned comparison of methodologies

In this section, methodological approaches to impact assessment of RTOs are discussed. First, a comparative analysis of the methods applied for economic impact assessments is presented in section 2.1. Next, the analysis for societal impact assessment methods is described in section 2.2. For each dimension, the internal and external perspectives are discussed and main takeaways from the comparative analysis are identified.

2.1. Methods for economic impact assessment

2.1.1 Introduction and clustering

In this section, **methodological approaches to economic impact assessment** are identified and analysed in a comparative way.

In the analysis we distinguish between economic impact studies that take an **internal perspective** on the one hand (i.e. direct effects and the economic footprint of an RTO's operational expenditures) and those with an **external perspective** on the other hand (i.e. analysing what the economic impact is for instance on companies that collaborate with RTOs). The lines between both are not always clearcut, and several studies combine both perspectives.

The methods for assessing the economic impact of RTOs **vary substantially by organisation and cover different impact pathways**. This does not mean that they are completely unrelatable, however it is important to be aware of the underlying system view that the researchers have in mind and the various hypotheses that are used.

First, there are the well-known differences between **qualitative and quantitative approaches** to assess the economic impact - where the former typically generate narratives, case studies, illustrations and the latter provide estimates in terms of e.g. contribution to GDP, GDP growth rates, jobs maintained and created, patents issued, etc. Evidently not every relevant aspect related to the economic impact of an RTO can be easily and meaningfully captured by numbers, e.g. potential economic (net) gains from the development of a specific technology or the benefits from providing ancillary services to help to create and gain business for the enterprises in the RTO's networks. The qualitative and quantitative methods thus often complement each other.

Second, depending on the perspective and scope taken and the aims of the impact assessment, **different methodologies** are applied ranging from surveys, interviews or cases, to indicator development and descriptive analyses, and finally elaborated macro-economic models or regression analyses.

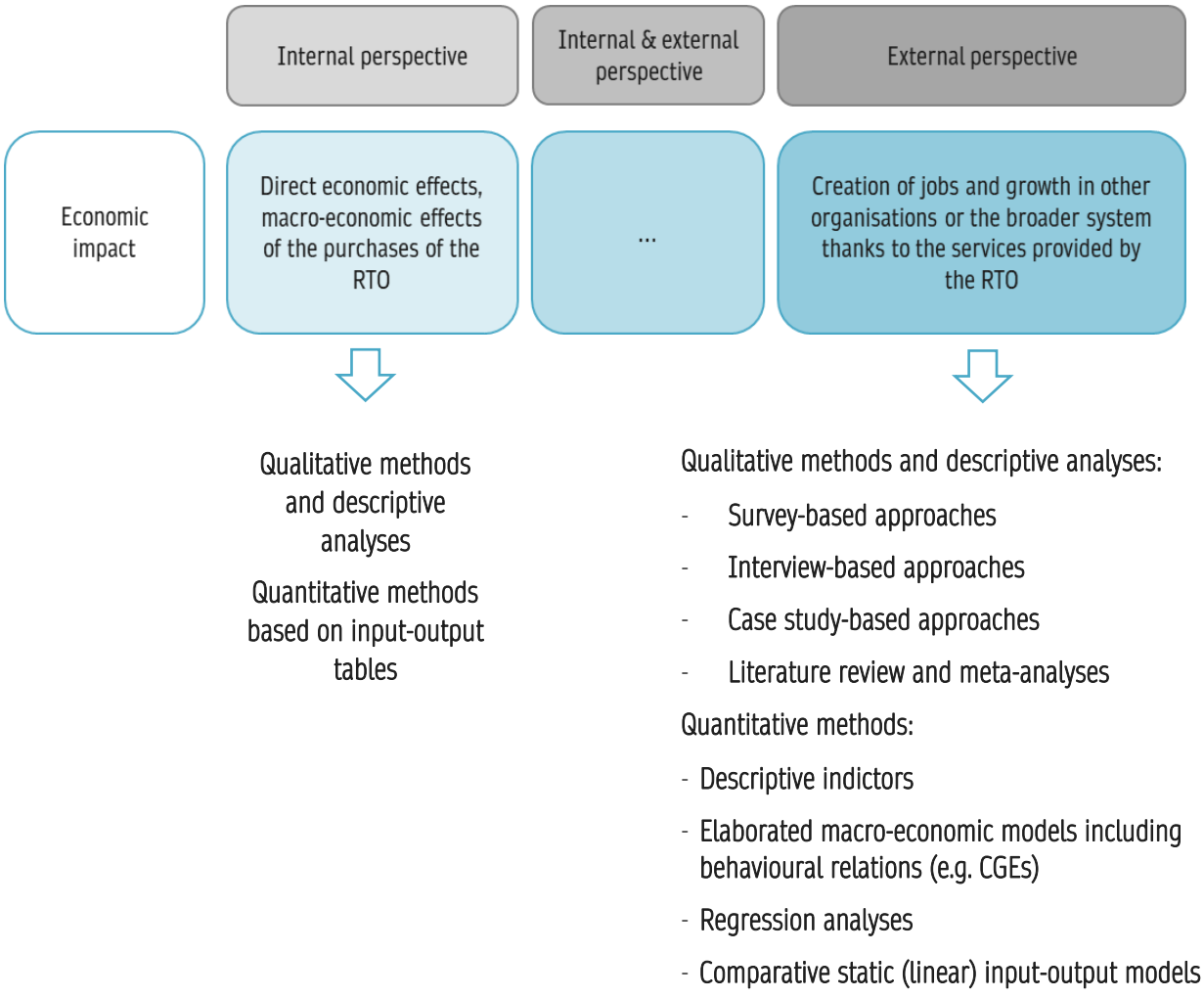
Figure 3 below maps the methodologies applied in the selected studies for economic impact assessments and taking the internal and external perspective explicitly into account. Both qualitative and quantitative methods are applied in each perspective. The strengths, weaknesses and types of results to be expected from each type of methodology are summarised in

Table 1.

Source: IDEA Consult

Table 2 provides a more detailed overview of the selected studies in this dimension.

Figure 3: Mapping of methods to the analytical framework for comparative analysis on economic impact



Source: IDEA Consult

Table 1: Overview of data needs, strengths, weaknesses and types of results by type of methodology

Methodology	Short description	Data and information needs	Strengths	Weaknesses or issues	Type of results and communication
Qualitative methods and descriptive analyses					
Literature review *Internal and external perspective*	Screening, gathering and analysing all kinds of available information in written sources.	All kinds of available information in written sources, e.g. journal articles, documents, annual reports, websites, etc.	Ability to cover a wide set of dimensions of the RTO, providing particular accents and focus, e.g. showcasing pilot projects and reporting key figures (with periodical updates in e.g. annual reports allowing for a structured overview of (main) activities).	Challenge to get a balanced and systematic view on the overall impact. Often lack of information on the mechanisms of impact.	Narratives, descriptive analyses or summary overviews. Can be relatively easily integrated in communication in press, reports and articles or as a basis supporting or complementing other methodologies of data collection and analysis.
Survey-based approaches *Mainly external perspective*	(Online) questionnaires inquiring about the effects of using RTO services.	Contact details of companies / RTO clients. Data on the cooperation/contracts to prefill the survey or contextualise the results (e.g. in relation to the portfolio). Content information for the questionnaire. Pilot-tested (online) questionnaire. In particular for more complex types of surveys: specific survey skills needed.	Depending on the set-up, often relatively simple to use. Can be aimed at getting responses from a larger group / a representative view. Results are quite easy to interpret if focussed on the questions and with proper survey set-up information (context). Topics covered can go beyond those for which data are available: so wider spectrum of impact analysis is possible. Questions can also focus more specifically on added value, attribution, etc.	For more extended analyses: potential bias, e.g. in case of positive selection (companies with positive relationship with RTOs) or when specific types of companies are more inclined to reply (e.g. larger SMEs who have more capacity to do so than smaller companies). Another example is the difficulty to assess attribution of effects when inquiring with RTO's clients only - it is not always feasible to balance this with a relevant control group survey. Hence for a macro view careful derivation of results and conclusions needed. Comparability of results across surveys may be difficult due to different questions asked and different survey set-up. Mainly suited for closed questions, open questions require more advanced analysis.	Frequency tables per question, and the most frequent open question answers. Relatively easy to communicate the results, yet communication of survey set-up and context is needed.
Interview-based approaches *Internal and external perspective*	A set of – more or less structured - questions inquiring about various aspects of the RTO's impact among (diverse) stakeholders.	Contact details of potential interviewees. Good view on stakeholders. Definition of selection criteria based on the ultimate objectives of the impact assessment.	Provides 'flesh around the bones': the stories behind the numbers, potential to capture aspects which cannot be put in numbers and therefore the potential to cover a vast spectrum of impacts. Good way to capture so-called 'tacit' knowledge.	Often lack of a systematic and coherent overview of the impact. Subjectivity may lead to potential bias of impact assessments. Difficult to grasp the impact in a concise manner.	Narratives, can be relatively easily used for analyses and reporting, for case studies, for developing articles, provided that proper context is given.

Methodology	Short description	Data and information needs	Strengths	Weaknesses or issues	Type of results and communication
		Pilot-tested set of interview questions. Depending on the type of interviews: specific interview skills needed.	If structured and with a considerable number of stakeholders, a more systematic overview can be obtained. Relatively easy to grasp and intuitively attractive.		
Case study-based approaches *Internal and external perspective*	Specific illustration of impact through the detailed description of examples or cases.	Selection of cases generally based on desk research and/or interviews. Definition of selection criteria based on the ultimate objectives of the impact assessment. Documents or data on the cases or further data collection needed through interviews.	Specific qualitative (and potentially quantitative) evidence from the real world. Focuses on the narrative and description of impacts and provides a concrete illustration of the impact pathway(s). By focussing on one example, the impact can be illustrated in a more detailed, specific and/or quantitative manner. Combining several cases can allow to illustrate a wider or more diverse impact.	Lack of a systematic and coherent overview of impact. Need to take into account often inherent positive selection bias (e.g. success stories). Case specific methodology and outcomes – can be challenging if not impossible to derive more general conclusions. What holds for one case does not necessarily hold for another.	Concrete illustrations of impact, to combine several cases to sketch a more diverse impact or to be used as illustrations accompanying other types of analyses. Often appreciated by policy makers to make the link between policy and real world applications.
Quantitative methods					
Descriptive indicators *Internal and external perspective*	Using indicators to describe the RTO's activities along various dimensions.	Descriptive indicators can be based on RTO's registration and portfolio data, accounting and contract data, data reported in annual reports, etc.	Ability to cover a wide set of dimensions of the RTO, providing particular accents and focus, e.g. on direct employment, turnover and value added or on research outputs or describing the portfolio, etc. Relevant to contextualise further impact assessment methods. Useful to create time series which allow for inter-temporal comparisons and evolutions.	Challenge to get a balanced, coherent and systematic view on the overall RTO impact with descriptive indicators only. However, they do focus and capture particular quantifiable aspects.	(Key) figures, relatively easy to communicate in infographics, newsletters, website, press, reports, articles, etc.
Elaborated macro-economic models including behavioural relations (e.g. CGEs*) *External perspective*	An abstraction of the economy is made using a set of equations that are mutually consistent and coherent and which model the crucial interactions under study i.e. the RTOs in relation to the economy. CGEs contain an input-output module, usually on a more sectoral aggregate	Model set-up: programming language, good background in economic theory. Empirical part for determining the values of the parameters and elasticities: extensive set of micro, meso and macroeconomic data.	Explicitly models the structural relations between RTOs and the macro economy. Encompassing view on the impacts, yet not necessarily on the precise detailed impact pathways. Simulations of changing conditions is possible. Dynamic versions could show time paths.	Labour and time consuming. Data intensive. Specific expertise required. Proper interpretation requires specialised knowledge e.g. on underlying hypotheses, data restrictions.	Scientific paper type of communication; convincing policy input. Requires an additional step to present to the uninformed reader and public.

Methodology	Short description	Data and information needs	Strengths	Weaknesses or issues	Type of results and communication
	level, yet contain behavioural relations with elasticities and parameters.				
Regression analyses *External perspective*	Empirical assessment of an equation relating e.g. GDP to variables linked to the RTO's activity (contracts, turnover, services) and presence.	So far regional and micro-economic firm level data have been used. Good knowledge of the data generation process and potential pathways that drive the effects on the dependent variable (e.g. GDP).	More cost effective than an elaborate economic model. Fairly straightforward interpretation of the results (elasticities).	Data intensive. Several rounds for testing the best statistical fit. No direct explanation of the reasons and pathways behind the correlations.	Scientific paper type of communication; convincing policy input. Requires an additional step to present to the uninformed reader and public.
Quantitative methods based on input-output tables (IO tables) *Internal perspective (upstream) and external perspective (downstream)*	The RTO's direct impact and activities are either built into an IO table or simulated as a demand shock in a comparative static exercise (the economy without and with the RTO).	Input-output tables from the RTO's country or from the EU as a whole. RTO expenditures and sales classified by IO sector.	A systematic meso-economic view of the RTO's position in the economy and its effects upstream for suppliers, as well as downstream to clients. Results can be directly related to share in an economy's GDP and sectoral performances. Calculation of multipliers and indirect effects (upstream and downstream). The IO analysis can be extended by making households endogenous and thus capture a wider set of impacts (so-called induced effects).	Comparative static exercise; rests on the hypotheses of absence of scale effects; every supply has a matching demand and vice versa; intersectoral relations remain fixed. No behavioural relations and elasticities.	Multipliers provide a relatively easy to understand and intuitive figure about the RTO's impact on the economy; e.g. 1€ RTO purchases provides X€ elsewhere in the economy. Due care needs to be taken on which effects are captured: direct + indirect (upstream and downstream) or induced as well.

(*) CGE: Computable General Equilibrium model: a set of equations that (inter-)relate economic variables related to firms, households, government, foreign trade and finance, in combination with a (simplified) input-output model. CGEs are used to assess the changes in one part of the economy on the other parts, for instance an economy with and without an RTO's activity. In essence CGEs supplement input-output models with behavioural equations which contain elasticity parameters. These parameters indicate the degree to which one (dependent) variable reacts on the change of another (independent) variable. CGEs can be comparative static in nature (before and after the exogenous shock, i.e. the RTO activities) and dynamic showing the gradual adjustment path to the new equilibrium after the shock.

Source: IDEA Consult

Table 2: List of studies evaluating economic impact grouped by RTO, country, year, availability and perspective adopted (ordered by perspective and country)

Study	RTO	Country	Year	Availability	Perspective
Impact assessment of imec	imec	Belgium	2020	Confidential	Internal & External
Impact assessment of VITO	VITO	Belgium	2020	Confidential	Internal & External
EARTO Economic footprint	EARTO	Europe	2018	Public	Internal & External
TO2 evaluation	TNO & other NLs RTOs	Netherlands	2021	Public	Internal & External
The economic footprint of the Dutch Research and Technology Organisation TNO	TNO	Netherlands	2016	Public	Internal & External
2018: impact study of Norwegian energy research from 2008-2017	8 research institutes	Norway	2018	Public	Internal & External
Evaluation of Norwegian Technical Industrial Research Institutes	14 technical-industrial research institutes in Norway	Norway	2016	Public	Internal & External
Impact Studies – TECNALIA's Contribution	TECNALIA	Spain	2020	Public	Internal & External
Roles, effectiveness, and impact of VTT	VTT	Finland	2013	Public	External
The importance of the Fraunhofer Society for German medium-sized companies	Fraunhofer	Germany	2016	Public	External

Study	RTO	Country	Year	Availability	Perspective
The contribution of the Fraunhofer Society to the German innovation system	Fraunhofer	Germany	2016	Public	External
Do companies benefit from public research organisations? The impact of Fraunhofer	Fraunhofer	Germany	2019	Public	External
The macroeconomic impact of Fraunhofer Gesellschaft - A CGE approach, using micro-evidence	Fraunhofer	Germany	2020	Public	External
A General Equilibrium Quantification of the Impact of Fraunhofer on the German Economy	Fraunhofer	Germany	2021	Public	External
The macroeconomic effects of the Fraunhofer-Gesellschaft	Fraunhofer	Germany	2021	Public	External
Understanding the macroeconomic effects of public research: An Application of a Regression-microfounded CGE-model to the case of the Fraunhofer-Gesellschaft in Germany	Fraunhofer	Germany	2022	Public	External
A microeconomic assessment of RTO's impact on Firms output: The case of TNO	TNO	Netherlands	2019	Public	External
The economic impact of applied research organisations (TO2) on Dutch company performance	TNO & other Dutch RTOs	Netherlands	2021	Public	External
Evaluation of the Norwegian Social Science Research Institutes - User survey and impact assessment	Social science research institutes	Norway	2016-2017	Public	External

2.1.2 Economic impact assessments – internal perspective “the economic footprint of the RTO”

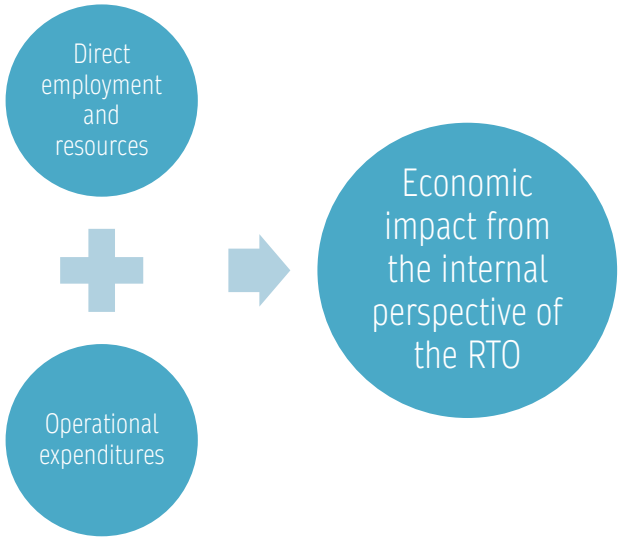
2.1.2.1 Scope

Studies that include the internal perspective focus on the operations of the RTO, be it from an input point of view or looking at impact of operational expenditures (see Figure 4). As shown by

Source: IDEA Consult

Table 2, it becomes clear that there are no economic impact studies focussing entirely and solely on the internal perspective – namely the direct economic effects or macro-economic effects of the RTO's operational expenditures. This should not come as a surprise since it is mostly at the core of an RTO's mission statement to develop, proliferate, promote and valorise new technologies and as such contribute to growth and jobs of a region, country or to the EU. Hence it is not surprising that economic impact studies tend to incorporate the external dimension quite naturally.

Figure 4: Scope internal perspective of economic impact



Source: IDEA Consult

2.1.2.2 Methodologies

Methodologies focused on the internal perspective (as mentioned mostly as part of a wider scope of analysis that also captures the external dimension) include mainly qualitative methods and descriptive analysis. A number of studies also apply quantitative methods based on macro-economic or meso-economic input-output tables to measure the contributions of the RTO's operational expenditures to the wider economy.

QUALITATIVE METHODS AND DESCRIPTIVE ANALYSES

Within the list of reviewed studies, a number use descriptive analyses and a more qualitative approach. Focussing on the internal dimension, a first observation is that a relatively small set of studies look at the **perspective of resources** that RTOs deploy to deliver their services. **Indicators** (numbers) about research and operational budget, employment, the direct impact, rather relate to an evaluation-perspective than to an impact assessment perspective, but are also applied as basis for or to contextualise an impact assessment. One specific case with evaluation-focus is

the Evaluation of the Norwegian Technical Industrial Research Institutes, where a panel of evaluators assessed areas and ways to improve the effectiveness and viability of the institutes and as such paying attention to the **internal processes and performance**.

The Dutch TO2 evaluation study assesses the economic impact as part of a wider evaluation exercise using a **scoring mechanism** on a scale from 0 to 4 following a predefined methodology. Also here the internal dimension is only presented in the context of **organisation characteristics** (turnover, funding, employment).

The 2018 impact study of the Norwegian energy research institutes employs a **case-study approach** in which both the internal and external dimension is covered. With respect to the internal dimension, beside funding also due attention is paid to **research and demonstration infrastructure** and (linking to the external dimension) ways this impacts investments in commercialisation and industrialisation by the Norwegian client companies.

Another interesting, yet more pragmatic approach of a descriptive analysis is the **development of KPIs** as seen in, amongst others, the studies by TECNALIA, imec, VITO and EARTO. The KPIs are calculated on the basis of registration or project data (employment, turnover, funding, investments, revenues, publications, researchers, patents issued, etc.).

Further information on the external perspective in these studies is provided in section 2.1.3.2.

Table 3: Studies using qualitative methods and descriptive analyses – a selection

Study	Objectives and scope	Methodology
Evaluation of Norwegian Technical Industrial Research Institutes (2016)	To evaluate the strengths and areas for improvement of 14 Norwegian technical-industrial research institutes and provide policy recommendations for improvement. From the internal perspective, recommendations were developed for improving effectiveness, improving access to funding and improving cross-cooperation. No impacts were assessed.	An evaluation panel was provided with existing materials among others self-assessments, impact analyses, bibliometric studies, telephone interview results, user survey results.
2018: impact study of Norwegian energy research from 2008-2017 (2018)	To document the effects of R&D investment in environmentally friendly energy through various funding programmes since 2008 and this for 8 research institutes. On the internal perspective the funds received are taken into consideration as well as the research infrastructure, pilots and demo facilities.	48 cases from 8 thematic areas representing somewhat less than 10% of the total project portfolio. All cases can be considered as successful examples with relatively simple and feasible dissemination processes. A mix of interviews and desk research was applied to make the case studies.

TO2 evaluation (2021)	A systematic evaluation of 5 applied research organisations on quality, impact and vitality as part of a 4 years evaluation cycle.	Impact performance scores are set by the evaluators for each of the 5 organisations and this according to a pre-defined methodology. The internal dimension is highlighted in terms of organisation characteristics: turnover, turnover growth, government contribution, staff.
Impact Studies – TECNALIA's Contribution (2013)	A systematic measuring of economic, social and scientific-technological impact.	A set of KPIs was developed based on existing studies, and project data. The internal dimension is covered through R&I investments, government and private company funding.
Impact assessment of imec (2020)	Multidimensional impact assessment, with from the internal perspective an analysis of (evolution in) direct employment and resources.	A set of KPIs was developed based on data collected internally. The internal dimension is covered through employment data (numbers – R&D versus other personnel), R&I investments, government and private company funding, available research infrastructures.
Impact assessment of VITO (2020)	Multidimensional impact assessment, with from the internal perspective an analysis of (evolution in) direct employment and resources.	A set of KPIs was developed based on data collected internally. The internal dimension is covered through employment data (numbers – R&D versus other personnel), R&I investments, government and private company funding, available research infrastructures.
EARTO Economic footprint (2018)	Economic footprint assessment, with from the internal perspective an analysis of direct employment and resources.	A set of KPIs was developed based on data collected internally by the RTOs. The internal dimension is covered through

		employment data, government and private company funding.

Quantitative methods

Most quantitative methods identified in this review, focus on the external perspective of the RTO's impact for the companies that make use of their R&D or services (see section 2.1.3). However, a number of studies also (and often in addition) apply quantitative methods to **assess the impact of the RTO's operational expenditures at its suppliers and in the broader economy.** Table 4 provides an overview of the studies where input-output models are used to assess the economic footprint of the RTO, based on operational expenditures, and hence identify the upstream effects that, as indicated by Poliakov and Hu (2016)[2], 'ripple' through the economy.

While the studies for imec, VITO and EARTO take the input-output model as given and **estimate the 'shock' of having an RTO or not as a comparative static demand shock**, the study for TNO first compiles another input-output model with an additional and distinct TNO sector both in the columns (inputs, suppliers) and rows (outputs, clients) and thus bring the intersectoral TNO relations more on the surface. This is done on the basis of detailed supplier and purchase data as well as data on contract research for the clients. Evidently this is not a trivial exercise requiring appropriate balancing of the IO matrix (inputs need to balance outputs). Subsequently **government subsidies are modelled as exogenous shocks through the increase of final government demand**.

Both the imec/VITO/EARTO approach and the TNO approach can be seen as two flavours of input-output analysis:

1. The first one assumes that the RTO is not of that size as to alter the economic structure of an economy, and the upstream expenditures are considered as sectoral level demand shocks.
2. The second approach explicitly incorporates the activities of the RTO in the economy model and assesses the upstream effects based on a government induced demand shock: the subsidies by which the outlays are financed.

Another difference worth mentioning is the **treatment of the household sector**. In the imec/VITO/EARTO studies households are considered as exogenous, hence part of final demand. The so-called induced effects are calculated 'outside the model' using additional information on saving rates, spending ratios, etc. The TNO study incorporates the household sector into its input-output model, and as such makes is endogenous. There the household sector becomes part of the economy generating direct feedback loops into the economy and the multiplier for the induced effects (incorporating household spending effects) can be readily derived from the so-called closed input-output model.

Both flavours of the input-output analyses have their advantages and disadvantages, yet they all bear on the **hypothesis of constants returns to scale, and absence of demand and supply restrictions**. Nevertheless they do provide a valuable view on the wider system impact of an RTO's operational expenditures.

Table 4: Studies using input-output models to assess the economic impact of the RTO's operational expenditures

Study	Objectives and scope	Methodology

[2] Poliakov & Hu (2016). The economic footprint of the Dutch Research and Technology Organization TNO. TNO Working Paper Series, Working paper 2016-1.

Impact assessment of imec (2020)	Measuring the effects of the RTO's operational expenditures at its suppliers and in the broader economy.	For this element in the study, a quantitative IO-analysis is applied.
Impact assessment of VITO (2020)	Measuring the effects of the RTO's operational expenditures at its suppliers and in the broader economy.	For this element in the study, a quantitative IO-analysis is applied.
EARTO Economic footprint (2018)	Measuring the effects of the participating RTOs' operational expenditures at its suppliers and in the broader economy.	For this element in the study, a quantitative IO-analysis is applied.
The economic footprint of the Dutch Research and Technology Organisation TNO (2016)	Measuring the economic footprint of 1€ subsidy to the Dutch TNO in terms of (additional) output generated.	The Dutch 2014 IO-table with 76 industries combined with detailed data on suppliers (upstream) and research projects (downstream). A separate "TNO sector" was added. The model was closed or made endogenous by including the household sector in the intermediary intersectoral section of the table. The subsidy was modelled as a change in government final consumption.

2.1.3 Economic impact assessment – external perspective "stimulating business elsewhere"

In addition to the above discussed internal perspective on economic impact, several studies also assess the **economic impact on companies** deriving from the RTO services (R&D support, access to infrastructures, business coaching,...) they receive (see

Source: IDEA Consult

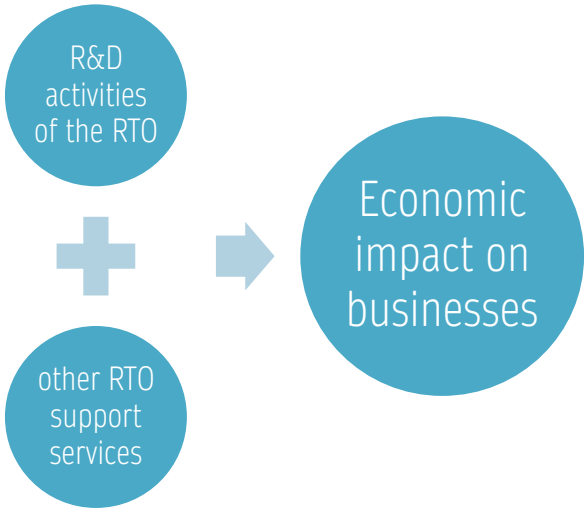
Table 2 for the overview of studies). Therefore, in this section, we analyse in a comparative way the main **methodological approaches** to assess this type of economic impact of RTOs.

2.1.3.1 Scope

Within the set of reviewed studies, we observe two clusters based on the type of RTO services that are considered for the impact assessment:

- The majority of studies focus on measuring the **impact of RTOs' R&D activities** on the performance of companies: how do joint research projects or contract research from RTOs help companies to strengthen their innovative capacity and as such also their economic performance (in terms of job creation, increased financial performance, etc.)?
- A second group of studies considers a **wider range of RTO services** (e.g. providing access to research and testing infrastructures, business incubation and acceleration services of RTOs,...) and also look at how these services (further) impact the business performance of companies.

Figure 5: Scope external perspective of economic impact



Source: IDEA Consult

2.1.3.2 Methodologies

Keeping in mind that the type and quality of information differ from one publication to another, the screening and comparative analysis made it possible to identify some methodological approaches and trends. In the next paragraphs we discuss the different clusters of methodologies

QUALITATIVE METHODS AND DESCRIPTIVE ANALYSES

In terms of qualitative methods and descriptive analyses, the main applied methodologies are survey-based approaches, interview-based approaches, case study-based approaches and literature review and meta-analyses. We discuss each cluster of methodologies below.

- **Survey-based approach**

This is a **common method** to get feedback from companies (or other users) that have collaborated with the RTO or have benefitted from its services. The types of questions normally depend on the type of study (impact assessment or classical evaluation), but we observe that in both cases questions are asked about the added value of the RTO services to the businesses.

Some of the studies reviewed acknowledge that the survey-based approach poses **some challenges** related to the representativeness of the survey sample and the commitment of the surveyed companies. In particular:

- For the first study in Table 5, in relation to the basic population, a clear bias in favour of **larger SMEs** can be observed. Thus, the conclusions drawn in the analysis rather apply to larger SMEs and mid-sized companies. This is not considered problematic in this study, since this group is also the one that is more likely to be considered as customers and cooperation partners of the RTOs. However, it can be considered a point of attention, knowing that by far the largest majority of companies has less than 250 employees (and this study even defines SMEs as companies up to 1,500 employees).
- As for the second case, the authors of the study indicate that survey respondents likely constitute a positive selection, meaning that they are mainly companies that had a positive relationship with the RTO. Therefore, there is a certain risk for a **positive bias** among survey respondents, primarily because positively inclined users may be expected to be more interested than dissatisfied ones in contributing to these types of study. However, the authors argue that this bias is not likely to be very large, at least for the overall population of respondents. The survey therefore probably paints a slightly more positive picture than is warranted, but this does not affect the overall assessment. The research institutes sent the authors extensive lists of users, which was interpreted as more or less complete sets of users over the last few years. Therefore, the authors believe that the risk of a positive selection bias is rather marginal.
- Another challenge or limitation consists in **assessing attribution or validating the results** of a survey. A counterfactual analysis or benchmark is not always feasible due to data limitations or the scope of the study. An alternative was applied in the survey-part of the imec impact assessment, which focused on one specific collaborative R&I programme targeted to companies in Flanders. An online survey was combined with validation interviews and follow-up email validation in order to ensure consistent interpretation of the answers provided and of the actual contribution of reported effects to the participation in the programme. In addition, the combination with interviews allows to add a narrative to the survey-based indicators. On the downside, this approach is not feasible for large numbers of companies, and is thus not recommended in the case of large and/or diverse populations.

Table 5: Studies using survey-based methods to assess the economic impact of the RTO's services on client companies' performance

Study	Objectives and scope	Methodology: Survey process and questionnaire
The importance of the Fraunhofer Society for German medium-sized companies (2016)	▶ To empirically ascertain the importance of Fraunhofer as an R&D service provider and cooperation partner for German SMEs. ▶ To show where there may be starting points for improving cooperation. To reach these objectives, a survey was combined with documentary research and interviews.	The target group to be surveyed were cooperation partners and customers of the FhG who worked with the FhG between 2011 and 2015. A random sample of 1,200 companies was drawn from this population. The selected companies had to have fewer than 1,500 employees and be autonomous, i.e. they were not to be part of larger corporate structures. The SME definition used here thus deviates from conventional definitions. After further cleaning of the sample, the remaining 1,025 companies were contacted by telephone and asked to participate in the survey. Eventually, 215 usable questionnaires remained. The questionnaire (available in the study) relates to: ▶ Profiling

		▸ SMEs innovation activities ▸ Importance of cooperation with FhG against a number of criteria ▸ Experience of cooperation with FhG
Evaluation of the Norwegian Social Science Research Institutes - User survey and impact assessment (2016-2017)	To assess the following dimensions: ▸ Client and partner satisfaction ▸ The institutes' delivery capacity, and the quality and relevance of the deliveries ▸ Collaboration, dialogue and exchange of knowledge between the institutes and their users ▸ The institutes' availability to the users ▸ The institutes' professional integrity and independence (from politics, public agencies and vested interests) ▸ How the users regard the institutes (alone and as a group) in relation to other R&D providers with similar kind of competence, in Norway and abroad. To assess these dimensions, the survey was combined with interviews.	Two types of questionnaires (consisting both of around 15 questions) were designed according to the type of target user: client or partner. The questions relate to: ▸ Relation with the research institute ▸ Typology of user ▸ Location ▸ Statements about motives for buying R&D services from the institute ▸ Statements about to what extent buying R&D services from the institute has contributed to, or is expected to contribute to a number of business dimensions ▸ Impact experienced ▸ Satisfaction ▸ Competitors ▸ Challenges for the institute After further cleaning steps and plausibility checks, 215 usable questionnaires remained in total. In terms of telephone contacts, a response rate of 21% and in terms of email invitations, a response rate of 29% was reached. The overall response rate is considered as very satisfactory by the authors. For the most part, web survey results are presented for the institutes as a group and are reported on a Likert type scale, where survey respondents have been asked to what degree they agree with a statement. Statements from interviews have been selected to help interpret web survey results and to support the discussion.
Impact assessment of imec (2020)	To assess the impact of participation in collaborative research projects (ICON) with imec on the economic performance of businesses.	Impact of participation in a specific collaborative R&I programme is measured in terms of research, development and innovation effects in the companies as well as in terms of the creation of additional turnover, employment or investments. For this, the study combines an online survey with interviews with companies that have participated in

		the collaborative R&I programme. The interviews are specifically applied to assess consistent interpretation of data (needed for aggregation) and attribution of the effects to the participation in the specific project. As a counterfactual analysis was not feasible in the scope of this study, the method thus built in an alternative validation step through these interviews. In addition, the interviews allowed to add a narrative to the survey-based indicators.
	To assess the impact of participation in imec's business incubation and acceleration programme (imec.istart) on the economic performance of the participants.	Survey data gathered for the UBI Global World Rankings of Business Incubators and Accelerators, are used to compare the performance of imec's incubation and acceleration programme with 364 benchmark programmes (latest UBI Ranking 2019-2020). Based on the survey, programmes can be benchmarked on 21 KPIs, clustered in three categories: 1/ economic impact and performance of the programmes and their client and alumni startups as well as the programmes' success in retaining human capital and start-ups in the ecosystem., 2/ value for client start-ups - number and efficiency of services provided by the programmes and 3/ the programmes' success in attracting deal flow and third-party support as well as their capacity to create viable companies.

- Interview-based approach

Another qualitative method used to assess the impact on businesses are expert interviews. As seen above, interviews are **often used to complement survey-based methods**. In a number of studies, expert interviews are also used as **a stand-alone methodological tool** of investigation and not as a complementary method. Among the reviewed studies, two in particular build on interviews as a primary tool, complemented by data analysis and literature review: the study on the contribution of the Fraunhofer Society to the German innovation system and the imec impact assessment.

Table 6: Studies using expert interviews to assess the economic impact of the RTO's services on client companies' performance

Study	Objectives and scope	Methodology
The contribution of the Fraunhofer Society to the German innovation system (2016)	Systematic assessment of FhG on the German economy with a focus on the services provided by FhG such as applied research, SME support, tech transfer, trainings,...	Assessment of FhG innovation role through expert interviews; analysis of patent and publication performance in various fields; use of micro data from German variant of the European Manufacturing Survey using statistical twin companies that do not cooperate with FhG as a control group.

Impact assessment of imec (2020)	Assessment of the impact generated by imec through a range of services it offers to companies, other organisations and governments to support them in the economic and social valorisation of new technological developments (access to piloting and testing facilities, incubation and acceleration services, access to (risk) capital, etc).	Internal interviews were conducted to understand how imec helped companies bridge the 'Valley of Death', one of the biggest challenges for technology ventures. The interviews focus on two dimensions of bridging the valley of death: technological and entrepreneurial. The interviews were complemented by literature review and analysis of data (among others the UBI Survey data, cf. Table 5).

- Case-based approach

One study tries to understand impact based on the **exploration of specific cases**. The study on Roles, effectiveness, and impact of VTT, identifies **a series of roles that VTT plays in the wider innovation ecosystem**. VTT's roles and impact are considered in the context of major global socioeconomic and technological challenges, and special attention has been paid to VTT's internationalisation and to VTT's role in enhancing the innovation performance of small- and medium-sized firms.

The selected cases aim to shed light on VTT's various roles and added value, as well as on VTT's wider socio-economic and ecological impact. The cases are examples that illustrate VTT's participation in processes leading to innovations, as well as highlight the various roles that VTT has pursued. These case examples clearly show that VTT has multiple roles, even in individual innovation development processes. Authors remark that this highlights the importance of assessing the contribution and impact of VTT's activities by qualitative means, rather than concentrating on quantitative indicators alone. According to them, much of the societal, economic and ecological impact is not quantifiable. The cases have been identified primarily from the Sfinno database and the authors' existing material. The report summarises the main roles that VTT has performed in technology or innovation development, highlights the added value of those activities to companies and industry, and pinpoints the materialised or attained societal, economic and ecological impact.

- Literature review and meta-analyses

Eventually, one study (TO2 evaluation) uses qualitative methods such **literature review and meta-analyses** to assess **cooperation with businesses and the impact generated on them**. As was already mentioned with respect to the internal perspective in section 2.1.2.2 on this study, an evaluation panel was provided with existing materials documenting aspects related to quality, vitality and impact of the RTOs under study. This information contained structured quantitative information about the RTO, a self-evaluation sheet, and evaluation and impact reports prepared by external committees. The panel used the material based on a pre-defined evaluation protocol and transposed the results into a four-point scale with value 1 for insufficient and 4 very good. In terms of external economic impact, the following aspects were covered:

- The economic impact on the Dutch industry;
- The relationships with SMEs;
- Support to start-ups and scale-ups;
- Internationalisation (contract research, knowledge base development).

Quantitative methods

In our review we distinguished four types of quantitative methodologies that focus on the impact of RTOs in the broader economy, based on their activities and services towards companies:

- Descriptive indicators;
- Elaborated macro-economic models including behavioural relations (e.g. CGEs);
- Regression analyses;
- Comparative static (linear) input-output models.

The three latter methods are not entirely unrelated in terms of methodological approach. Where the elaborated macro-economic models aim to define the relevant interrelations explicitly, say laying bare the structure of the interactions, regression analyses actually focus on a reduced form of the (unknown) structural model. In case of computable general equilibrium models quite often the sectoral interrelations, which are depicted in input-output models, are taken on board in one way or another adding behavioural equations which allow for adding complexity and more realism compared to the comparative static linear input-output models.

All quantitative approaches have in common that they are heavily data driven. They all require substantial data gathering. **Timely availability of data is important**, especially if one wants to assess the evolution over time. Evidently the concepts and definitions used need to be well understood and comparable which helps qualifying the results and put them in proper context.

Descriptive indicators

A first approach is the use of descriptive indicators on economic impact beyond the operational activities of the RTO. Next to their indicator development for the internal perspective (see section 2.1.2.2), studies of imec, VITO and the EARTO economic footprint have also collected information on the external perspective - **e.g. spinoffs, training, outflow of personnel and/or contracts** - and have analysed this information by applying further calculations (including external economic parameters) to **estimate the value of these elements for the organisations involved or the broader economy**. The model of calculations and application of external economic parameters requires specific assumptions and hypotheses, which lead to estimations rather than exact measurements. Another example of a study using descriptive indicators is the one by TECNALIA, which includes e.g. the number of new jobs created in new technology-based companies and researchers transferred to companies.

Table 7: Studies using descriptive indicators to assess the economic impact of specific external elements in the RTO's activities

Study	Objective and scope	Methodology
Impact assessment of imec (2020)	Multidimensional impact assessment, with from the external economic perspective focus on R&D collaborations with industry (collective research and one-on-one research services), creation of spin-offs, training of staff in industry, mobility of RTO staff to industry.	Quantitative methods: descriptive statistics, IO-analysis, application of literature-based technology multiplier

Impact assessment of VITO (2020)	Multidimensional impact assessment, with from the external economic perspective focus on contract research (one-on-one research services) for industry and governments, creation of spin-offs, training of staff in industry, mobility of RTO staff to industry	Quantitative methods: descriptive statistics, IO-analysis, application of literature-based technology multiplier
EARTO Economic footprint (2018)	From the external economic perspective focus on R&D collaborations with industry (collective research and one-on-one research services), creation of spin-offs, mobility of RTO staff to industry	Quantitative methods: descriptive statistics, IO-analysis, application of literature-based technology multiplier
Impact Studies – TECNALIA's Contribution (2013)	Objective to present the current work on impact measurement and KPIs used in TECNALIA	A selection of KPIs was developed as part of a scoreboard. The external dimension is covered through e.g. the number of new jobs created in new technology-based companies and researchers transferred to Basque industrial companies.

- **Comparative static (linear) input-output models**

Comparative static input-output models can also be used to assess the impact on the clients of the RTOs. In the studies of imec, VITO and EARTO, listed in the above Table 7, the **downstream IO analysis** is used to **complement and validate the indicator-based analysis** on R&D collaborations with industry, which makes use of a literature-based technology multiplier.

Typically, one uses the so-called Goshen input-multipliers to assess the downstream effects. A few important underlying assumptions have to be taken into account for a proper interpretation of the results:

1. **Constant returns to scale** (due to the linearity of the intersectoral relations in the model);
2. **Absence of demand constraints**. Specifically, this implies that an increase in an RTO's output will in the same proportion lead to an increase in de services demanded by the client.

Both methods provide an estimation, yet in the IO-based method, it is important to take note of the fact that the input-output analysis **captures only the monetary value of the research contracts**; therefore not 1) the discounted present value of future potential, yet unknown, income streams that are due to the knowledge produced, 2) the scientific value, 3) environmental value, 4) societal benefits. It is therefore considered a lower boundary to the real effects.

- **Elaborated macro-economic models including behavioural relations (e.g. CGEs)**

Fraunhofer is the only RTO that uses computable general equilibrium models (CGEs) to assess its macro-economic impact on the German economy. There is a clear line of progress in terms of methodological refinement, data source development and granularity of the results. Furthermore, as the modelling work further develops, also the evidence base of FhG impact becomes more pronounced. The studies reviewed are represented in Table 8. These

studies are interrelated and it is fair to say that the later studies build further on the insights and modelling-experiences of the former ones.

As indicated by Grant, Figus and Schubert (Understanding the macroeconomic effects of public research, 2022) **the CGE approach allows having a view on how science affects the economy and through which sectors**, whereas the regression approach (see next section) would be inconclusive about the impact pathways and 'leave a black box' in this respect. In combination with the input-output intersectoral module the CGE also allows identifying the most important sectors through which the impacts run through the German economy. Additionally, Comin (A General Equilibrium Quantification of the Impact of Fraunhofer on the German Economy, 2021) builds in endogenous innovation and technology adoption which brings in an additional layer in the system that is considered for assessing the impact with additional knock-on effects and hence a wider view and capturing of the FhG impact.

Table 8: Studies using macro-economic models (e.g. CGEs)

Study	Objectives and scope	Methodology
Understanding the macroeconomic effects of public research: An Application of a Regression-microfounded CGE-model to the case of the Fraunhofer-Gesellschaft in Germany (2022)	Estimating the effects on the German economy of the activities of the FhG, thereby identifying the impact pathways and main sectors in the economy. The value added of the study is that indirectly the effect and impact of knowledge creation in the German economy is brought to surface.	The authors use a combined micro-macro approach with empirical estimates using regional level micro data which in turn are integrated in an existing CGE model of the German economy.
A General Equilibrium Quantification of the Impact of Fraunhofer on the German Economy (2021)	Assess the long-run contribution of FhG to the German economy	Dynamic Stochastic General Equilibrium Model with endogenous development and adoption of technologies at firm level. FhG performs R&D and helps companies closing the technology frontier gap.
The macroeconomic effects of the Fraunhofer-Gesellschaft (2021)	The goal was to update the Frietsch et al. 2016 study and to extend the impact indicators (GDP, tax revenues and patenting). The study assesses what the activity and presence of FhG in a region attribute to GDP per capita and patenting activity.	Estimation of reduced form equations using panel data at regional NITS3 level, controlling for endogeneity and including robustness checks; dependent variables GDP per capita and patents.
The macroeconomic impact of Fraunhofer Gesellschaft - A CGE approach, using micro-evidence (2020)	To assess the impact of FhG on the German economy. The focus is on pathways and sectors through which the German economy is impacted by the FhG.	Combination of CGE modelling in which the effect of FhG is simulated as a demand shock and regression analysis using micro data to estimate the total size of the FhG demand shock.

- Regression analyses

From a methodological point of view, one could argue that regression analyses go around the challenges to specify the structural model and interactions between the RTOs' activities on the one hand and the various impact variables in an economy on the other hand. All studies surveyed use **micro-level (panel) data** to assess the effects of RTO participation on a company's performance. Yet this 'short-cut' may come at a cost in the sense that size **heteroskedasticity and endogeneity** may affect the estimation results and hence if not treated carefully erroneous interpretations may arise. All studies use their own approaches to deal with this – either by exploring the information in the heteroskedasticity using **instrumental variables**, as in Comin et al. (Do companies benefit from public research organizations? The impact of Fraunhofer, 2018) or by explicitly introducing a **control group** of 'nearest neighbours' that match the companies in the treatment group (the ones participating with RTOs) in terms of firm characteristics save for RTO participation. Examples of the latter are the studies of TNO (2018) and the Dutch Ministry of Economic Affairs and Climate (2021).

Table 9: Studies using regression analyses

Study	Objectives and scope	Methodology
The macroeconomic impact of Fraunhofer Gesellschaft - A CGE approach, using micro-evidence (2020)	To assess the impact of FhG on the German economy. The focus is on pathways and sectors through which the German economy is impacted by the FhG.	Combination of CGE modelling in which the effect of FhG is simulated as a demand shock and regression analysis using micro data to estimate the total size of the FhG demand shock.
Do companies benefit from public research organizations? The impact of Fraunhofer (2018)	Analyse whether project interaction with FhG affects firm performance and strategic orientation. The focus is on the effects of FhG on companies' performance; the only internal part is the amount spent by firms on FhG spending.	Econometric analysis using micro-level panel data with firm performance as dependent variable and FhG interaction as explanatory variable (amounts spent on FhG services). Size heteroskedasticity and endogeneity problems are treated with instrumental variables (Lewbel 2012 approach).
A microeconomic assessment of RTO's impact on Firms output: The case of TNO (2018)	Assess the effect of RTOs on firms' productivity.	Econometric analysis using propensity score matching to control for endogeneity (treatment and control group) using firm level micro data; dependent variable is the firm's growth rate, independent variables include TNO [0/1].
The economic impact of applied research organisations (TO2) on Dutch company performance (2021)	A quantitative assessment of the TO2 on company performance in the Netherlands. The focus is on the effects on firms' value added growth rates.	Econometric analysis using difference-in-difference model and propensity score matching to control for endogeneity (treatment and nearest neighbour control group) using firm level micro data; dependent variable is the firm's growth rate, independent variables include TO2s [0/1].

2.1.4 Main takeaways

Although descriptive analysis and qualitative research certainly have their place in the spectrum of economic impact assessments providing narratives, illustrations and case material, quantitative methods have the advantage of 'making a long story short' and provide the results in a fairly easy to communicate monetary value or relatively simple number. Quantitative methods pertain to evidence-based policy making and they have a fact-based nature. Nevertheless, in stark contrast to the benefits of having hard numbers to illustrate an RTO's impact and the relative simplicity of communication and persuasive power that go together with it, the underlying methodologies to assess the numbers are far more complex than the qualitative methods and hence more costly to develop. Additionally proper interpretation of the numbers is needed and a good view on the assumptions used is paramount.

The **main takeaways** of this comparative analysis are that:

- The various studies surveyed do fill in a gap in the academic literature that investigates the link between government R&D funding and the effects on the economy.
- The studies cover both qualitative and quantitative methodologies. Yet the far majority aim at quantification of the economic impacts.
- Methodologies used are quite rigorous explicitly stating underlying hypotheses, and addressing potentially compromising issues such as self-selection, endogeneity problems.
- One can make a distinction between internal impacts which focus on the operational and capital expenditures of the RTO and the external impacts which focus on the business activities generated elsewhere in the economy. All reviewed studies include an external perspective.

The comparative analysis of economic impact studies show that in most cases, the **combination of methodologies** is preferred to the use of a single methodology, as exposed in the table below.

Table 10: List of reviewed studies and triangulation of methods

Study	Cases	Survey	Interviews	Literature review/data analysis	Quantitative approach (econometric or IO-based methods)
Impact assessment of imec		x	x	x	x
Impact assessment of VITO			x	x	x
EARTO Economic footprint				x	x
TO2 evaluation				x	
The economic footprint of the Dutch Research and Technology Organisation TNO					x
2018: impact study of Norwegian energy research from 2008-2017	x		x	x	
Evaluation of Norwegian Technical Industrial Research Institutes				x	

Study	Cases	Survey	Interviews	Literature review/data analysis	Quantitative approach (econometric or IO-based methods)
Impact Studies – TECNALIA's Contribution				x	
Roles, effectiveness, and impact of VTT	x			x	
The importance of the Fraunhofer Society for German medium-sized companies		x	x	x	
The contribution of the Fraunhofer Society to the German innovation system			x		x
Do companies benefit from public research organisations? The impact of Fraunhofer					x
The macroeconomic impact of Fraunhofer Gesellschaft - A CGE approach, using micro-evidence					x
A General Equilibrium Quantification of the Impact of Fraunhofer on the German Economy					x
The macroeconomic effects of the Fraunhofer-Gesellschaft					x
Understanding the macroeconomic Effects of public Research: An Application of a Regression-microfounded CGE-model to the case of the Fraunhofer-Gesellschaft in Germany					x
A microeconomic assessment of RTO's impact on Firms output: The case of TNO				x	x
The economic impact of applied research organisations (TO2) on Dutch company performance					x
Evaluation of the Norwegian Social Science Research Institutes - User survey and impact assessment		x	x		

2.2. Methods for societal impact assessment

2.2.1 Introduction and clustering

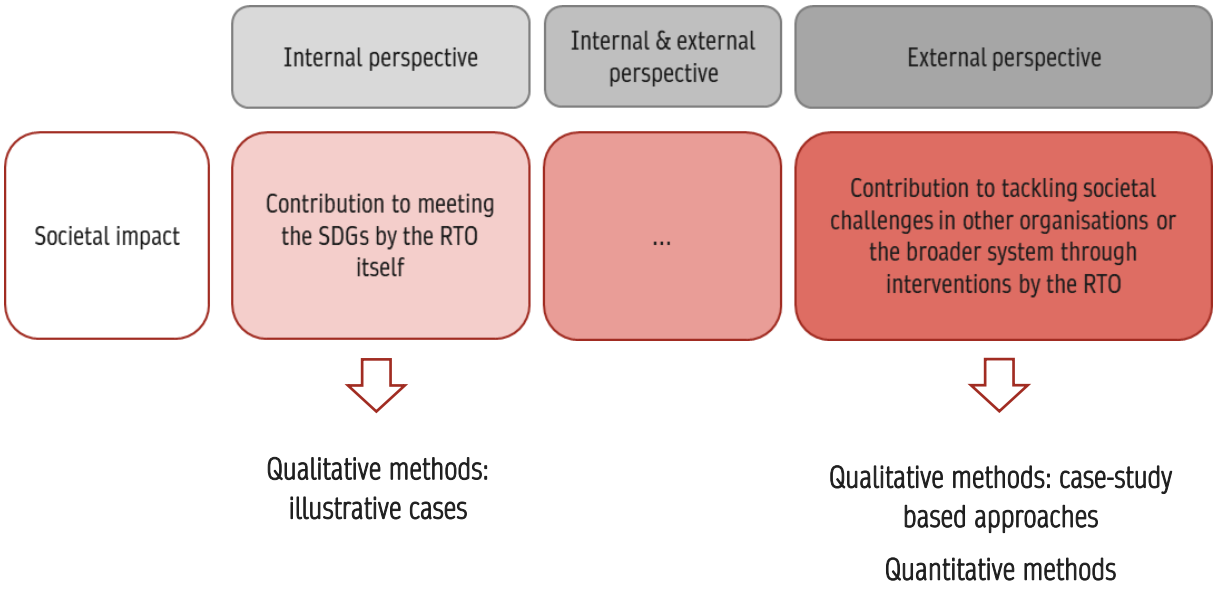
In this section, **methodological approaches to societal impact assessment** are identified and analysed in a comparative way. Some of the studies analysed in this section have already been partially presented in the previous section: this is due to the fact that often the same study aims to cover different dimensions (economic, business and/or societal) and therefore different methodologies have been adopted by the authors.

When we consider the typology of studies analysed in relation to the societal dimension, as for the economic dimension, a distinction needs to be made between **impact assessments and evaluations**. In fact, some studies explicitly aim at assessing the impact of the RTO and its activities on society and the economy, while others evaluate and monitor the performance of RTOs themselves. A third category sees impact assessment as incorporated into the evaluation itself. Furthermore, another category of documents that have been screened is represented by **sustainability reports**, in which the organisations disclose and communicate information concerning their internal activities and how these contribute to achieving the Sustainable Development Goals[3].

As with the economic dimension, here too we find **studies that adopt an internal or an external perspective, or combine both**. Similar to the economic impact assessment, also for societal impact the internal and external perspectives are not always clearcut and methods may capture both of these dimensions in one study.

Figure 6 below **maps** the methodologies applied in the selected studies for societal impact assessments and taking the internal and external perspective explicitly into account. Table 11 provides a more **detailed overview** of the selected studies in this dimension and their characteristics.

Figure 6: Mapping of methods to the analytical framework for comparative analysis on societal impact



Source: IDEA Consult

[3] The United Nations Sustainable Development Goals: https://sdgs.un.org/goals.

Table 11: List of studies evaluating societal impact grouped by RTO, country, year, availability and perspective adopted (ordered by perspective and country)

Study	RTO	Country	Year	Availability	Perspective
Imec Sustainability report	imec	Belgium	2020	Public	Internal
SINTEF sustainability report	SINTEF	Norway	2021	Public	Internal
Impact Studies – TECNALIA's Contribution	TECNALIA	Spain	2013	Public	Internal
Impact assessment of imec	imec	Belgium	2020	Confidential	External
Impact assessment of VITO	VITO	Belgium		Confidential	External
Roles, effectiveness, and impact of VTT	VTT	Finland	2013	Public	External
Mapping VTT's publications and activity regarding SDGs	VTT	Finland	2020	Public	External
Measuring the Social Impact of RD&I	TECNALIA	Spain	2013	Public	External
TO2 evaluation	TNO & other NLs RTOs	Netherlands	2021	Public	External
Evaluation of the Norwegian Social Science Research Institutes - User survey and impact assessment	Norwegian social science research institutes	Norway	2016-2017	Public	External
2018: impact study of Norwegian energy research from 2008-2017	SINTEF (and other research institutes)	Norway	2018	Public	External

2.2.2 Societal impact assessment - internal perspective: "sustainable behaviour of the RTO itself"

2.2.2.1 Scope

Publications looking at the internal perspective of the societal dimension, focus on the sustainable behaviour of the RTO itself. This can concern for instance contributions of the organisation to the Sustainable Development Goals (SDGs) or the measurement of one's carbon footprint.

2.2.2.2 Methodologies

Two publications (imec Sustainability report and SINTEF Sustainability report) look at societal impact from the perspective of the **contribution of the RTO's own activities (internal policies and organisation, infrastructures, management of activities,...) to the Sustainable Development Goals (SDGs)**.

Both the imec and SINTEF sustainability reports link their internal activities (mainly their R&D investments, but also their organisation and management) to the SDGs framework. In terms of methodologies, **both reports make use of examples and illustrative cases** of how the RTOs contribute to sustainable development by adopting sustainable behaviours at organisational and management level, but also by describing how their research activities relate to specific societal challenges.

As part of this societal impact dimension, one study focuses explicitly on its **environmental impact** as an organisation, i.e. from this internal perspective. TECNALIA calculates its Carbon Footprint (CF)[4] using the principles of the UNE-ISO 14064-1: 2012 standard to assess environmental impact of its direct and indirect activities in order to implement improvement actions to reduce it, with a focus on energy efficiency and sustainable mobility. In 2019, new indirect activities were considered while calculating the Organizational Environmental Footprint (OEF) using its own tool, which resulted in an update to the CF. The method relies on a Life Cycle Assessment (LCA) methodology.

[4] See TECNALIA Annual Report 2020: https://informeanual.tecnalia.com/wp-content/uploads/2021/08/TECNALIA_2020_ANNUAL_REPORT.pdf

Table 12: Studies adopting an internal perspective to assess the societal impact of the RTO's services

Study	Objectives	Scope	Methodology
Imec Sustainability report (2020)	The objective is to give a picture of imec's social, environmental and ethical performances relevant for imec stakeholders and for imec itself.	In addition to showcasing how sustainability is embedded at organisational and management level, the report presents examples (non-in-depth cases) of R&D projects that impact society and contribute to making it more sustainable. These examples are provided for those areas in which imec makes the biggest difference, such as manufacturing, health, energy and digital.	Over the years, several teams within imec worked on a prioritisation exercise: in workshops, the employees determined the stakeholder groups, and defined a list of topics. This exercise was updated in the course of 2021 and a broader exercise will be implemented in the near future. The set of topics that was determined can be split into the core activities of imec: on the one hand, the internal functioning of the organization and, on the other, the external impact of these activities on people, society and the environment. Imec's research portfolio is focused on creating a strong, positive impact by strengthening building blocks of a more sustainable society, whether it is in reducing power consumption of data centres through developing technologies for more energy-efficient high-performance chips, developing photovoltaic technologies, new software for adaptive and personalized learning, or new genome sequencing technologies for a better healthcare. SDGs are used as the long-term compass to assess whether activities contribute to a more sustainable society. Examples of inspiring R&D projects are grouped based on correlation with specific SDGs.
SINTEF Sustainability report (2021)	The objective is to document the contribution of the organisation to sustainable development. Contrary to regular sustainability reports, SINTEF's report has the ambition to become an impact report, including indicators and cases. For this purpose, SINTEF is working on identifying good indicators and descriptions for their approach. It aims to go beyond	Same as for the imec Sustainability report (see above). In-depth cases have not been developed.	The types of examples included in this report mainly regard R&D projects, but also other initiatives such as labs and research centres promoted by the RTO. Similar to the imec sustainability report, the SINTEF report focuses on the main areas of expertise of SINTEF (and corresponding SDGs). Even though this is only marginally addressed, collaborations with external partners play a crucial role in contributing to the sustainable development. In fact, SINTEF's research and innovation

Study	Objectives	Scope	Methodology
	traditional sustainability reporting and to cover SINTEF's total contribution to society. SINTEF started developing "systematic assessments of sustainability impacts" in 2019/2020 to assess the impact that technology has on society in relation to the SDGs and their indicators. The idea is to develop a platform for assessing the societal impact of new technologies and structural changes based on the UN's indicators for sustainable development. This system could be used by clients who want to analyse the impact they are having on society, or internally in SINTEF to estimate the effects of their research. The ambition is to develop new methods and combine existing modelling tools and different data sources with data for sustainability analysis. This is especially important since SINTEF is involved in the development of technologies and products from an early stage where there is still room for making decisions and different approaches are assessed.		work is mainly carried out in collaboration with partners in the private and public sectors. According to SINTEF, this allows to make sure that the research is relevant and has impact. The report highlights that the SDG framework presents some limitations: ▶ The goals have been set for 2030 but many of the themes require measures and solutions with a significantly longer horizon. ▶ The applicability of the SDGs is not always a good fit in relation to the country's issues (for example, health and wellbeing).
Impact Studies – TECNALIA's Contribution (2013)	The objective is a systematic measuring of the environmental impact of its direct and indirect activities.	KPI on CO2 emission to assess CO2 emission reduction.	Carbon Footprint based on the principles of the standard UNE-ISO 14064-1: 2012 and Organisational Environmental Footprint including also more indirect activities.

2.2.3 Societal impact assessment – external perspective: "RTOs contribution to tackling societal challenges"

This cluster includes studies that analyse how the activities of RTOs contribute to a more sustainable society at large. We first identify two types of studies in this cluster based on the focus they take when assessing societal impact. Next, we review the methodologies applied in the studies.

2.2.3.1 Scope

Two types of studies can be identified in this cluster, based on the focus they take:

1. Studies **analysing how the work of RTOs** (their R&D work, publication/dissemination of their knowledge,…) **contributes to more sustainable societies;**
2. Studies specifically taking a **transition perspective** and **analysing how the RTO contributes to** redirecting our economy and society at large towards **long-term sustainability**.

RTOs' CONTRIBUTIONS TO BETTER SOCIETIES

A first set of studies **analyses how the work of RTOs (their R&D work, publication/dissemination of their knowledge,…) contributes to more sustainable societies:** biodiverse environments, improved health and wellbeing of people, more efficient governments, etc.

As directly measuring the impact of an RTO's research activities on society is difficult because the effects do not only occur at user level, but also at ecosystem level and the wider society, the studies adopt an **impact value chain logic**. They analyse the activities of the RTO (R&D projects, scientific publications, contributions to policy reports and discussions, etc) and link those to tackling problems in society.

In that context, two studies of the Norwegian Social Science Research Institutes talk about 'intermediate societal impact' versus 'societal impact':

- **Intermediate societal impact**: e.g. policy discussions, policies, policy instruments, publicly available reports and other information material, participation in media, knowledge spillovers;
- **Societal impact** as such includes:
  - **Economic impact:** impact related to e.g. increased turnover, profit, productivity, competitiveness, investment, employment and capabilities in the private and public sectors, as well as creation of spin-off companies;
  - **Environmental impact:** impact related to e.g. improved adaptation to or prevention of climate changes, improved environmental sustainability, improved energy efficiency, as well as improved environmental safety and protection;
  - **Health impact:** impact related to e.g. improved physiological and mental well-being, improved family relations, prevention of illnesses, and improved medical treatments;
  - **Social impact**: impact related to e.g. strengthened democracy or democratic institutions, improved trust between societal stakeholders or in society as a whole, higher tolerance towards foreigners, improved integration of immigrants, improved gender equality, more equal conditions for prosperity in all parts of the country, improved public welfare systems and better education;
  - **Impact on efficiency of public services**: impact related to e.g. information on available social services; efficiency improvements of health and welfare services, research and education systems, and tax collection; reduced corruption; and positive effects of better monetary policies;

- **Symbolic impact:** impact on e.g. maintaining or improving the country's reputation as conflict mediator and defender of humanitarian values, increasing regions' attractiveness to tourism or enterprise, and improvement of companies' brands and trademarks.

This perspective describes societal impact through **collaboration or interaction with several users**, such as ministries, government agencies, international policy organisations, non-governmental organisations, companies and societal actors.

This model mainly takes into account the R&D activities of RTOs and believes that these benefit users in two main ways: through delivering **knowledge outputs**, such as reports, datasets, software, etc., and through **enhancing the skills** of individuals of the user organisation. While in a first stage the benefits only concern a limited part of the user organisation, in a second stage the benefits (e.g. knowledge, reports, results) are spread within the entire organisation. At a certain point, the user organisation produces an output that may be referred to as an 'intermediate societal impact'. Examples are:

- A ministry or a government agency may present a new policy or policy instrument that in turn leads to societal impact when it affects actors in society (organisations or individuals);
- A company may for instance introduce a new product on the market that leads to societal impact when customers buy and use it;
- Other intermediate societal impact may be the dissemination of material intended to inform or educate societal actors, or knowledge spillovers from the user organisation, such as mobility of staff, publications in scientific or professional journals etc.

"Throughout this gradual development, the initial contribution of the institute is blended with input from a range of internal and external sources in a process that is also influenced by general societal and economic developments".[5] According to these studies, in most cases the institutes contribute to 'intermediate societal impact', rather than to 'ultimate' societal impact, meaning that the direct link between the R&D activity of the RTO and the impact on society is difficult to prove.

A third publication (Measuring the Social Impact of RD&I, TECNALIA) also looks at societal impact broadly. It adopts the so-called **'theory of the 6 social capitals'**:

1. **Economic capital**: corresponds to resources oriented to exchange goods and maintain the activity in times of low capacity to generate resources;
2. **Knowledge Capital**: used to predict and solve problems of any kind. It is indispensable for moments of change;
3. **Capital Welfare**: personal well-being that establishes the basis of happiness. This is a capital that is translated into quality of life;
4. **Cultural Capital**: collective beliefs, group emotions, the development of cultural elements, rites, symbols, rules of conduct, and recognitions that make up the identity and the sense of belonging in human groups; they are the cultural and artistic assets that bind us emotionally;
5. **Relational Capital**: corresponds to trust between people, in their positive sense and in the deception, domination and exploitation of one over others in the negative;
6. **Ecological Capital**: it is in harmony with the living environment, as a living environment with and in which we relate.

[5] User survey and impact assessment of the Norwegian social science institutes, p. 3, 2016.

This theory is based on a conceptual framework composed of the three following challenges that society faces:

1. Social Groups' Demand: groups at risk of exclusion - people with disabilities, seniors
2. Great Social Challenges: climatic change – aging - hyperconnected world…
3. Systematic change: organizational development and relations with stakeholders.

One publication (Roles, effectiveness, and impact of VTT, 2013) identifies a number of **roles played by the RTO** in strengthening Finnish industrial innovation and enhancing national socio-economic welfare. The roles identified in the study are:

- Building and utilisation of R&D&I networks;
- Developing companies' innovation and business activities (with means of technology);
- Commercialisation of research results;
- Strengthening and expanding knowledge base;
- Meeting energy, environmental, safety & security challenges;
- Supporting government decision-making;
- Creation of forefront research and technologies; and
- Promotion of employment, wellbeing and quality of life.

These roles cover both the economic dimension as discussed in section 2.1.3 (e.g. developing companies' innovation and business activities) and a wider societal dimension.

RTOs' CONTRIBUTION TO SYSTEMIC TRANSITIONS TOWARDS LONG-TERM SUSTAINABILITY

A second set of studies specifically take a transition perspective and **analyse how the RTO contributes to redirecting our economy and society at large towards long-term sustainability**.

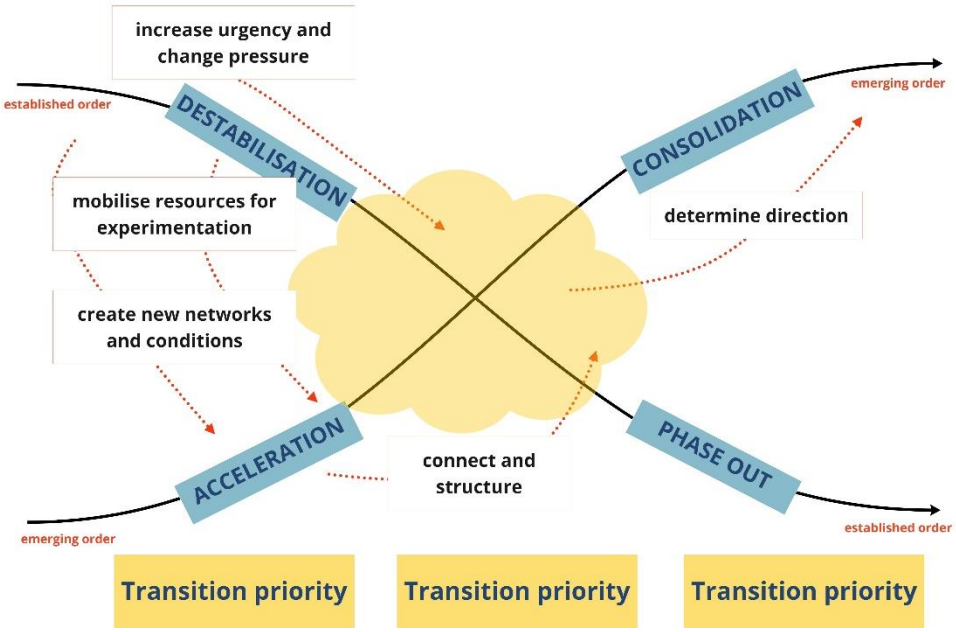
Similar to the first cluster of studies, also the transition impact studies focus on describing **'intermediate societal impact'** of the RTOs (i.e. how they contribute to increasing pressures for change, etc.) to finally come to necessary **systemic changes** in society in the long-term.

To analyse the contribution of RTOs to societal transitions, two studies (Impact assessment of imec and Impact assessment of VITO) make use of the so-called X-curve of transition **by the Dutch Research Institute for Transitions "DRIFT"** (see Figure 7 below - Loorbach et al., 2017[6]). This framework not only visualises the process of transition - with patterns of build-up and breakdown, but also provides a framework for thinking about the **different roles that are important to stimulate and accelerate this transition from the established to the emerging order**. This so-called transition steering can be shaped in 5 ways, i.e. by:

1. Increasing urgency and pressures for change in the system;
2. Mobilising resources for experimentation;
3. Creating new networks and conditions;
4. Connecting and restructuring;
5. Determining direction.

[6] Loorbach, Derk & Frantzeskaki, Niki & Avelino, Flor. (2017). Sustainability Transitions Research: Transforming Science and Practice for Societal Change. Annual Review of Environment and Resources. 42. 10.1146/annurev-environ-102014-021340.

Figure 7: X-curve of transition by DRIFT: roles in transition management



Source: Loorbach et al., 2017

To identify the most pressing societal challenges and status of long-term sustainability, a commonly used framework in the societal impact assessments is the set of 17 Sustainable Development Goals for 2030 from the United Nations, although some studies also use other long-term regional strategies for sustainable development (e.g. imec and VITO using the 'Vision 2050' strategy for sustainable development of the Flemish government).

Finally, the TO2 evaluation study – although with primary focus on impact of R&D on businesses and on the general innovation ecosystem – also refers to 'transition', although not so clearly embedded in an impact assessment framework as in the imec and VITO studies. It is stated that one of the main tasks of the TO2 institutes is the development, application and dissemination of knowledge for solving social issues. However, the evaluation looks beyond: in addition to the positive impact the TO2 is already having, the evaluation committee refers to a greater **contribution to societal transitions** that TO2 could make. Similarly to other studies on societal impact, the TO2 evaluation considers **collaboration** as crucial in that respect. The current societal challenges call for a problem-oriented approach that brings together resources and knowledge from different fields (e.g. social sciences institutes), technologies and disciplines. Therefore, cross-sectoral collaboration is also taken into account when evaluating the societal impact of an RTO.

2.2.3.2 Methodologies

Keeping in mind that the type and quality of information differ from one publication to another, the **screening and comparative analysis** made it possible to identify a number of methodological approaches and trends to assess the societal impact of RTOs from an external perspective.

Case-based approach (combined with other methodologies)

Case studies are the most frequently used method to get an in-depth understanding of a complex and multi-faceted issue such as societal impact. In Table 13 below, we compare how the case-based approach was applied in the publications analysed.

Most of the publications that adopt a case-based approach and that are under revision (see table below) combine other methodologies, namely **literature review and interviews**, for the development of the cases. These complementary methodologies can be considered as functional as they aim at gathering data and information to develop the in-depth case studies.

The comparative analysis between the methodological approaches adopted in the various studies shows that there are similar **challenges** related to a case-based approach:

- It is **hard to document** realised effects and impacts, or to **predict** future effects of research results that have a low level of technological maturity (low TRL).
- When selecting cases within a variety of research sub-themes, these may have a wide range of effects. Therefore, it is **hard to find a uniform approach and methodology** to expose effects and impact that can be applied to all the cases. The case study development and choice between quantitative and qualitative methods need to be adapted to the individual sub-themes and cases, thus making difficult a comparative analysis of the results.
- In most studies, the selected cases constitute an **already positive selection** (subjectivity choice of the organisations). This may constitute a bias.
- In the context of an assessment/evaluation performed by externals, the **effort put in ensuring high quality and comprehensiveness of the information** may be not in line with the expectations of the evaluators. Sometimes the cases are concise and describe impact well, while in others they are very poor in terms of narrative and/or whether it is even possible to understand what the impact is supposed to be. Others can lie somewhere in between these two extremes. This may be due to the fact that the institute(s) is not familiar with case study development on societal impact and/or does not have the necessary information to complete the task.

Table 13: Studies using a case-based approach to assess the societal impact of the RTO's services

Study	Objectives	Scope and selection criteria	Methodology: Case study development
2018: impact study of Norwegian energy research from 2008-2017 (2018)	▸ To document the effects of investments in R&D on environmentally friendly energy through initiatives related to specific programmes since 2008. ▸ To identify the achieved and/or potential effects, and in addition to describe some of the dispersed effects that cannot be quantifies. The study considers effects such as reduced costs, greenhouse gas emissions, reduced energy use and reduced emissions. In addition, many other effects are documented that are important for society, but where the research behind is not always so visible.	48 selected cases were selected from eight thematic areas related to environmentally friendly energy. The cases are not randomly selected: they are projects that have produced good results and are relatively simple to disseminate. The cases have been selected from a total portfolio of about 670 projects from specific programmes (RENERGI, ENERGIX, CLIMIT and FME). The cases were selected in close collaboration with the research community, based on the following criteria: • Maturity: mature projects have been prioritised since it is more likely to demonstrate effects and provide qualified assumptions about future effects (potential) for projects at a high TRL level, compared to projects with low TRL level. • Subject/thematic breadth: the cases give a representative picture and show the breadth within the current sub-theme area. In many cases, breadth has therefore been prioritised over selecting only the most mature projects. • Theme or individual projects: a majority of the cases are based on individual projects that have received funding from the Research Council in the period 2008-2017. However, in some cases, it has been natural to merge two or more single projects into one research theme. The majority of the projects and cases have a prior research history (before 2008).	There have been individual meetings and telephone conversations with key persons and professionals responsible for the individual projects to ensure that the case descriptions have been accurate. More than 50 people from the research communities have been directly involved in this work. The case studies were developed in two different ways: ▸ Approach 1 - quantitative: to quantify realised and potential impacts for the cases and their sub-themes. The quantification was based on data and information shared during interviews and several working meetings aiming at identifying and calculating effects and potential. ▸ Approach 2 - qualitative: to describe the story, demonstrating qualitative impacts and making visible, for example, investments in industrialisation and commercialisation. 12 (direct) effects are studied: Reduced energy consumption, reduced costs (possibly increased revenues), redistributed outputs, reduced material consumption, increased production/use of renewable energy, increased security, reduced risk and health benefits (HMS), increased security of supply, reduced environmental impact (broad definition, climate gas emissions not included), better decisions (broad definition), strengthening training and recruitment to the

Study	Objectives	Scope and selection criteria	Methodology: Case study development
		• Knowledge of the projects in-house: the projects within a single sub-theme are carried out by many research institutes, and with some organisations, such as SINTEF, at the centre of the research process. Due to time and resources issues, in-house knowledge has been crucial in the choice of case. • Made in more recent times: access to key persons (project officers) and their knowledge of results and impacts have been decisive for the choice of projects (cf. above point). • Communicability: some of the projects in the portfolio are so complex or abstract that it would be challenging in itself to communicate the essence and results of the projects. These projects have been given low priority. It is also challenging to demonstrate impacts from such projects since they are often still at a low TRL and commercial maturity.	field, development of a strong national research environment, moving the knowledge frontier through international cooperation. Three concepts have been distinguished throughout the study (but not applied to all the impact dimensions assessed: ► Research results: outcomes that can be described and articulated, typically knowledge, concepts, systems, products, etc. ► Effects: demonstrable impacts resulting from the application of research results and have provided benefits to others. ► Potential effects (future potential): assumed/expected future effects as a result of the research results being put into use that can either be anticipated or predicted. Quantitative calculations are mainly done for economy (realised profit, reduced investments and costs, increased revenues, turnover and exports, net present value of future net cash flow), energy use and emissions (reduced costs, greenhouse gas emissions, reduced energy use and reduced emissions). For the other impact areas, quantification has not been done systematically due to lack of data. This refers especially to so-called 'other social effects' that are assessed via a qualitative approach. These effects are assessed as a binary variable (demonstrated/not demonstrated) without further implications and secondary/tertiary effects being assessed in detail. As anticipated above, the distinction between research results, effects and potential effects has

Study	Objectives	Scope and selection criteria	Methodology: Case study development
			not been applied to the analysis of the so-called This means examples of demonstrated effects are: ▸ Knowledge transfer ▸ Increased research activity ▸ Commercialization and application of technology ▸ Research infrastructure, pilots and demo facilities ▸ Application and commercialisation of technology ▸ • Increased employment.
Evaluation of the Norwegian Social Science Research Institutes - User survey and impact assessment (2016-2017)	▸ To evaluate the institutes that make up the social science 'competition arena' within the Norwegian institute system. ▸ To inform research policy and research strategy goals and analyse the role of the institutes in the research system. The evaluation therefore has a holistic	Several dimensions were mapped. In the context of the analysis of societal impact assessment, the most relevant dimension to consider is the 'relevance of the institutes to public administration, business and society'. While most of the internal dimensions were assessed on the basis of self-evaluations (including statements about the societal impact of the institutes) and internal meetings, other methodologies (corresponding to the additional studies commissioned by the Research Council of Norway, the body that appointed the evaluation committee) were applied to assess the contribution of the research institutes to society (and other dimensions). This study includes an impact assessment, among others.	In terms of topics, the impact cases focused on: business, innovation and entrepreneurship, health and welfare system, democracy, education, immigration, environment, gender equality, etc. The cases were classified in terms of topics, beneficiary types and geographical reach of the impact. The classification into up to three topics and beneficiary types implied no ranking. This exercise is inspired by the 2014 British Research Excellence Framework.[7] Topics and beneficiaries were adapted due to the differences in national contexts or lack of cases.

[7] The 2014 Research Excellence Framework (REF) is a peer assessment of the quality of UK universities' research in all disciplines. The REF was undertaken by the four UK higher education funding bodies, who will use the REF results to distribute research funding to universities on the basis of quality, from 2015-16 onwards. 154 UK institutions made submissions in 36 subject-based units of assessment (UOAs). The submissions were assessed by panels of experts, who produced an overall quality profile for each submission. The overall quality profile awarded to each submission is derived from a sub-profile for each of three elements of the assessment, which are weighted as follows: the quality of research outputs (this counts for 65 per cent of the assessment.), the impact of research beyond academia (this counts for 20 per cent of the assessment. Impact is a new feature in the REF 2014), the research environment (this counts for 15 per cent of the overall results). More information here: https://www.ref.ac.uk/2014/results/intro/.

Study	Objectives	Scope and selection criteria	Methodology: Case study development
	and structural perspective.	The impact assessment is predominantly based on 71 impact cases. Only cases based on R&D that to a significant extent had been carried out by the institute during the last 10–15 years were allowed, although references to longer R&D traditions at the institute could be made. The evaluation panel only asked for societal impact, which was defined as any impact except impact on other R&D and impact on the institute's own organisation. Examples of what societal impact could be were also provided: e.g., changes in activities, perspectives, economy, competence, policy etc. among individuals, groups, organisations, in a certain public sphere, or in other parts of society. From the initial list of 71 cases, the research team selected 15 for in-depth analysis. These cases were selected because well presented, well underpinned by evidence and references, and because they provide a fair picture of the total population of cases.	
Impact assessment of imec (2020) and Impact assessment of VITO (2020)	The objective is to outline the broader social contribution that imec and VITO makes in Flanders as a result of its scientific-technological and catalytic activities and, in particular how imec and VITO contribute to various social transition priorities of the Flemish Government.	The analysis of imec's and VITO's transition impact was structured around Vision 2050, the long-term strategy for Flanders that was approved by the Flemish Government in March 2016 and reaffirmed by the new government in 2019. This political framework was combined with the X-curve of transition from DRIFT. It visualises the mutually reinforcing or counteracting patterns of build-up and breakdown that characterise transitions from established to emerging regimes. The reports highlight imec's and VITO's contributions in some specific transition domains where the RTO itself	The cases were developed by means of desk research and interviews with the case providers. Each case was developed in such a way as to emphasise the transition roles played by imec and VITO, namely: ▸ increase the urgency and pressure for change; ▸ mobilising resources for experimentation; ▸ developing new conditions and networks; ▸ connecting and structuring; ▸ setting the direction.

Study	Objectives	Scope and selection criteria	Methodology: Case study development
		experienced strong growth in the period 2019-2020 in the role it took on to help the transition in Flanders: mobility and lifelong learning for imec and energy, circular economy and smart living for VITO. In addition to an in-depth analysis including several examples, one in-depth case study per domain was developed. The cases were co-selected together with RTO representatives during interviews and exchanges. More specifically, they were selected based on their representativeness of multiple transition roles played by imec and VITO.	
Roles, effectiveness, and impact of VTT (2013)	The objective is to shed light on the roles played by VTT within the Finnish innovation ecosystem.	The study identifies a series of roles that VTT plays in the wider innovation ecosystem. VTT's roles and impact are considered in the context of major global socioeconomic and technological challenges, and special attention has been paid to VTT's internationalisation and to VTT's role in enhancing the innovation performance of small- and medium-sized firms. The selected cases aim to shed light on VTT's various roles and added value, as well as on VTT's wider socio-economic and ecological impact.	The cases are examples that illustrate VTT's participation in processes leading to innovations, as well as highlight the various roles that VTT has pursued. These case examples clearly show that VTT has multiple roles, even in individual innovation development processes. Authors remark that this highlights the importance of assessing the contribution and impact of VTT's activities by qualitative means, rather than concentrating on quantitative indicators alone. According to them, much of the societal, economic, and ecological impact is not quantifiable. The cases have been identified primarily from the Sfinno database and the authors' existing material.

Quantitative approach

Next to the case-based approach, several studies apply a quantitative approach to assess societal impact of RTOs.

The publication on Mapping VTT's publications and activity regarding SDGs aims to measure **VTT's contribution to solving the world's most pressing societal challenges** presented by the 2030 Agenda. The study uses Scopus as one of the leading databases in the market, and SciVal, an analytical solution which has achieved data harmonisations and normalisation on a large scale through being built on a foundation of high-quality Scopus data.[8] They utilized the pre-defined SDG Research Areas in SciVal to identify who is doing what in regard to SDGs and explored VTT's relative national activity related to SDG goals and targets.

The study looks at scientific publications, which are considered as among the main outcomes of VTT's activities. This served as a natural proxy for the contributions of VTT to the SDGs.

1. The output activity rate is illustrated per SDG category where the rates are normalized to show the general activity trend over time.
2. The number of publications being relevant to SDGs is calculated.

Looking across the entire citation network of Scopus from 1996 onwards, SciVal breaks the network into roughly 96,000 Topics and 1,500 Topic Clusters (VTT contributes to almost 600 Topic Clusters).[9] On a macro level, Topic Clusters indicate the breadth and depth of scientific activities across disciplines. Topic Clusters can, however, also offer insights into micro level analysis when combined with comparisons on institutional, national and global perspectives. The detail and granularity of research Topics is inspiring in many ways with one of them being the ability to aggregate articles in new ways to different subject areas (the SDGs being one example subject area) in order to get valuable insights.

A quantitative **SDG impact analysis** is also conducted in the TO2 evaluation. The titles and abstracts of the H projects2020 of the TO2 were analysed using the SDG classification model developed by Dialogic.[10] For comparison, the entire H2020 projects database (CORDIS database) was also included in the analysis. The SDG classification model is based on a public algorithm of Google, namely Google's BERT. The model is developed with public data sources and open-source technology. The model can be used to make a prediction about the content of the text based on textual data. The main advantage of the BERT algorithm is that, unlike other text classification models, it is able to look at relationships between words. In this case the BERT algorithm was used to make a prediction of a project's contribution to the various SDGs on the basis of textual data. For each project, the algorithm gives a score concerning the likelihood of this project contributing to a specific SDG. For each project, it gives a score between 0 and 1 for each SDG. Projects with an 80% or higher chance of contributing to a specific SDG x are classified as 'Contributes to SDG x'.

[8] https://www.scival.com/.

[9] A Topic in SciVal is a collection of Scopus publications with a common, focused intellectual interest. You consider the entire citation network – over 1 billion citation links between 48+ million Scopus-indexed documents from 1996 forward and an additional 20+ million non-indexed documents that are cited at least twice. A Topic is then created where the linkages within the citation network are strong and the linkages outside these Topics are weak. Only the indexed documents are included in Topics and there are roughly 96,000 Topics and 1,500 Topic Clusters.

[10] https://www.dialogic.nl/en/services/ai/.

2.2.4 Main takeaways

The **main takeaways** of this comparative analysis of the methodologies used to assess societal impact, are:

- The **framework and perspectives used** to assess or narrate societal impact differ among RTOs. Only a few RTOs adopt a precise framework for societal impact and (aim to) map it systematically. Moreover, two of the aforementioned publications also aim to **define a direction for future impact assessment studies** within the RTO. We refer in particular to the publications on Measuring the Social Impact of RD&I by TECNALIA aiming at building a toolbox for societal impact assessment that the RTO itself can use in the future, and on Roles, effectiveness, and impact of VTT providing recommendations on future approaches towards impact assessment (cf. Box 1).[11]

Box 1: Two studies looking at impact in a systematic way

Measuring the Social Impact of RD&I (2013)

In particular, via its toolbox, TECNALIA aims to improve and measure the Social Impact of the R&D&I activities of technology centres, and TECNALIA in particular, through the development of a systematic methodology (including indicators). As anticipated in paragraph 2.2.3, TECNALIA developed its toolbox based on the theory of 6 capitals: analysis and synthesis of quantitative and qualitative indicators (corresponding to up to 300 questions) in relation to the 6 capitals was conducted, by consulting around 15 sources. Then a workshop was organised to collaboratively identify the most relevant indicators. Based on the results of this workshop, TECNALIA concluded that continuous development of the methodology is needed, that is very relevant to incorporate the societal impact mindset into internal processes and that social impact should be introduced in public funding requirements.

Roles, effectiveness, and impact of VTT (2013)

The study provides an overview of key methodologies to assess impact. Based on this overview, it is suggested to use a multifaceted approach as a benchmark for future studies. The authors recommend launching a new series of VTT impact studies to analyse the different aspects of VTT's impact on the Finnish economy and society. These studies would benefit from better data and use of the latest evaluation methods. Ideally, impact studies should use complementary methods (providing quantitative and qualitative evidence) to test the robustness of their results. Moreover, the studies provide a list of methodologies per objectives to reach.

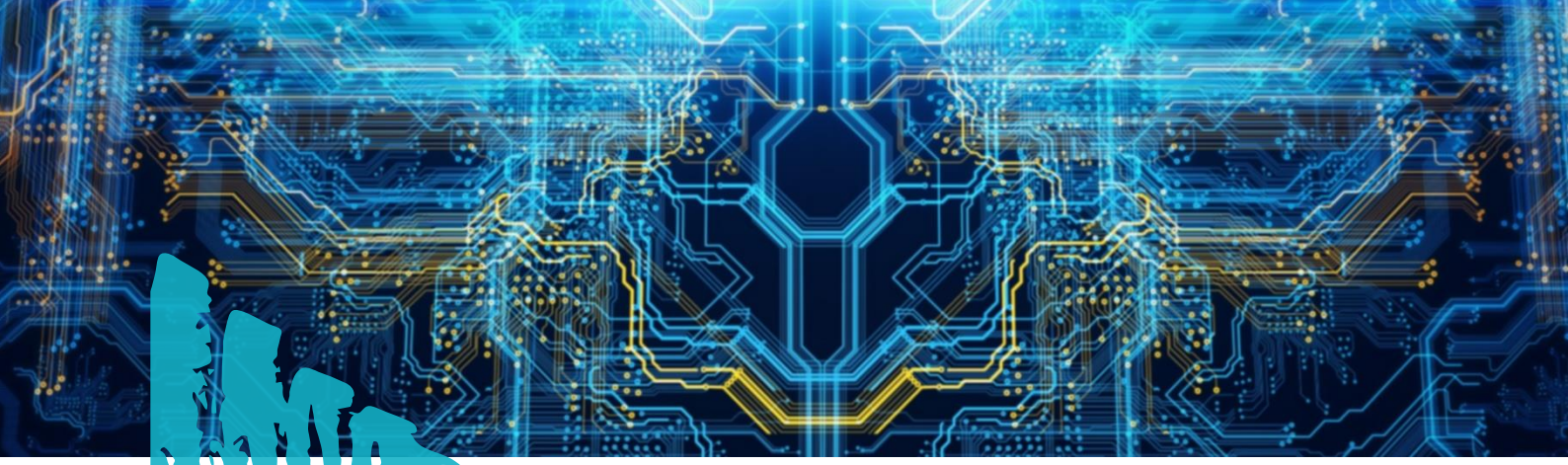
- As shown in the table below, most studies **combine different methodologies to assess the societal impact**. The methodological approach is in most studies of a qualitative nature, to capture the complex and multifaceted nature of societal impact. We observe that the qualitative approach, and in particular the **case-based approach,** is the most used to assess or simply narrate the impact of RTOs on society. Quantitative approaches, let alone indicators, are rarer and are rather used in very specific assessment exercises (e.g., relating publication to SDGs). Looking to the future, the adoption of quantitative approaches is still an open path for RTOs and, in general, for all those organisations that want to assess the societal impact of their activities. Literature tends to confirm that mixed methods are most effective, as both quantitative and qualitative data present issues when used in isolation.

[11] We emphasize that both publications are rather old (2013) and that any following developments are not captured by the publications in question.

Table 14: List of reviewed studies and triangulation of methods

Study	Cases	Interviews	Literature review/data analysis	Quantitative approach	Development of an impact toolbox
Imec Sustainability report	x		x		
SINTEF sustainability report	x		x		
Impact Studies – TECNALIA's Contribution			x		
Impact assessment of imec	x	x	x		
Impact assessment of VITO	x	x	x		
Roles, effectiveness, and impact of VTT	x		x		x
Mapping VTT's publications and activity regarding SDGs				x	
Measuring the Social Impact of RD&I, TECNALIA				x	x
TO2 evaluation			x	x	
Evaluation of the Norwegian Social Science Research Institutes - User survey and impact assessment	x				
2018: impact study of Norwegian energy research from 2008-2017	x		x	x	

- We observe a growing use of the **Sustainable Development Goals as an analytical framework**. This is particularly evident in the publications that aim to document how the activities of RTOs contribute to each of the SDGs, while the approach that looks at the SDGs as a framework to analyse the long-term (transition) impact on society is still less developed.
- Finally, we note that through the societal impact dimension a **complementary set of roles and activities of RTOs are highlighted beyond their core R&D activities** and interactions with companies, such as their advisory role towards policy makers and other stakeholders in society, roadmap development, orchestrator role in complex transition processes, etc.



3 / A reasoned comparison of results

3.1. Results of economic impact assessment

3.1.1 Overview

In the table below we provide an overview of the main results reached by the studies (fully or partly) focused on economic impact assessment.

Table 15: Main results on economic impact assessment per study and methodological approach adopted

Study	Methodological approach	Results
Understanding the macroeconomic effects of public research: An Application of a Regression-microfounded CGE-model to the case of the Fraunhofer-Gesellschaft in Germany	Quantitative approach - CGE analysis	The activities of the FhG increase Germany's GDP with 1.6% and employment by 437.000 jobs. The impact pathways run mainly through chemicals, pharmaceuticals, motor vehicles and machinery.
The macroeconomic effects of the Fraunhofer-Gesellschaft (2021)	Quantitative approach – reduced form equations, micro data	The results corroborate the substantial macroeconomic effects on GDP, in which a one euro increase in budget implies a 21 euro increase in GDP in the baseline model. Moreover, they show that the effects increase substantially over time, with the GDP multiplier in 2015-2017 around 23% larger than in the period up to 2014. The result is robust with respect to the possible effects of selection biases, endogeneity biases, stationarity/ cointegration.
A General Equilibrium Quantification of the Impact of Fraunhofer on the German Economy (2021)	Quantitative approach – CGE model	1. FhG. significantly contributes to output, productivity, the world technology frontier and technology adoption level in Germany. 2. FhG. increases the long-run level of output, wages and productivity by 3.65%. 3. The long-run level of technology increases by 13.49%.
The macroeconomic impact of Fraunhofer Gesellschaft - A CGE approach, using micro-evidence (2020)	Quantitative approach – CGE model	FhG activities have significant macroeconomic effects on the German economy. As expected, these effects are much larger when the entire budget is considered (Scenario 2) in comparison to a budget increase (Scenario 1). 1. Scenario 1 is associated with a 0.21% contribution to employment and government revenue, as well as a 0.45% contribution to investment. 2. Scenario 2 is associated with a 1.0% contribution to employment, a 1.1% to government revenue, and a 2.4% to investment.

Study	Methodological approach	Results
		Under both scenarios, the impact on investment and government revenue exceed total Fraunhofer funding. The impact of Fraunhofer is concentrated in industries that can be notionally defined as "knowledge intensive" and that are of critical importance to the German economy. In particular, we find that the economic impact of Fraunhofer is concentrated in the chemical pharmaceutical and the automotive-machinery sectors.
Do companies benefit from public research organisations? The impact of Fraunhofer (2019)	Quantitative approach using firm-level micro data	The authors find a strong, positive effect of project interaction on turnover and productivity growth of the participating companies. They also provide evidence that a major driver of the positive performance effects is the firms increased share of sales from new products and an increase in the share of workers with tertiary education. More detailed analyses reveal, amongst others that the performance effects become stronger the more often firms interact with FhG and that interactions aiming at generation of technology have a stronger effect than interactions aiming merely at the implementation of existing technologies.
The contribution of the Fraunhofer Society to the German innovation system	Interviews and micro data	The finding from the micro analysis is that cooperation with Fraunhofer is of particular importance for innovative companies, companies with complex product portfolios and especially for small and medium-sized companies - both in financial and scientific technological terms. This underscores the overall economic significance from the companies' perspective.
The importance of the Fraunhofer Society for German medium-sized companies (2016)	Survey-based approach (including interviews and literature review)	Firms that cooperate with FhG are innovative and dynamic, pointing as such to the important amplifier role of FhG in the German economy. Quite a wide enterprise network is serviced with heterogenous demands. Services range from product and technology development, IP support, R&D services. There was less interest in market related services. The reputation of FhG with the SMEs is extremely positive which goes together with a high willingness to collaborate.
A microeconomic assessment of RTO's impact on Firms output: The case of TNO (2019)	Quantitative approach (including literature review)	Results show that TNO services bring about an impact in the form of additional growth of value added of the client firms one year after the intervention. The average size of the impact lies in the range of 14.5-18.7 percent of the extra value added growth in the next year. The impact seems quite large and authors believe this might be caused by the fact that firms could be inclined to involve TNO in more advanced research projects with a higher probability to success. TNO services therefore yield a higher impact than average firm R&D activities.
TO2 evaluation (2021)	Quantitative approach (including literature review/data analysis)	All TO2 have intensive cooperation with Dutch and foreign companies. 20% of the turnover of all TO2 together is financed directly by private clients. Various customer satisfaction measurements and several institution evaluations indicate that these private clients are (very) satisfied with their cooperation with and the performance of the TO2. The

Study	Methodological approach	Results
		added value of companies that cooperate with a TO2 grows significantly more than that of comparable companies that did not. In the years during the cooperation, the added value of the companies was between 4 and 8% higher. In the year after the cooperation, the positive effect increased to between 9 and 14%. These results confirm findings of previous (international) studies on the impact of cooperation with public research institutions. The accessibility of TO2 for SMEs remains a major bottleneck. There are three thresholds. SMEs are not very familiar with the TO2, there are major cultural differences between the hands-on mentality of many SME entrepreneurs and the research approach of TO2, and TO2's rates are often considered high.
The economic footprint of the Dutch Research and Technology Organisation TNO	Quantitative approach using input-output models	1€ government subsidy to TNO leads to 1.88€ output creation elsewhere in the Dutch economy. Per million € subsidy, 13.34 jobs are created. For each € subsidy 0.28€ additional tax revenue is generated.
Economic impact of applied research organisations on the Dutch business community (2021)	Quantitative approach	The general finding of this effect measurement is that cooperation with the TO2s (in a PPP trajectory) has positive effects on the added value of the companies involved. In the years during the cooperation, the effects vary between 3 and 9 percent, depending on the model specification. In the year after the cooperation, the effect rises to between 9 and 14 percent.
Impact assessment of imec (2020)	Data analysis, survey-based methods, quantitative approach using input-output models	The study finds that per euro that the Flemish government invests in imec, the imec cluster creates 7 euro of added value in the Belgian economy and 3.7 euro financial return on the subsidy through taxes (upstream and downstream). Every 1 million invested also creates 90 jobs, of which 23 at imec and 67 elsewhere in the economy.[12] With respect to the impact of imec's support to companies and governments to bridge the so-called 'valley of death' and to valorise the results of R&I as much as possible, the study finds that thanks to the increasingly extended portfolio of support services imec assists technological startups/ventures in the economic and social valorisation of their R&D activities at three levels: 1/ by accelerating the technological development and commercialisation of new

[12] https://trends.knack.be/economie/bedrijven/economische-impact-van-imec-groeit/article-normal-1794683.html

Study	Methodological approach	Results
		innovations; 2/ by supporting innovative public procurement and 3/ by strengthening the entrepreneurial capacity of technology ventures. The survival rate of imec.istart alumni is significantly higher than the average survival rate of startups in a comparative study of university-related accelerator programmes worldwide. Imec.istart alumni also manage to attract substantial external follow-up investments after investments from imec's investment fund.
Impact assessment of VITO (2020)	Data analysis, quantitative approach using input-output models	The results of this study are not made public.
EARTO Economic Footprint	Data analysis, quantitative approach using input-output models	The study finds that a total of 284,000 jobs (HC) are created in the European economy that can be linked to the activities of the 9 RTOs included in this footprint, corresponding to a total turnover of 35.8 billion euro and a total value added of 16.8 billion euro. The total fiscal return adds up to 6.7 billion euro (core activities, contract research, spin-off activities), of which 2.6 billion euro stems from the RTOs' core activities. Moreover, in terms of multipliers: ▶ For each job in the RTOs, another 4 jobs are created elsewhere in the European economy (on top of the 1 direct job in the RTO) either at the suppliers of the RTOs and further upstream, or in the broader economy thanks to the economic activity of the employees of both the RTOs and their suppliers, and thanks to the effects of knowledge transfer through contract research and spin-offs. ▶ The operational grants received by RTOs, are earned back by national governments through fiscal return mechanisms. For each euro invested in the form of operational grants, almost 3 euro flow back to the national governments.
Impact Studies – TECNALIA's Contribution	Data analysis	TECNALIA's annual report 2020[13] reports the following multipliers: ▶ For every euro invested by a company in R&D with TECNALIA, revenue of €10.3 is produced in its income statement;

[13] https://informeanual.tecnalia.com/wp-content/uploads/2021/08/TECNALIA_2020_ANNUAL_REPORT.pdf

Study	Methodological approach	Results
		▸ For every job position at TECNALIA, 5 other jobs are kept in the Basque country; ▸ For every euro invested by Basque Public Institutions in TECNALIA, a GDP of €16.2 is generated. ▸ For every euro invested by Basque Public Institutions in TECNALIA, a tax return of €1.9 is generated.
2018: impact study of Norwegian energy research from 2008-2017	Case-based approach (combined with interview and data analysis)	The 48 cases show that research pays off: the cumulative, realised economic impact for the period 2008-2017 is €16 billion. The identified potential economic impact is 25 times higher when Europe is included. Moreover, Norwegian and European industry has reduced energy consumption by 26 TWh/year and greenhouse gas emissions by 25 mill. tonnes CO2e/year, partly through energy efficiency improvements in the industry and partly by Norwegian solar cells replacing fossil energy use. The potential for the future is significant in all 48 cases - much is not realised yet.
Evaluation of Norwegian Technical Industrial Research Institutes	Data analysis	The TI institutes contribute to value creation in Norway and current customers generally express satisfaction with the services they receive from the TI institutes. This is reflected in the fraction of total revenues stemming from industrial customers. However, in the industrial transition period that Norway is facing and increasing international competition, TI institutes need to prepare for the future by strengthening their innovation capabilities and speeding up their adaptation to changing markets. To support these changes, incentives and metrics for innovation must be strengthened and properly directed. There is a need for nurturing and further developing the partnerships between the TI institutes and the universities, and to encourage complementarity and strong competence centres.
Evaluation of the Norwegian Social Science Research Institutes - User survey and impact assessment (2016-2017)	Survey-based approach (including interviews)	The user survey reveals that the users of the social science institutes for the most part are highly satisfied. Overall, the institutes receive high scores in the web survey and the interviews paint a similar picture.
Roles, effectiveness, and impact of VTT (2013)	Case-based approach (including literature review/ data analysis)	The main conclusion is that the roles of RTOs are changing in Europe and beyond. The study identifies the following trends, among others: - Innovations are an important complementary indicator in impact assessment: the industrial, socio-economic, and ecological impact of research investments emerge via the innovation outputs of both existing and new companies

Study	Methodological approach	Results
		and via changes in their subsequent performance and size. The knowledge generated can subsequently spill over via existing or new networks. - VTT's diverse roles are highlighted in an analysis of individual innovations: seven empirical case studies exemplify the significance of focused long-term research in developing competencies that are critical to VTT's industrial customers' solutions. The socio-economic and ecological impact emerges after the commercialisation phase. Environmental or health benefits, for example, are the sum of various factors driven by marked demand or regulations, and it is often difficult to attribute final impact to one specific innovation.

3.1.2 Main takeaways

RTOs do have a **positive return on government investment for the economy**. This is evidenced by both quantitative evidence and qualitative findings. Contributions go along various impact pathways: GDP and value-added creation, employment creation and sustainment, patent generation, investments, additional private investments (input additionality).

Given the wide set of approaches and methodologies, each with their own merits and hypotheses, it is not surprising that the **results** obtained **vary** as well **and are of a different nature**. Focussing on the quantitative results one can distinguish mainly three different classes of methodologies each with their own range of results:

1. **Computable General Equilibrium models** assessing the impact of the RTO to the economy, in this review mainly the effect of Fraunhofer on the German economy. These studies find that **1€ subsidy to the FhG generates in the long-term between 18€ and 21€ to the GDP**. This corroborates with the results of TECNALIA that uses third-party input, retaining a result of **16.2€ GDP per 1€ subsidy.**
2. **Econometric estimates of reduced form equations based on micro-economic (panel) data** assess the effect on the firms' sales controlling in one way or another for selection bias through counterfactual analyses or exploiting the heteroskedasticity in the error terms with instrumental variables. These type of studies are done by Fraunhofer, TNO and for the Dutch RTOs on behalf the Dutch Ministry of Economic Affairs and Climate. These studies aim to assess the effect on sales or on company value added of 1€ of company investment in an RTO. **The effects are very positive yet the ranges differ markedly.** The Dutch studies find that **during cooperation the company value added increases with 3€ to 9€ for every euro services bought from the RTO**. These studies find that **after the years of cooperation these effects increase and range from 9€ to 14€ additional value added creation per euro services purchased**. This is in the same range as the Fraunhofer study which finds an **increase of 18€ in company sales**.
3. The **IO-based approaches to calculate economic multipliers** differ in terms of what is taken into account in the calculations (upstream effects, downstream effects, economic value of specific activities, etc.) and are thus not fully comparable. Nevertheless, the employment multiplier for the specific studies that count both upstream and downstream effects range **around 4 jobs created in the broader economy** (on top of the direct employment). For the fiscal return multiplier, the broad range – depending on the specific scopes and approaches of the studies - lies between 1.3 **and 3.7 euros flowing back to the government for each euro invested in the RTO(s)**. These figures can be considered lower barriers, as only a selection of activities or effects are included in the calculations (driven by data availability) and thus the scope is not exhaustive for all potential effects.

More generally, it is worthwhile to mention that the studies in this review contributed in '**opening the black box**' which existed in the academic literature on the effects of government R&D spending on the macroeconomy. The evidence from the studies surveyed give an insight in the impact pathways and in the ways a euro funding for an RTO 'ripples through' the client companies and further to the rest of the economy.

Since all RTOs provide a wider set of services beyond the R&D, the effects generate **additional leverage to the valorisation of technology development**. It can be perceived that over time studies started to put more attention to the diversity of services provided and the additional services on top of the pure technology and innovation services. In this context, we also mention the results of a recent Danish review study[14] which compiled the findings from academic literature on firm effects of interactions with RTOs - selected on relevance for the Danish context and focusing on the match-making role of RTOs between SMEs and potential knowledge providers. Although there is heterogeneity in the size of the effects found, most of the identified studies in this review give indications

[14] Van Criekingen et al. (2021). RTO firm effects. A review of academic literature on firm effects of interactions with Research and Technology Organizations. Danish Centre for Studies in Reserach and Research Policy, Department of Political Science, Aarhus University.

of **positive effects of RTO-collaboration for small non-R&D firms**: *"Firms, which collaborate with an RTO, become more economic performant, more innovation active and have increased networking capabilities."*

In sum, the studies surveyed are definitely **filling a gap in the literature** that analyses the effects of government subsidies and support on a nation's wealth creation. RTOs are part of the institutional structure through which government R&D funding is channelled and made effective in a wide set of sectors. Economic theory tends to put this part of the equation in a black box putting technology as part of the macroeconomic production function (together with capital and labour). Yet **the studies surveyed do bring the impact pathways forward and provide evidence of the positive impacts.**

3.2. Results of societal impact assessment

3.2.1 Overview

In the table below we provide an overview of the main results reached by the studies (fully or partly) focused on societal impact assessment.

Table 16: Main results on societal impact assessment per study and methodological approach adopted

Study	Methodological approach	Results
Imec Sustainability report (2020)	Case-based approach and literature review	Being this a sustainability report and not an impact assessment nor an evaluation, the main results concern the contribution of imec to the SDGs via its internal activities, but also via R&D and its link with society, users and beneficiaries. The examples in the report show that across imec's research domains, imec's research portfolio is focused on a strong, positive impact by enabling building blocks of a better world in a more sustainable society (e.g., reducing power consumption of datacentres, developing photovoltaic technologies, new software for adaptive and personalized learning, etc.). In addition to interesting examples on how the organisations made their internal processes and policies more sustainable (HR, procurement, etc.), the report also offers some conclusions on the sustainable partnerships that imec started. Imec has developed a unique partnership model: its R&D programs unite all key players, from leading suppliers, companies, application partners, to leading academia and knowledge centres.
SINTEF sustainability report (2021)	Case-based approach and literature review	As above, the main results concern the contribution of SINTEF to the SDGs via its internal activities, but also via R&D and its link with society, users and beneficiaries. SINTEF acknowledges that the mapping indicates how much clients, authorities and SINTEF invest in each SDG through R&I projects. This is considered rather superficial information by SINTEF itself. For this reason, SINTEF concludes that it will focus on identifying good indicators and descriptions for their approach. Not least, they are looking at the need to use the data to strengthen their actual contributions to sustainable development. Measuring the impact of research is difficult because the effects do not only occur at clients, but also far out in value chains and at end-users. Some examples of concrete individual projects in SINTEF whose effects have been evaluated/estimated/quantified in relation to sustainable development, are described in detail in this report. Nevertheless, methods that allow to be clearer about the aggregated effects of our activities still need to be developed. In this context, climate effects and value creation are two key areas. Further quantification of reporting is a clear SINTEF's ambition for subsequent sustainability reports.

Study	Methodological approach	Results
Impact Studies – TECNALIA's Contribution	Indicator	TECNALIA's Annual Report 2020[15] mentions: "The data for the last two financial years, 6501 total GHG (t CO2 e) and 3315 (tCO2) respectively, show that the reduction in impact has been due to the reduction in energy consumption and travel due to the pandemic. The energy efficiency of buildings and sustainable mobility are therefore maintained as lines of action in the 2024 strategic period."
Impact assessment of imec (2020)	Case-based approach and interviews (combined with data analysis)	In each of the two transition domains, imec was assigned a central role by the Flemish government in the rollout of an important innovative government investment, namely Mobilidata and iLearn. Both cases show how imec, from its unique expertise and position in a broader network of stakeholders (policy makers, industry, public service providers, civil society), can act as a neutral discussion partner and succeed in making new connections in the relevant ecosystem and establishing new collaborations that are necessary to make the transition.
Impact assessment of VITO (2020)	Case-based approach and interviews (combined with data analysis)	With its primary focus on cleantech and sustainable development, VITO works at the heart of various (international) research missions that seek to provide answers to important societal challenges and to achieve sustainability goals. This is clearly illustrated by the analysis of VITO's contribution to various transition priorities and missions defined in Vision 2050, the future vision of the Flemish Government. This analysis clearly shows how VITO actively contributes in different domains to bringing together and stimulating cooperation between different actors in the quadruple helix (government, knowledge institutions, companies and citizens), to informing and sensitising the Flemish government and broader society about the status of transition and the most important (policy) priorities to realise progress, to competency development and behavioural change in companies and citizens. The scientific excellence of VITO in its research areas forms the necessary basis for this and gives VITO the necessary 'authority' to take on these transition roles in Flanders (and internationally). At the same time, this contribution of VITO to the realisation of the transition priorities also feeds the own research agenda of VITO, giving the social relevance of VITO's work a continuous touch.
Roles, effectiveness, and impact of VTT (2013)	Case-based approach (including literature review)	Please refer to the previous table.

[15] https://informeanual.tecnalia.com/wp-content/uploads/2021/08/TECNALIA_2020_ANNUAL_REPORT.pdf

Study	Methodological approach	Results
Mapping VTT's publications and activity regarding SDGs (2020)	Quantitative approach	This scientific article shows that the overall number of VTT's publications between 2009–2018 is about 9,200 records of which 1,700 can be categorized as being relevant to SDGs. Without adjustments on organizational size, VTT's position on some of the SDGs is among the top seven positions nationwide (e.g. SDG 7 3rd, SDG9 4th, SDG 11 7th, SDG 12 4th). Looking at the trends in VTT's publication activity related to SDGs, authors observe a cyclical behaviour with a sharp increase in activities in the most recent years, particularly around SDG 8 and SDG 15/ Moreover, thanks to the use of SciVal, while most of the SDG indicators are on a country (macro) level, this study advances the practice of identifying individual organizations and their contributions to SDGs (micro level).
Measuring the Social Impact of RD&I, TECNALIA	Quantitative approach (combined with qualitative)	In this publication, TECNALIA aims to develop a systematic methodology (toolbox) to measure the Social Impact of the R&D&I activities of technology centres, and TECNALIA in particular. TECNALIA developed its toolbox based on the theory of 6 capitals: analysis and synthesis of quantitative and qualitative indicators (corresponding to up to 300 questions) in relation to the 6 capitals was conducted. Based on the results of this workshop, TECNALIA concluded that continuous development of the methodology is needed, that is very relevant to incorporate the societal impact mindset into internal processes and that social impact should be introduced in public funding requirements.
TO2 evaluation (2021)	Literature review and quantitative analysis	For most TO2, the societal themes have clearly become the guiding principle in developing strategies. It is concluded that the TO2 make an important contribution to social missions, to underpinning government policy, and to specific policy objectives of various ministries. The role of the TO2 in mission-driven innovations can be seen, for example, in its participation in the Horizon2020 programme. This analysis shows that the TO2 are active in all seven societal challenges. Within the grand societal challenges, TO2 is particularly successful in the themes 'food safety, sustainable agriculture, marine and maritime research and bio-economy'. Another indication of the TO2's role in social issues is the connection of TO2's research to the SDGs. During the evaluations of the individual TO2, many good examples of societal and economic impact were highlighted, but there is a challenge for the TO2 to make even better use of their impact and profile, to increase their intertwining in the Dutch knowledge system and to play a greater role in the public debate on the major societal challenges and the importance of applied research. The Dutch government also has a role to play in the

Study	Methodological approach	Results
		international position of the TO2, not only in terms of financing but also in terms of more explicitly positioning the TO2 institutions as knowledge partners on social issues. It is also concluded that TO2 should do more to demonstrate the impact of its own research and be more active on that basis in the social debate on social missions.
Evaluation of the Norwegian Social Science Research Institutes - User survey and impact assessment (2016-2017)	Case-based approach	The impact cases elaborated build on the descriptions of the information from the self-assessments that authors complemented through additional document studies and interviews. Taking a closer look at the impact cases, authors observe quite significant differences: the cases from the internationally oriented institutes mainly belong to the topics of international development, foreign policy, defence and security, and other parts of the world (Africa, Russia and Asia). These topics are nearly completely absent for the other two institute groups (there are only two cases on international development and one on Asia from the institutes in welfare and society). The impact cases of the regionally anchored institutes show a completely different pattern: their focus is very strongly on stimulating business and regional growth, as well as to on nature and the environment. All institute groups have cases with policy makers and businesses as beneficiaries.
2018: impact study of Norwegian energy research from 2008-2017 (2018)	Case-based approach (combined with interview and quantitative analysis)	The authors studied the results, effects and potential (future) effects of 48 projects (cases) selected from a portfolio of approximately 670 projects. The conclusions therefore only apply to these 48 selected cases. Ten of the 48 cases have large realised and potential impacts linked to economy, emissions and energy use. Eight of the ten cases are qualified technology or are in commercial phase (respectively TRL 8 and 9). As for the non-quantified effects (on societal and environmental dimensions), in two thirds of the 48 cases, research results, knowledge and tools have led to better and more professionally qualified decisions in industry and organisations. The use of the ZEB definition in the planning of zero-emission buildings, and the Environmental Handbook in the planning of hydropower development are two good examples. Energy research has strengthened training and recruitment. Around 1600 Master candidates and 450 PhD/post.doc have been selected. Together with the research results (including those not yet in use or commercialised), this constitutes crucial knowledge and resources for maintaining, transforming and developing Norwegian green competitive industry.

Study	Methodological approach	Results
		The research activities have in sum produced major employment effects, both internally in the research environments and at the FMEs, and not least externally in industry and commerce. Since it is difficult to map direct and indirect employment effects, we have chosen not to do so in this study. In general, authors conclude that the potential for the future is significant in all 48 cases – although much is not realised yet.

3.2.2 Main takeaways

As for the societal impact dimension, the screening of studies and their results led to the following main takeaways:

- **Each study adopts its own methods**, as well as own analytical and conceptual frameworks. This does not allow for a thorough comparative analysis of results, nor for overarching conclusions on the themes where RTOs have most impact.
- When it comes to societal impact, the **intermediary role played by RTOs** beyond pure R&D is highlighted in most studies as a result of the assessment/evaluation. It is evident that RTOs play the role of orchestrators in the ecosystem. In particular, they build bridges and connect industry, policy makers and other knowledge institutes and most studies consider this as impactful for society.
- Adding the societal impact dimension to impact assessment studies or evaluations, gives a **more complete vision** on what RTOs do (beyond R&D – see above) and allows to make more **explicit** this role.
- The **SDG framework** seems to be an emerging framework that is increasingly used to reflect on the societal impact generated by research carried on by RTOs. However, as previously stated, it is not yet possible to draw general conclusions on the themes that are more or less present in the RTOs' work and services, or their complete impact: in fact, the evidence is still anecdotal at this time, with a selection of examples and cases on the contribution to the SDGs covering only a part of the total picture or impact.

4 / Conclusions: main findings and lessons learned

Research and Technology Organisations (RTOs) are **bridging organisations**, covering all scientific fields, that connect basic research with practical applications in new products or services: they **produce, integrate and transfer research and technology to the market** and by this they aim to support both industrial competitiveness and the broader society in a multitude of ways. For this, they collaborate with enterprises of all sizes, across disciplines and geographical boundaries, as well as with intermediary or public actors, including policy makers.

The role of RTOs to bring technological development and innovation to industry, and the **economic impact** achieved through this, are still considered a primary objective. Yet also the **societal role of RTOs has become increasingly important** in recent years. Recent work by the OECD and EARTO[16] emphasises that "the need to respond to the social imperative is the most important change in RTOs' missions in the last ten years". In the context of tackling societal challenges and, more recently, transition and mission-oriented thinking, RTOs throughout Europe have taken on and made more explicit their role in the societal dimension. Currently, also the role of RTOs in **informing, advising and cooperating with policy makers** is emphasised more strongly than before. The mentioned study by OECD and EARTO has identified that the way RTOs are perceived, has changed - with a growing contribution in the policy landscape as one of the main changes. This goes hand in hand with the increasing importance of the societal dimension in the missions and activities of RTOs and further integrates cooperation among all stakeholders in the multiple helix.

This review study is the first in its kind. While several studies and reviews have discussed the effects of R&D&I funding initiatives or evaluations in the field, **there is much less evidence on the impact of RTOs on economic and societal dimensions**.

A recent Danish review study[17] did compile the findings from academic literature on firm effects of interactions with RTOs. However, the study does not include societal impact, and only screens publicly available studies that are selected based on, amongst others, comparability with or relevance for the Danish context. The focus is on the match-making role of RTOs between SMEs that want to innovate and potential knowledge providers. However very valuable to provide insights on this matter, a need remained to bring together evidence collected or developed by RTOs across Europe (not all publicly available). Moreover, in light of the clear evolution towards

[16] Laruelle P. (2022). Joint Project OECD-EARTO on the Funding of Research & Technology Organisations (RTOs): New challenges and opportunities for supporting socio-economic recovery, resilience and transitions. Forthcoming. https://www.earto.eu/wp-content/uploads/OECD-EARTO-Workshop-on-the-Role-of-RTOs-in-supporting-the-Sustainable-Transitions-Presentation-19-November-2021.pdf

[17] Van Criekingen et al. (2021). RTO firm effects. A review of academic literature on firm effects of interactions with Research and Technology Organizations. Danish Centre for Studies in Reserach and Research Policy, Department of Political Science, Aarhus University.

transition and mission-oriented thinking and the evolving role of RTOs in the R&D&I ecosystem, also other dimensions related to societal impact (including environmental impact) need to be brought to attention.

The present review study therefore has identified and reviewed impact studies of and by RTOs, including economic and societal impact assessments, and thus brings together the existing evidence in one structured overview. By this, it aims to address the evidence gap and provide insights and lessons learned for future pathways of impact assessment.

With respect to the **availability and accessibility** of the evidence, the following findings prevail:

- The number of studies focussing on the assessment of impacts, is still somewhat limited. Other studies still take a strong evaluative approach. However, several RTOs have been committed to measuring their impact since many years and have continued to develop improved or new approaches, following the evolutions described above. Several have plans to develop a more systematic impact assessment framework or approach in the near future.
- Impact studies of or by RTOs are not always publicly available, or in available English. This limits the accessibility of the available evidence and underlines the need for this review study.

With respect to the **methodologies** applied, we find the following:

- The methodological approaches vary depending on the objectives and scope of the impact assessments. All methods have their own value and they strengthen each other in jointly establishing a more complete picture of the impact of RTOs.
- Both in economic and societal impact assessments, qualitative research and descriptive analysis have their place in the spectrum of impact assessments providing narratives, illustrations and case material. Yet while qualitative methods are predominant in societal impact assessment, more quantitative methods prevail in economic impact assessment. This corresponds to the nature of the expected effects.
- Quantitative methods have the advantage of 'making a long story short' and provide the results in a fairly easy to communicate monetary value or relatively simple number. Quantitative methods pertain to evidence-based policy making and they have a fact-based nature. Nevertheless, the underlying methodologies to assess the numbers are far more complex than the qualitative methods and hence more costly to develop. Additionally proper interpretation of the numbers is needed and a good view on the assumptions used is paramount.

With respect to the **scope** of the impact assessments in this review, the following observations are made:

- The analytical framework applied in this review study (cf. section 1.2) allowed to distinguish not only between impact dimensions, but also between perspectives taken: internal or external. Not surprisingly, the external perspective is covered more often in impact assessments than the internal perspective. The external perspective focuses on the effects the RTOs have on the firms or stakeholders that interact with them in terms of economic or societal impacts. The internal perspective focuses on the effects of the operational activities of the RTO. It are precisely the external-oriented activities that are characteristic and very different from other organisations: RTOs (co-)produce knowledge that may be embedded in technologies and which serve as an input and asset in other organisations and companies business creation schemes, as well as in societal challenges.
- The exception concerns studies with environmental impact focus: here sustainability reports or environmental footprint calculations focus on the internal perspective of the operations of the RTO, rather than on the value of the R&D&I developed at the RTO for improving environmental elements directly or via the collaboration with stakeholders and firms. In this review, one case-based study on the impact of Norwegian energy research (2018) takes this latter focus.

- Along with the evolving role of RTOs, also the impact assessment needs, scopes and methodologies have evolved. Societal impact assessment received more attention in recent years, including the internal contributions to sustainability and the external contributions to transitions beyond the pure R&D&I activities. Yet more is to be done in this area, and the connection with transition impact and policy impact (contribution to policy) is to be further explored.

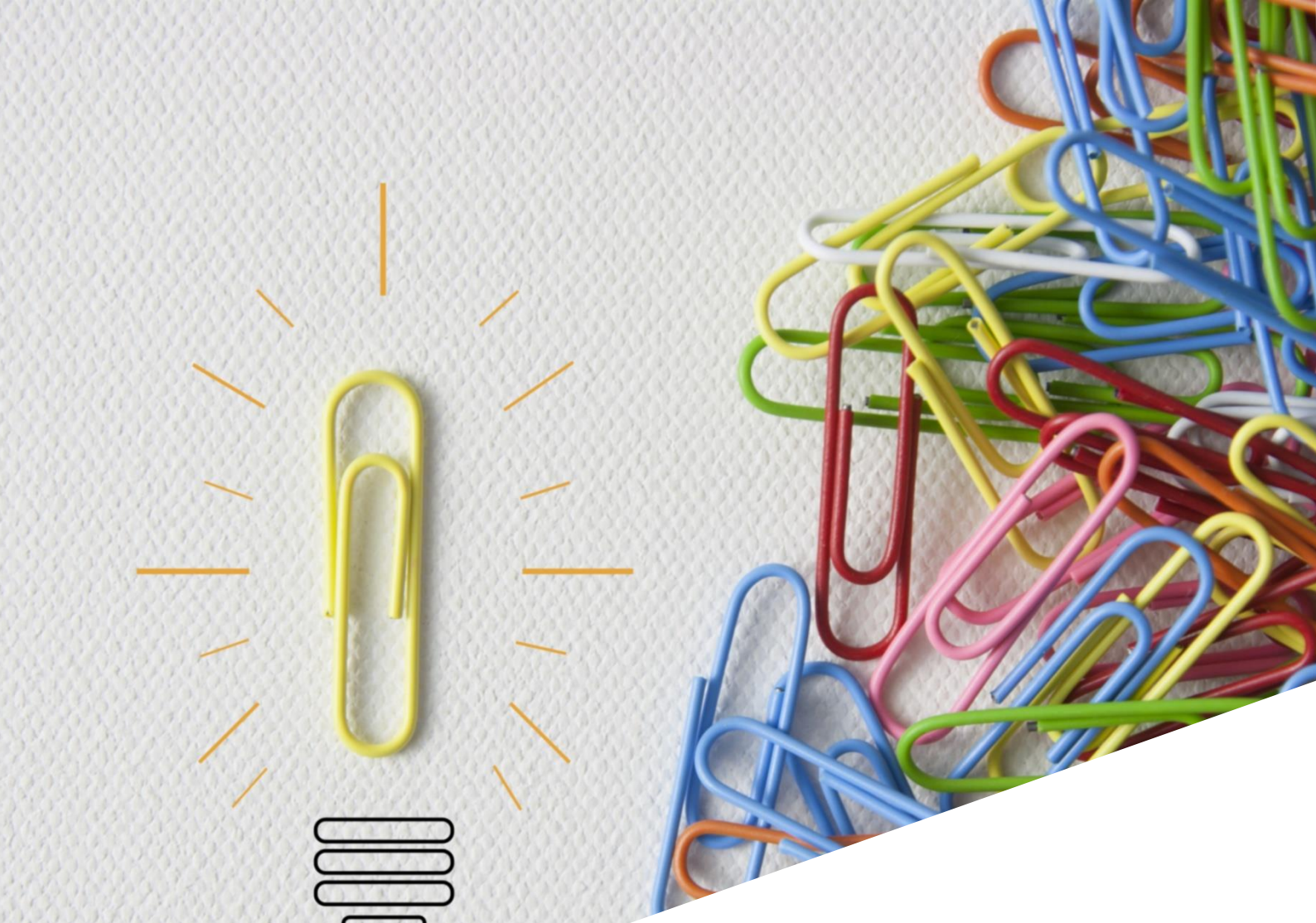
Finally, with respect to the **results**:

- All studies point at a **range of positive effects** both in the economic and societal dimension.
- RTOs do have a **positive return on government investment for the economy**. Contributions go along various impact pathways: GDP and value-added creation, employment creation and sustainment, patent generation, investments, additional private investments (input additionality). Although the methods applied have different scopes and underlying hypotheses, general ranges of results can be identified.
- Since all RTOs provide a wider set of services beyond the R&D, the effects generate **additional leverage to the valorisation of technology development**.
- When it comes to societal impact, the **intermediary role played by RTOs** beyond pure R&D is highlighted in most studies as a result of the assessment/evaluation. It is evident that RTOs play the role of orchestrators in the ecosystem. In particular, they build bridges and connect industry, policy makers and other knowledge institutes and most studies consider this as impactful for society.

More generally, the studies contributed to '**opening the black box**' which existed in the academic literature **on the effects of government R&D spending on the macroeconomy**. The evidence from the studies surveyed give an insight in the impact pathways and in the ways a euro funding for an RTO 'ripples through' the client companies and further to the rest of the economy. Furthermore, **adding the societal impact dimension** to impact assessment studies or evaluations, gives a **more complete insight on what RTOs do** (beyond R&D – see above) and allows to make this role more explicit.

Yet work remains to be done to improve the strength, credibility and generalisability of the evidence base:

- There is no common framework for economic or societal impact assessment, which makes comparability difficult. Although bottom-up initiatives are very valuable and it should not be the goal to develop one standard methodology, a common framework can help to create a common understanding of concepts, structure thinking on impact and stimulate innovative bottom-up approaches to develop new ways of measuring.
- It is important to generate evidence on a broader range of RTOs across Europe. For this, RTOs (individually or as a sector) need to be stimulated to organise for impact assessment, including addressing data-related challenges (collecting consistent and comparable data over time as required for a methodology chosen – or vice versa explore which methodology is feasible given the available or collectable data; building databases) and developing the skills needed to implement a methodology (e.g. quantitative skills but also interview or survey skills).
- From the perspective of the methodological development, it is important to continue developing methods for quantitative evidence building and mixes of methods that can provide the narrative to explain these quantitative results.
- From the perspective of the scope and coverage of impact assessments, it is important to generate more systematic evidence on the different roles of the RTO, including its societal contributions, the external environmental perspective, and the role towards policy makers, etc.



ANNEXES

A.1 / List of references

Title	Country	Authors	Year	Availability	Link
Impact assessment imec	Belgium	IDEA Consult	2020	Confidential	/ Results: https://trends.knack.be/economie/bedrijven/economische-impact-van-imec-groeit/article-normal-1794683.html
imec Sustainability report	Belgium	imec	2020	Public	https://www.imec-int.com/sites/default/files/2021-06/imec_Sustainability_Report_2020_0.pdf
Impact assessment VITO 2016- 2019	Belgium	IDEA Consult	2020	Confidential	/
Economic Footprint of 9 European RTOs in 2015-2016	Europe	IDEA Consult	2018	Public	https://www.earto.eu/earto-publishes-new-economic-footprint-study-the-impact-of-9-rtos-in-2015-2016/
Roles, effectiveness, and impact of VTT	Finland	Various authors	2013	Public	https://publications.vtt.fi/pdf/technology/2013/T113.pdf
Mapping VTT's publications and activity regarding SDGs	Finland	A. Hajikhani	2020	Public	https://www.elsevier.com/__data/assets/pdf_file/0016/1114126/SciVal-VTT-publications-and-activity-SDG-CS-FINAL-WEB.pdf
The importance of the Fraunhofer Society for German medium-sized companies	Germany	F. Dornbusch and others	2016	Public	https://www.fraunhofer.de/content/dam/zv/de/leistungsangebot/wirkung-von-forschung/Studie-Bedeutung-der-Fraunhofer-Gesellschaft-fuer-deutschen-Mittelstand.pdf

Title	Country	Authors	Year	Availability	Link
The contribution of the Fraunhofer Society to the German innovation system	Germany	Various authors	2016	Public	https://www.fraunhofer.de/content/dam/zv/de/leistungsangebot/wirkung-von-forschung/Studie-Beitrag-Fraunhofer-Gesellschaft-zum-deutschen-Innovationssystem.pdf
Do companies benefit from public research organizations? The impact of Fraunhofer	Germany	Various authors	2018	Public	http://wp.circle.lu.se/upload/CIRCLE/workingpapers/201807_comin_et_al.pdf
The macroeconomic impact of Fraunhofer Gesellschaft - A CGE approach, using micro-evidence	Germany	Fraunhofer, University of Strathclyde	2020	Public	https://www.fraunhofer.de/content/dam/zv/de/forschung/leistungsangebot/The-macroeconomic-impact-of-Fraunhofer-Gesellschaft.pdf
A General Equilibrium Quantification of the Impact of Fraunhofer on the German Economy	Germany	D. Comin	2021	Public	https://www.fraunhofer.de/content/dam/zv/de/forschung/leistungsangebot/GEFhG-study.pdf
The macroeconomic effects of the Fraunhofer-Gesellschaft	Germany	T. Schubert	2021	Public	https://www.fraunhofer.de/content/dam/zv/de/forschung/leistungsangebot/The-macroeconomic-effects-of-the-Fraunhofer-Gesellschaft.pdf
Understanding the macroeconomic effects of public research: An Application of a Regression-microfounded CGE-model to the case of the Fraunhofer-Gesellschaft in Germany	Germany	Grant et al.	2022	Public	https://www.isi.fraunhofer.de/content/dam/isi/dokumente/cci/innovation-systems-policy-analysis/2022/discussionpaper_72_2022.pdf

Title	Country	Authors	Year	Availability	Link
The Economic footprint of the Dutch Research and Technology Organization TNO	Netherlands	E. Poliakov, J. Hu	2016	Public	https://www.researchgate.net/publication/305709748_The_economic_footprint_of_the_Dutch_Research_and_Technology_Organization_TNO
A microeconomic assessment of RTO's impact on Firms output: The case of TNO	Netherlands	E. Poliakov and others	2019	Public	https://repository.tno.nl/islandora/object/uuid%3Aad536ac7-ff22-4b8e-bf62-4c776b2eb9dd
TO2 evaluation	Netherlands	Technopolis, Dialogic, Seo Economisch Onderzoek	2021	Public	https://open.overheid.nl/repository/ronl-fcfb8752-43ae-4085-bd00-b724385a0aa1/1/pdf/evaluatie-to2-definitief.pdf
Economic impact of applied research organisations on the Dutch business community	Netherlands	G. de Jong, E. Brouwer	2021	Public	https://www.seo.nl/publicaties/economische-impact-van-de-toegepast-onderzoek-organisaties-op-het-nederlandse-bedrijfsleven/
Evaluation of Norwegian Technical Industrial Research Institutes	Norway	The Research Council of Norway	2016	Public	https://www.forskningsradet.no/contentassets/4c9af6fa297d4cbabad73222f8dbd2ac/evaluering tekniskindustrielleinstitutter.pdf
Evaluation of the Norwegian Social Science Research Institutes + User survey and impact assessment of the Norwegian social science institutes	Norway	The Research Council of Norway	2017	Public	https://www.forskningsradet.no/contentassets/4c9af6fa297d4cbabad73222f8dbd2ac/evaluering samfunnsvitenskapeligeinstutter.pdf
		Technopolis	2016	Public	https://www.forskningsradet.no/om-forskningsradet/publikasjoner/2017/user-survey-and-impact-assessment-of-the-norwegian-social-science-institutes/
2018: impact study of Norwegian energy research from 2008-2017	Norway	Impello	2018	Public	https://impello.no/en/referanse/forskningsradet/

Title	Country	Authors	Year	Availability	Link
SINTEF sustainability report	Norway	SINTEF	2021	Public	https://www.sintef.no/globalassets/sintef-konsernstab/barekraftsrapport/sustainability-report/sintef-sustainability-report-2020_en.pdf
Measuring the Social Impact of RD&I	Spain	TECNALIA	2013	Public	/
Impact Studies – TECNALIA's Contribution	Spain	TECNALIA	2020	Results public via annual report 2020	Results: https://informeanual.tecnalia.com/wp-content/uploads/2021/08/TECNALIA_2020_ANNUAL_REPORT.pdf
RTO firm effects. A review of academic literature on firm effects of interactions with Research and Technology Organizations	Scoping	Various authors	2021	Public	https://pure.au.dk/portal/files/224337296/RTO_review_report_Final_24_09_2021.pdf
Joint Project OECD-EARTO on the Funding of Research & Technology Organisations (RTOs): New challenges and opportunities for supporting socio-economic recovery, resilience and transitions.	Scoping	P. Laruelle	2022 (forthcoming)	Public	https://www.earto.eu/wp-content/uploads/OECD-EARTO-Workshop-on-the-Role-of-RTOs-in-supporting-the-Sustainable-Transitions-Presentation-19-November-2021.pdf