RTO firm effects

- A review of academic literature on firm effects of interactions with Research and Technology Organizations

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Abstract

The present literature review brings together the latest research-based evidence and knowledge in the international research literature in the field on how RTOs' technological service advice and infrastructure affect firms' financial performance, how they contribute to firms' innovation processes and innovation capacity, and their significance to firms' subsequent collaboration with knowledge institutions and others. The focus is primarily on GTS-like RTOs[1] to increase the applicability of the review in a Danish context, including giving the Danish Agency for Higher Education and Science (UFS) a knowledge base on RTOs' significance for Danish firms. An overview table in the appendix summarizes the identified literature, giving references, short summaries and categorizations about, e.g. empirical methods and data, its coverage and placement in our evidence hierarchy.

In Section 1, the review introduces arguments for RTOs' importance and placement in the National Innovation System. Section 2 introduces the three research questions, which is followed by a thorough methodology description in Section 3. Section 4 gives a detailed account of the literature's distribution across a number of categorizations. Finally, Section 5 analyzes the literature's contribution to empirical evidence on RTOs' effect on firms' economic and innovative performance and networking capacity, i.e. the three research questions. Section 5 also includes a subsection on the literature on what characterizes RTOs that most efficiently contribute to collaborating firms' performance. Section 5 does not include all literature accounted for in Section 4 and listed in the references. However, a comprehensive overview of coverage and characteristics of all identified literature is placed in Table A.1 in Appendix A.

[1] GTS stands for Approved Technological Service Institutes, and covers the seven Danish RTOs that operates in prioritized technological fields on contracts with UFS.

The task of the Danish RTOs is to contribute to a more efficient use of knowledge and technology in the Danish Innovation System (DIS) and thereby contribute to reducing market imperfections and increasing innovation, productivity and growth in society. The Danish RTOs handle three functions: building research and development competencies; development and maintenance of technological infrastructure; and dissemination of new technological knowledge to the business community.

Contents

Summary in Danish

Det en stor udfordring for mange små og mellemstore virksomheder selv at frembringe eller besidde den viden, der er nødvendig for at gøre dem innovative og konkurrencedygtige. Man kan derfor argumentere for, at det er en central (national) opgave at understøtte disse virksomheders uforløste potentiale for vækst ved at gøre forskningsbaseret viden og teknologi – som ellers ofte er forbeholdt større virksomheder – tilgængelig og anvendelig for dem. Generelt er behovet for 'Research and Technology Organizations' (RTO'er) til at understøtte gruppen af vidensvage (små og mellemstore) virksomheder bredt anerkendt. Det kan fx ske ved at etablere videnoverførsler og samarbejder mellem RTO'er og virksomheder og derved øge omfang og kvalitet af virksomhedernes innovationsaktiviteter, økonomiske resultater og konkurrenceevne. Effekterne af et RTO-samarbejde for de virksomheder, der således efterspørger ny nødvendig viden, er generelt positive i litteraturen, om end litteraturen er mindre entydig om effektstørrelserne.

Så vidt vi er bekendt, er et review som dette af den empirisk baserede litteratur om effekterne af et RTO-samarbejde ikke tidligere blevet udført. Nærværende litteraturgennemgang samler den nyeste forskningsbaserede evidens og viden i den internationale forskningslitteratur om, hvordan RTO'ers teknologiske rådgivning og infrastruktur (RTO-samarbejde) påvirker virksomheders 1) *økonomiske resultater*, hvordan de bidrager til virksomheders 2) *innovationsprocesser* og *innovationskapacitet* og deres betydning for virksomheders 3) *efterfølgende samarbejde* med videninstitutioner og andre virksomheder. Reviewets fokus er primært på litteratur om virksomhedseffekter af GTS[2]-lignende RTO'er eller deres ydelser for at øge anvendeligheden i en dansk sammenhæng, herunder at give Uddannelses- og Forskningsstyrelsen (UFS) en viden om danske RTO'ers potentiale for danske virksomheder.

Formålet med indeværende litteraturgennemgang er således at give UFS et videngrundlag om RTO'ers betydning for virksomheder med henblik på at understøtte den fremadrettede udvikling af GTS'erne og deres virksonhedsrettede aktiviteter. Reviewet baserer sig på en systematisk litteratursøgning i relevante faglige databaser som Scopus og Web of Science men er også suppleret med søgninger hos interessenter på området. I reviewet inddrages studier,

[2] GTS'er er Teknologiske Serviceinstitutter, der er godkendt af Uddannelses- og Forskningsministeren, og udøver deres virke via resultatkontrakter med ministeriet. Der er syv i Danmark.
Internationalt er GTS-lignende organisationer kendt som RTO'er, hvis formål er at bidrage til en mere effektiv anvendelse af viden og teknologi i de nationale innovationssystemer, og dermed medvirke til at øge innovation, produktivitet og vækst i samfundet. De danske RTO'er varetager tre funktioner: 1) opbygning af forsknings- og udviklingskompetencer, 2) udvikling og vedligehold af teknologisk infrastruktur og 3) spredning af ny teknologisk viden til erhvervslivet.

som adresserer RTO'ers betydning for virksomheder i forhold til de tre effekttyper beskrevet ovenstående. Effekterne kan observeres enten *direkte*, hvor man måler effekterne fra et virksomhedsperspektiv, eller *indirekte*, hvor man identificerer karakteristika blandt RTO'er, der mest effektivt bidrager til at forbedre de samarbejdende virksomheders præstationer. Studierne er benævnt 'firm perspective' og 'RTO perspective' i reviewet.

I nedenstående afsnit opsummerer vi kort reviewets fundne resultater. Konkret vil vi kort opsummere, hvad der fremgår af kapitel 4, hvis hensigt er at give et overblik over den identificerede litteratur. Derudover vil vi gennemgå resultaterne af reviewets kapitel 5, der analyserer RTO'ers betydning for virksomhederne i forhold til de tre effekttyper. Det skal bemærkes, at tidsrammen for litteraturen er begrænset til en periode på ti år fra 2010 til 2020, hvor kun enkelte ældre artikler og rapporter er inkluderet, hvis de var særligt relevante i en dansk kontekst.

Oversigt over den identificerede litteratur

Vi har i alt identificeret 69 studier, der hovedsageligt undersøger én eller flere af de tre effekttyper. Som beskrevet i reviewets kapitel 4, er der en overvægt af studier, der fokuserer på effekten af et RTO-samarbejde på virksomhedens innovationsprocesser og innovationskapacitet. Det er dog væsentligt at bemærke, at selvom det har en analytisk fordel at skelne mellem de tre effekttyper, er de tæt forbundne. Eksempelvis må det antages, at virksomheders øgede økonomiske resultater som oftest er drevet af innovationsaktiviteter, dvs. at øgede økonomiske resultater (fx øget salg eller konkurrenceevne) kan betragtes som en konsekvens af innovationer og/eller samarbejder i nye netværk (fx nye og forbedrede varer, processer eller samarbejder).

Reviewet anvender både kvalitative og kvantitative studier til at opnå en dybere forståelse af RTO'ernes betydning for virksomhederne i forhold til de tre effektyper. Der er derfor forskel på i hvilket omfang, den identificerede litteratur benytter eksplicitte og entydige effektindikatorer. Studierne, der målte effekterne fra et virksomhedsperspektiv, benyttede i højere grad klare definerede effektindikatorer. Studierne, der derimod målte effekterne fra et RTO-perspektiv, var i højere grad case- og interviewbaserede og benyttede færre eller ingen eksplicitte indikatorer. De identificerede og benyttede indikatorer i litteraturen kan findes uddybet i tabel 4.12 i kapitel 4 og tabel A3 i Appendix. I Appendix A findes også en oversigtstabel, der opsummerer den identificerede litteratur med referencer, korte resuméer og kategoriseringer om blandt andet studiernes empiriske metoder, data og placering i et evidenshierarki.

Effekterne af et RTO-samarbejde

Selvom der er forskel på effektstørrelsen i den identificerede litteratur, peger størstedelen af studierne på en positiv effekt af et RTO-samarbejde for små og mellemstore virksomheder, der ikke selv har eller er i stand til at frembringe den nødvendige viden for deres innovationsaktiviteter. Det vil sige, at der generelt findes en positiv effekt af et RTO-samarbejde for virksomhederne, således de opnår bedre økonomiske resultater, bliver mere innovative og at deres efterfølgende samarbejde med videninstitutioner og andre virksomheder øges. Nedenfor vil de tre effekttyper blive gennemgået.

Økonomiske effekter af et RTO-samarbejde

Økonomiske effekter opstår igennem vellykket innovation i enten produkter eller processer, der positivt bidrager med et omkostningsbesparende potentiale eller ved at øge salget for virksomheden. Empirisk har flere af studierne målt de økonomiske effekter ved blandt andet at undersøge virksomhedernes omsætning eller deres ændring i markedsandele.

15 fundne studier beskriver sammenhængen mellem et RTO-samarbejde og virksomheders økonomiske resultater. Overordnet indikerer litteraturen, at et RTO-samarbejde har en positiv økonomisk indflydelse for virksomhederne, herunder for virksomhedens produktivitet, omsætning og beskæftigelsesfremgang.

Innovationseffekter af et RTO-samarbejde

Innovationseffekter er en mere direkte måde at undersøge, om virksomhedernes interaktion med RTO'er er vellykket. Der er flere måder at undersøge, om virksomhedens innovationsprocesser og innovationskapacitet er øget over tid. Eksempelvis har flere studier målt innovationseffekterne ved undersøge, om virksomheden bliver hurtigere til at innovere nye produkter, services eller processer.

49 fundne studier beskriver sammenhængen mellem et RTO-samarbejde og virksomheders innovationsprocesser og innovationskapacitet. Den identificerede litteratur finder generelt en positiv sammenhæng mellem faktorerne. Dog understreger en række af studierne, at de positive effekter af et RTO-samarbejde for virksomhedernes innovation er betinget af andre faktorer som fx virksomhedens forudgående videnbase og absorptionskapacitet.

Netværkseffekter af et RTO-samarbejde

Netværkseffekterne er et fremadskuende effektmål, idet målet vurderer virksomhedernes kapacitet til at danne vellykkede samarbejdsrelationer efter den initiale interaktion med en RTO.

Empirisk har forskningen målt virksomhedernes netværkseffekter ved blandt andet at undersøge, om et RTO-samarbejde efterfølgende medfører øget interaktion og samarbejde med RTO'er, videninstitutioner eller andre virksomheder.

14 fundne studier beskriver sammenhængen mellem et RTO-samarbejde og virksomheders efterfølgende samarbejde med videninstitutioner og andre virksomheder. Overordnet finder den identificerede litteratur en positiv sammenhæng mellem faktorerne, således at et RTO-samarbejde har en positiv indflydelse for virksomhederne, herunder i forhold til at fremme virksomhedens netværk og partnerskaber.

Opsummerende er det reviewets vurdering, at effekterne ved at indgå i et RTO-samarbejde er positive. En større del af de nuværende undersøgelser af RTO'ers betydning for de samarbejdende virksomheder er baseret på cases og kvalitative undersøgelsesmetoder (placeret lavere i evidenshierarkiet), hvor det er sværere at isolere og vurdere den eksplicitte effekts årsag, dvs. kausaliteten i den fundne empiri. Alligevel giver reviewets litteratur – også den case baserede del - mange indikationer på, hvordan RTO'er positivt påvirker de virksomheder, der ikke selv er i stand til at besidde eller frembringe deres nødvendige og efterspurgte viden. Fordi så stor en del af den identificerede litteratur ligger i den lave ende af evidenshierarkiet, så bør reviewets anbefalinger og konklusioner, især med hensyn til effektstørrelser, anvendes med omhu og respekt for eventuelle kontekstuelle påvirkninger. Vi mangler i litteraturen flere studier af effekter af et RTO-samarbejde, som gennemføres i stærkere metodiske designs, fx studier over tid med mange virksomheder, hvor der kan kontrolleres for kontekstuelle faktorer via kontrolgrupper, og hvor det bliver muligt at isolere RTO-samarbejdets reelle effekter, se også afsnit 5.5. Den store andel case studier giver på den ene side en stor indsigt i mange problemstillinger og tilfører reviewet meget kontekstspecifik evidens, men det kvantitative eksperimentelle design vil på den anden side være nødvendigt for at virksomhedernes effekter entydigt kan identificeres som konsekvens af et RTO-samarbejde og ikke forårsaget af andre (ukendte) kontekstuelle faktorer.

1. Introduction

Today small and medium sized enterprises (SMEs) operate in a world where few big corporations dominate the competitive market landscape (see e.g. Autor et al., 2020). Many small firms thus face the challenge of keeping up with the technological advances in their field of business. In order to be able to face these challenges, smaller firms need to find ways to keep up and stay competitive without having access to the large asset base that the incumbent firms have.

In contrast to, large, technology heavy firms can usually build on their own internal research and development (R&D) practices and competences to advance their innovations and remain competitive. Given this internal technology advantage, these firms can also more easily connect to external sources of knowledge and collaborate on innovation activities with partners in existing networks (Escribano et al., 2009). Conversely, low technology or non-R&D SMEs often do not possess sufficient absorptive capacity, i.e. competences, to source knowledge externally or find collaborative partners for innovation activities. Consequently, many small firms are limited to innovate at both ends of their innovation spectrum, i.e. they can neither innovate from purely internal efforts nor form strictly external sourcing. Therefore, they have a hard time committing to internal innovation efforts because of the lack of size, resources and especially competences. Furthermore, they face a tougher challenge in sourcing externally and setting up successful collaborations due to the lack of absorptive capacity or existing collaborative networks. One way to tackle this problem is to bypass the process of building up the required absorptive capacity for innovative activities at the stages of their life cycle when these firms are not conducting internal R&D, e.g. by offering them network, collaboration and knowledge from local, national or international research and technology organizations, RTOs.

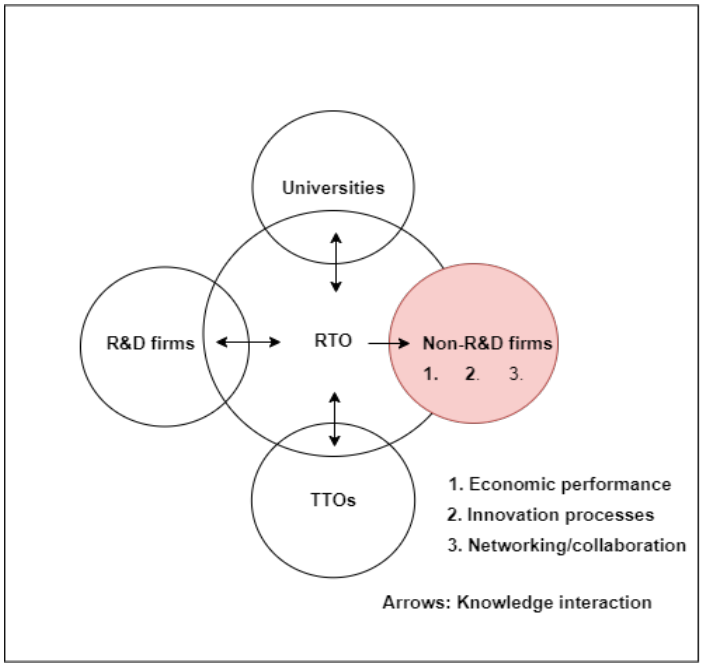
The notion of absorptive capacity as introduced by Cohen and Levinthal (1990) and reviewed in Zahra and George (2002) is frequently referenced in work relating to 'open and collaborative' modes of innovation (see Spithoven et al., 2010, for an example from traditional industries) and is often implied as a condition for successful collaboration on innovative activities. Governments around the globe have widely acknowledged the need for so-called 'bridging organizations' (RTOs) to support smaller non-R&D firms in setting up successful innovation collaborations and thereby to support their current economic performance and competitiveness and thus become the challengers of today's incumbent firms.

While the evidence is scarce, Arnold et al. (2010) conclude from a few studies that "whatever approach is used the impacts appear to be significant in size", but also that "studies tend to attribute all the economic benefits to the RTO intervention, whereas clearly many other economic factors are in play and the efforts of the RTOs are necessary but not sufficient to obtain the economic effects" (p. 37). To the best of our knowledge, no one has previously synthesized the empirical literature on the effects of RTOs on their non-R&D clients. Our review summarizes this literature.

In the Danish National Innovation System, the GTS institutes are a subtype of research and technology organizations (RTOs) bridging the sector specific needs of especially smaller non-R&D firms and available knowledge in the broader innovation community. They were set up to build and maintain research, technological development and innovation (RDTI) competences; to develop and maintain a technological infrastructure; and, to disseminate new technological knowledge primarily to SMEs. Thereby, they specifically address the needs of small innovators and entrepreneurs but may also address cutting edge innovation needs of small as well as larger R&D active firms. In this review, we primarily consider studies on the effects of GTS-like RTOs, also outside of Denmark, on their non-R&D (and R&D) performing firm clients. We consider three types of effects of the RTOs on their SME clients: 1) economic effects relating to general firm performance (e.g. sales or competitiveness); 2) innovation effects relating to the capacity of the small firms to successfully innovate (e.g. new to the firm or market); 3) collaborative effects in terms of the subsequent networking or collaborative performance of the small firms (e.g. new or improved networks). Figure 1.1 summarizes our review's locus of attention.

As the figure illustrates, our attention is mainly directed to the effects among non-R&D firms. The RTOs are central to their ability to import necessary knowledge (the one way arrow illustrates the innovation knowledge delivered by RTOs to the non R&D-firms in the slightly red shaded circle). The RTOs are mediators or bridging organizations for new knowledge, networks and collaboration from and with the remaining national innovation system, e.g. universities, technological transfer organizations (TTOs) and R&D firms with which they collaborate (the two way arrows illustrate the exchange of innovation knowledge between these actors in the innovation system). Hereby, the RTOs increase their own knowledge stock, their capability to augment the non-R&D firms' ability to innovate, create networks and increase competitiveness, but may also, in a more interactive way, achieve similar results for small as well as larger R&D firms' cutting edge innovation (the left hand side circle in figure 1.1).

Figure 1.1: Locus of attention



The rest of this paper is structured as follows. In Section 2, the review's focus and three research questions are described and defined in more details, Section 3 describes the review methodology and resulting literature sample, and Section 4 gives a statistical overview of the identified literature. Finally, Section 5 analyzes and concludes on the economic, innovative and networking firm effects of RTO interactions and on what characterizes efficient RTOs as technology intermediaries for SMEs.

2. Research Questions

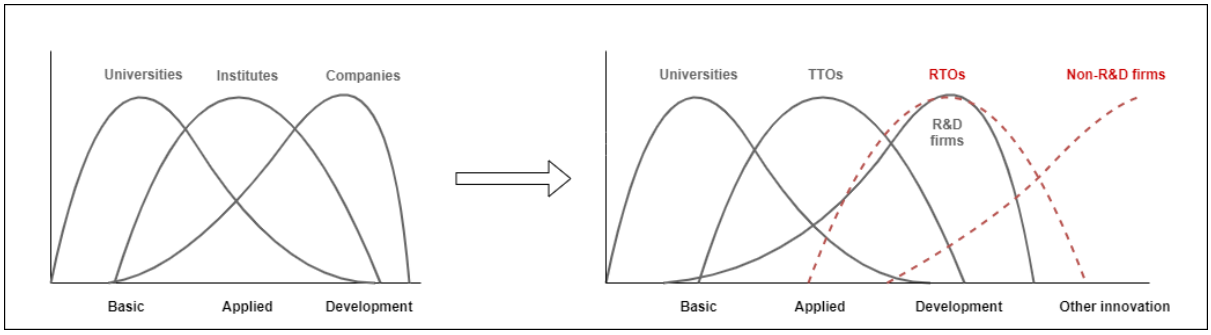
This section lays out the main research questions addressed in this study. The main goal is to collect the available empirical evidence on the effects of firm-RTO interactions on several dimensions of the firms' subsequent performance. We aim to synthesize the relevant research along three lines and investigate which types of technological knowledge advice and infrastructure have effects on (1) firm's economic performance (and Research, Technological Development and Innovation, RTDI), (2) firm's innovation processes and innovation capacity, and (3) firm's subsequent collaboration with knowledge institutions, other knowledge providers or other firms.

We follow the literature from e.g. Arnold et al. (2010) when we conceptualize the mechanism driving these effects via a RTO-based bridging role that improves the firms' innovation spectrum and possibilities. In this modelling, small aspiring innovators may often lack the scientific knowledge needed to find demanded innovative solutions, i.e. go from ideation of change in product or process to actual innovations and implementation. In addition, their experience in terms of bringing an innovation successfully to the market may also be lacking. Here, the RTOs perform a bridging function as they amass technological knowledge relevant to their client firms and, as such, they are able to connect small, aspiring innovators to the sphere of academic as well as private research and innovation competences. The effect of such connections to the small firms can then consist of increases in subsequent economic, innovative and collaborative or networking performance.

Figure 2.1 below summarizes our conceptualization of the bridging function that RTOs perform in a National Innovation System (NIS). It builds on the classical 'three hump' model that is depicted on the left-hand side of the figure and found in Arnold et al. (2010), and adds to it by splitting up the technology institutes into technology transfer offices (TTOs) and research and technology organizations (RTOs). The TTOs are usually situated in connection to universities and serve mainly R&D capable firms that have the required absorptive capacity for efficient uptake of the transferred knowledge and technology. RTOs on the other hand mainly serve smaller non-R&D firms that require their expertise to be matched by the RTO or mediated towards relevant partnering universities, TTOs or R&D active firms. Hence, RTOs 'bridge' a part of the basic-applied-development innovation spectrum to bring technological knowledge in reach of their SME clients, i.e. non-R&D firms.

Parallel, the RTOs may also themselves collaborate with universities, TTOs or R&D firms on cutting edge innovation and the like, in order to improve own competences or augment knowledge among e.g. R&D firms with such needs. As figure 2.1 also illustrates, the RTOs' innovation commonality space on the basic-applied-development innovation spectrum in figure 2.1 is primarily with R&D firms and to a lesser extent with TTOs and non-R&D firms. Hence, they have a unique potential to augment the innovation capacity among the latter firm group, c.f. figure 1.1, as they act as a publicly supplied knowledge pool accessible for everybody in the NIS.

Figure 2.1: Firm and knowledge actors on the Innovation (RTDI) Spectrum in National Innovation Systems



Note: The figure to the left from Arnold et al. (2010) is extended to cover the present description of the national innovation system (to the right) where Institutes are separated in TTOs and RTOs and Companies are separated in R&D and non-R&D firms. The latter is the primary, but not sole, collaborator with RTOs in the present review.

For empirical research, it is important to be aware of adequate outcome measures to be able to capture the three types of effects in a quantitative or qualitative analysis. Such firm effect evidence can be observed either directly at firm level (firm perspective) or indirectly through identification of characteristics among RTOs (RTO perspective) that efficiently improve customers' or interacting firms' broad defined market competitiveness. We summarize potential outcome measures to gauge the effects and define our research questions covering the three potential effect types.

2.1. Economic

Economic effects stem from successful innovation, in either products or processes, that can positively contribute to the bottom-line through either their cost-cutting potential or by increasing sales. Empirically, one can consider several measures to gauge these effects:

- Purely output related (e.g. measured in turnover, sales or export)
- Productivity oriented (e.g. relative or actual increase in amounts)
- Competitiveness (e.g. change in market shares)

RQ1. Do aspiring innovators that interact with RTOs benefit from increased economic performance?

2.2. Innovation

Innovation effects are a more direct way of examining the successfulness of firms' interactions with RTOs. There are several ways to assess whether the firm's innovative capacity has increased over time:

- Firm's innovative success (e.g. new to the firm or market products or processes)

- Firm's research and innovation processes (e.g. decreased time-to-market for new products and services)
- Firm's innovation capacity (e.g. improved innovation capacity[3] and readiness)

RQ2. Do aspiring innovators that interact with RTOs benefit from increased innovative performance?

2.3. Networking

The effect on firms' collaborative performance is a forward looking measure in that it assesses the firms' capacity to form successful subsequent collaborations and be partners in networks after the initial interaction or collaboration with the RTO. Empirically, the research can try to assess whether:

- Firm's subsequent collaboration or networking is increased (e.g., collaboration with RTOs causes increased interaction with RTOs, knowledge institutions and other knowledge providers, and other firms).

RQ3. Do aspiring innovators that interact with RTOs benefit from increased subsequent networking performance?

3. Review Methodology

The following section describes the search strategy and the software employed in the literature screening process. The search was initiated with a scoping review aimed at structuring and documenting the literary field in terms of the three areas of interest: (1) firm's economic performance and RTDI, (2) firm's innovation processes and innovation capacity, (3) firm's networking/collaboration with knowledge institutions and other knowledge providers. This was followed by a systematic search after which the identified literature was screened. The time frame for the review was limited to a ten year period, from 2010 to 2020. However, older articles and reports were considered if they were targeting reviews or especially relevant to a Danish context.

3.1. Scoping review

The first part of the scoping process focused on identifying grey literature regarding the Danish GTS-network. This part of the search identified various evaluations on the GTS-network and

[3] Innovation capacity refers to improved competences, knowledge or know-how among firm employees, i.e. embedded human knowledge.

the individual GTS-institutes, mainly performed by the Danish Agency for Science, Technology and Innovation (DASTI), now taken over by UFS. In addition, foreign grey literature on GTS-like institutes was identified. Initially in this process, key actors were approached and asked for known key references no matter its reference period. UFS (the Danish Agency for Higher Education and Science), GTS NET (Danish Association of Research and Technology Organizations), and DEA (The Think Tank DEA) delivered potential references which further targeted the scoping review. Similarly, publication lists from RTO organizations in the field such as e.g. GTS NET, Taftie (European Network of Innovation Agencies), and EARTO (European Association of Research and Technology Organizations) were consulted, and relevant literature was included. The identified publications contributed with relevant keywords for the further scoping process.

48 publications were identified in the first part of the scoping process. These were screened according to the three areas of interest. Inclusion required agreement from two reviewers. If there were conflicting opinions on the inclusion/exclusion of a study, a third reviewer was required to solve the conflict by making the defining decision. The screening process excluded 31 publications, meaning that 17 publications were included in the final review. Reasons for exclusion were e.g. lack of empirical results, no coverage of the three effect types, no analysis, etc.

The second part of the scoping review identified relevant peer-reviewed articles using Google Scholar. This search was an iterative process which aimed to identify different terms and concepts used in relation to RTO-like organizations and agencies. One of the main challenges regarding the search was to identify different uses of the term RTO as this covers different functions and services in different countries. Thus, it was important to uncover whether the organizations examined in the articles were sufficiently comparable to a Danish context. Furthermore, RTO-like functions and services are performed by various organizations that appear under other terms than RTOs, e.g. public research organizations, bridging organizations, or innovation intermediaries. The scoping review identified these different keywords and concepts and thus contributed with a list of search words for the creation of relevant search strings in the systematic pre-defined search strategy. 16 potentially relevant articles were identified in this process and included in the further screening process (section 3.3)

3.2. Search strings and systematic search

The choice of search strings was tested in various preliminary searches and abstract screenings to ensure that the strategy was capable of identifying relevant literature within the three

areas of interest. In addition, the choice was based on the number of search hits accumulated by the search strings. Search strings accumulating more than 50 hits where the majority of the hits did not cover our interest area were discarded for being non-specific/too broad. The final search strings are listed below in table 3.1. The pre-defined search was performed in Scopus and Web of Science and identified 796 peer-reviewed articles, which were extracted for further screening.

Table 3.1 Search strings

"Research and technology organizations" and • impact • productivity • knowledge • cooperation • innovation technology transfer • innovation collaboration • bridging organizations • intermediary roles • growth • linkages	• RTO innovation processes • "Research and technology" export • "Public research organizations" productivity or SME • "Bridging organizations" • "Bridging organizations" technology • Intermediary innovation transfer SME • "Innovation intermediaries" impact • "Innovation intermediaries" effect • External knowledge sourcing intermediaries • Innovation intermediaries organizations

3.3. Screening process

The primary sorting of the identified literature from the bibliometric databases, Scopus and Web of Science, was performed in the software Covidence. Covidence supports the process of sorting literature, as it provides a systematic management tool in the screening process. It also makes it possible to upload the identified articles, remove duplicates and review the remaining articles in two separate processes: (1) title and abstract screening and (2) full text review. Both screening processes follow the same principle as the screening of the grey literature: agreement from two reviewers is required for inclusion/exclusion, and a third reviewer solves conflicting opinions. The full text review also requires that two reviewers agree on the reason for excluding an article at this stage. Furthermore, Covidence makes it possible to manage the identified articles by the use of tags that systematize the articles in relevant categories, e.g. areas of interest.

After duplicates were removed and the 16 articles from the scoping review were included, 468 articles remained for the title and abstract screening. This screening was based on the following predefined selection criteria (see table 3.2). In this process, 375 studies were excluded leaving 93 studies for the full text review.

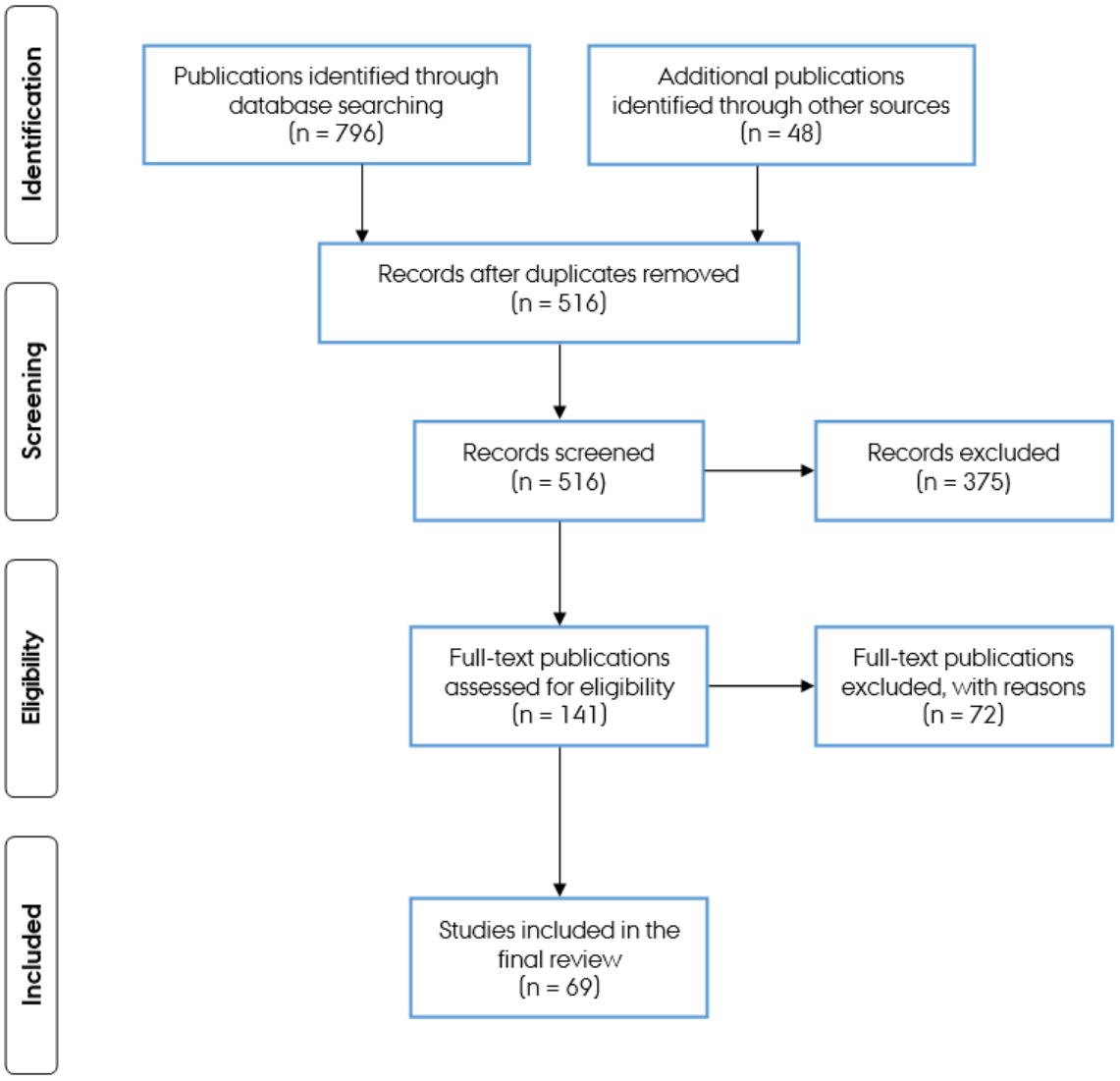
Table 3.2: Inclusion criteria

Inclusion criteria
Deals with RTOs' services for firms
Measures RTOs' effects on firms regarding the three areas of interests
Deals with empirical evidence (purely theoretical studies are excluded)*)
Relevant to the Danish National Innovation System (context)
Not older than 2010 (unless especially relevant)

Note: *) However, one simulation study has been included.

The full-text review involved an in-depth review of the remaining articles. Here, the main focus was on the research question(s), the primary findings and the methodology. The full text review excluded 41 articles, which left 52 articles for the final review. The 52 articles from the Covidence-screening in addition to the 17 grey literature items gives a total of 69 publications in the final review. The search and screening process is summarized in the PRISMA Flow Figure below.

Figure 3.1: Summary of the search and screening process (PRISMA)



Note: grey literature was not excluded until the eligibility-step

4. Review outcome – general overview

This section creates an overview of the nature of the identified literature. The included publications in the literature review were provided with pre-defined tags, which helped to create an overview of the literature. The tags included the three areas of interest and the methodology (quantitative, qualitative or mixed method). In addition, all studies were tagged with either 'firm perspective' or 'RTO perspective'. These tags were included as both the scoping review and the systematic search revealed that the number of publications dealing strictly with RTOs' impact on firms measured at the firm level (i.e. firm perspective) is limited. Consequently, it was decided to include studies that discuss the RTO-firm relation from the RTO perspective

investigating characteristics among RTOs that make them efficient intermediaries. The pre-defined tags are listed in table 4.1 below.

Table 4.1: Pre-defined tags

Tags
Economic performance
Innovation processes
Networking/collaboration
RTO perspective
Firm perspective
Qualitative
Quantitative
Mixed method

As stated above, all studies were categorized according to the three areas of interest: economic performance, innovation processes and networking/collaboration. Some studies cover more than one of the three areas, consequently they figure in more than one of the categories. In addition, a few studies did not fit into either of the three categories. For instance, literature reviews that present general observations regarding the functions of RTOs and their optimal role and performance in the innovation system. These are still highly relevant to the review and were thus ascribed to a fourth category named 'other'. As evident from table 4.2, there is a clear overweight of studies focusing on innovation processes, whereas the number of studies focusing on economic and networking/collaboration aspects are more limited. This is expectable considering that one of the primary functions of RTOs is to stimulate their clients' innovation.

Table 4.2: Overview of literature by area of interest

	Number of studies
Economic performance	15
Innovation processes	49
Networking/collaboration	14
Other*	10

Note: Some of the studies cover more than one area of interest.

*Other include relevant studies which fall outside the 3 areas of interest, e.g. literature reviews, a study on perceived barriers to collaboration and studies that examine the optimal functions of RTOs.

While the distinction between the three areas of interest has clear analytical benefits and serves to create an overview of the nature of the literature in the field, it is also important to highlight the interconnectedness between the areas. As with all categorization, the analytical distinction may create a picture of three isolated areas, but in reality these are very much entangled. For instance, it must be assumed that firms' increased economic performance is driven by innovation, i.e. increased economic performance (e.g. productivity or employment growth) can be regarded as an indicator of improved innovation (e.g. new-to-market products or processes). Similarly, networking and collaboration with external knowledge sources are closely tied to innovation as knowledge sharing plays an essential role in the innovation process.

As stated above, it was decided to include literature that discusses the RTO-firm relation from the RTO perspective as well as the firm perspective. These studies are relevant to the review as they identify the roles and functions of the RTOs – for instance, which services RTOs offer their clients, and how the RTOs themselves perceive their contribution to firm innovation, economy and networking/collaboration. Thus, these studies are valuable to the review because they *indirectly* address the impacts of RTOs on firms. The review includes 34 studies with an RTO perspective and 38 studies with a firm perspective (Appendix A, table A.3) where a few studies display both perspectives. As illustrated by table 4.3, most studies examining economic performance measure the effects from the firm perspective. Apart from this small tendency, there is a somewhat even distribution between the two perspectives in terms of areas of interest.

Table 4.3: Distribution of literature by areas of interest and whether the effects are measured from an RTO or a firm perspective

	Firm perspective	RTO perspective
Economic performance	11	5
Innovation processes	29	22
Networking/collaboration	6	8
Other*	2	9

Note: Publications with more than one effect tag will appear more than once in the table.

*Other include relevant studies which fall outside the 3 areas of interest, e.g. literature reviews, a study on perceived barriers to collaboration and studies that examine the optimal functions of RTOs.

Common to all the identified publications is that they focus on RTO-like organizations that offer innovation-related services to firms. However, these organizations appear under various terms in the literature. Table 4.4 provides an overview of the most common types. The term applied most frequently is *intermediaries.* The literature review by Clayton et al. (2018) define intermediaries as "entities that operate in the void between the scientific discovery and the ultimate realization of value for commercialization" (p. 104). Similarly, Fukugawa (2018a) defines innovation intermediaries as "individuals or organizations that help others improve productivity. They connect actors in national, sectoral, and regional innovation systems, thereby indirectly fostering innovations, as well as directly helping actors innovate as external sources of knowledge" (p. 297). Thus, *intermediaries* can be understood as an umbrella term, which covers different innovation-related organizations depending on the definitions in the specific study. To illustrate, in Clayton et al. (2018), this includes incubators and universities, whereas intermediaries in Dicecca et al. (2016) designate consultants, knowledge transfer organizations (KTOs) and broker organizations.

Similarly, *RTO* can be regarded an umbrella term covering more organization types. For instance, Barge-Gil & Modrego (2011) compare the impacts of two types of RTOs: public research organizations and technology institutes. According to EARTO's definition, RTOs are distinguished from universities "whose main mission is education" (Arnold et al., 2010, p. i). The distinction between RTOs and universities is also evident in figure 2.1 (section 2), illustrating how universities are more engaged with basic research, whereas RTOs focus more on development. This is also reflected in the literature, where Giannopoulou et al. (2019) and Barge-Gil et al. (2011) compare RTOs and universities as distinct collaboration partners. Thus, the definitions of RTOs are slightly different from the definitions of intermediaries, as the latter sometimes include universities (Clayton et al., 2018). However, as previously stated, all studies focus on innovation-related collaboration partners, which make their functions relevant to the focus of the review.

Table 4.4: Distribution of literature by areas of interest and RTO types involved

	RTOs	Intermediaries*	Brokers	Bridging organizations	GTS	Other**
Economic performance	5	1	-	1	3	5
Innovation processes	7	18	4	1	4	15
Networking/ collaboration	1	7	1	1	-	4
Other***	5	1	-	-	-	4

Note: Publications with more than one effect tag will appear more than once in the table.

*Intermediaries include: innovation intermediaries and technology intermediaries

**Other includes e.g. applied research and/or innovation organizations, technology institutes or hubs, knowledge and technology transfer organizations, and collective research centers.

***Other include relevant studies which fall outside the 3 areas of interest, e.g. literature reviews, a study on perceived barriers to collaboration and studies that examine efficient functions of RTOs.

All studies were assessed in terms of how easily transferable the results are to a Danish GTS-like context, where RTOs disseminate (technological) knowledge to private sector firms. Here 'transferability' refers to whether the study, its results or purpose, contributes with evidence that are suitable in a Danish innovation policy framework for the Danish GTS-system, i.e. whether some parts of the study's result can provide evidence for policy making. Hence, being 'transferable' to a Danish context does not mean that it may be fully copied and implemented in Denmark. In table 4.5, a 'Less' means that the literature deals with broader evidence of for instance national innovation systems or sectors not covered by the GTS-like system, or illustrates mechanisms behind collaboration effects using data from less comparable countries or innovation systems, and hence delivers evidence for RTO effects on firms although not directly transferable to the existing Danish set up, i.e. less transferable. Overall, the results of the studies are to some extend transferable to a Danish GTS-like context, regardless of whether the studies are taking a firm- or RTO perspective. This is also generally the case when looking at transferability in terms of the three areas of interest, except for networking/collaboration which shows an equal distribution of transferable and less transferable results in the studies.

While there still is a large proportion of studies that are less transferable to the present Danish GTS-like context, these studies still contribute with knowledge usable in a national innovation system like the Danish, for instance construction of other knowledge transferring institutions or

other outcomes of knowledge transferring organizations. Thereby, they contribute with inspiration that may be usable in a broader RTO view.

Table 4.5: Distribution of literature by areas of interest and studies' transferability to a Danish GTS-like context

	Firm perspective		RTO perspective	
	Yes	*Less*	*Yes*	*Less*
Economic performance	9	2	1	4
Innovation processes	17	12	14	8
Networking/collaboration	2	4	5	3
Other*	1	1	5	4

Note: 'Transferable to a Danish GTS-like context' means that the study, its results or purpose contributes with evidence suitable in the present Danish innovation policy framework for the Danish GTS-system. A 'Less' means that the literature deals with broader evidence of e.g. national innovations systems or sectors not covered by the GTS-like system, or illustrates mechanisms behind collaboration effects using data from less comparable countries or innovation systems. The evidence can deal with firm as well as RTO system perspectives.

*Other include relevant studies which fall outside the 3 areas of interest, e.g. literature reviews, a study on perceived barriers to collaboration and studies that examine the optimal functions of RTOs.

As illustrated in table 4.6, the literature review has a large geographical coverage, but a clear overweight of European studies, as many non-European studies were excluded in the screening process because of a lack of relevance to a Danish GTS-like context. However, some non-European studies were included, if the examined organizations, their interactions or found results were deemed comparable or inspirational to the Danish GTS-system or the Danish innovation system in general.

Table 4.6: Distribution of literature by analyzed countries crossed by areas of interest

	Denmark	Other Nordic	Other European	Rest of world
Economic performance	6	3	7	2
Innovation processes	5	8	30	12
Networking/collaboration	-	5	9	2
Other*	1	3	8	5

Note: Publications with more than one effect tag will appear more than once in the table. Furthermore, one publication can appear in more than one geographical category if it covers countries across the established categories. The study by Lin & Wei (2018) is not included in the table because it is a simulation study with no case countries.

*Other include relevant studies which fall outside the 3 areas of interest, e.g. literature reviews, a study on perceived barriers to collaboration and studies that examine the optimal functions of RTOs.

The identified studies differ in terms of their empirical geographical coverage. A smaller number of studies examine the RTO-firm relation in a local context (table 4.7) – to illustrate, Matschoss and Heiskanen (2018) conduct a case study of the relation between an intermediary and the local energy company based in Helsinki. Similarly, only a few studies are conducted in a regional context – for instance, Fernández-Esquinas et al. (2016) examining RTO-firm relations in Andalusia, Spain. As evident from table 4.7, most studies show a national or multinational perspective on the RTO-firm relation, especially studies targeting firms and RTOs in other European countries.

Table 4.7: Distribution of literature by analyzed countries crossed by empirical geographical coverage

	Denmark	Other Nordic	Other Europe	Rest of world
Local	-	4	3	1
Regional	-	-	5	6
National	8	2	18	7
Multinational*	1	6	14	6

Note: one publication can appear in more than one geographical category, if it covers countries across the established categories. The study by Lin & Wei (2018) is not included in the table because it is a simulation study with no case countries.

*Multinational includes reviews covering various studies with different empirical geographical coverage.

The review covers publications from a ten-year period: 2010-2020. Especially analyses of innovation processes have gained interest in the entire period resulting in a continuous flow of literature. Conversely, the literature on economic performance has been sparse and mostly from the beginning of the decade. This is illustrated in table 4.8 below.

Table 4.8: Distribution of literature by year of publication and areas of interest

	2010 and before	2011-2012	2013-2014	2015-2016	2017-2018	2019-2020
Economic performance	4	4	-	1	5	1
Innovation processes	7	10	8	5	11	8
Networking /collaboration	-	3	4	2	3	2
Other*	2	-	2	4	2	-

Note: Publications with more than one effect tag will appear more than once in the table.

*Other include relevant studies which fall outside the 3 areas of interest, e.g. literature reviews, a study on perceived barriers to collaboration and studies that examine the optimal functions of RTOs.

In terms of methodology, the literature review covers both qualitative and quantitative studies. As illustrated in table 4.9, the methodological approach is to some extent connected to the area of interest studied in the specific publication. Studies focusing on economic performance predominantly have a quantitative research design (12 cases), whereas studies discussing networking/collaboration tend to have a qualitative research design (9 cases). In terms of innovation processes, this topic is approached quantitatively as well as qualitatively. A smaller number of studies demonstrate a mixed method approach, for instance informing a quantitative questionnaire with preceding personal interviews (Albors-Garrigós, 2010; Gassmann et al., 2011; Knockaert & Spithoven, 2014; Knockaert et al., 2014) or allowing a more exploratory approach to certain topics in addition to close-ended survey questions (Dietsch & Khemiri, 2018; Memon & Meyer, 2017; Spithoven & Knockhaert, 2012). Furthermore, the identified publications include three literature reviews (see "System view" in table 4.9). Further elaboration on the methodology of the studies is found in table A.2, Appendix A.

Table 4.9: Distribution of literature by areas of interest and analytical method

	Quantitative	Qualitative	Mixed method	System view
Economic performance	12	-	3	-
Innovation processes	24	16	9	-
Networking/collaboration	3	9	2	-
Other*	2	5	-	3

Note: Publications with more than one effect tag will appear more than once in the table.

*Other include relevant studies which fall outside the 3 areas of interest, e.g. literature reviews, a study on perceived barriers to collaboration and studies that examines the optimal functions of RTOs.

The methodology of all the individual studies were classified according to two evidence hierarchies. An evidence hierarchy is a constructed indicator often used to rank or compare relative strength of different scientific research outcome and results, and ranks studies according to their risk to suffer from systematic bias (Stegenga, 2014). The lower the risk, the higher value in the evidence hierarchy and the more generalizable are the results. In this review, two evidence hierarchies were applied: the general evidence hierarchy proposed by the Karolinska Institute library (2020) and the empirical study hierarchy proposed by Kongsted (2018). The evidence hierarchy from the Karolinska Institute is more general, and the focus lies on the specific research method. The empirical study hierarchy, on the other hand, concentrates on the quality, robustness or inter-reliability of the identified evidence rather than the research method in itself, and thus can be used as a supplement to the general hierarchy. For further elaboration on the evidence hierarchies, see Appendix B.

Looking at the distribution of literature by area of interest and ranking in the general evidence hierarchy (table 4.10), we find a general tendency, across areas of interest, in the choice of research design. All areas of interest show an overweight of level 2 studies, followed by level 3 studies and finally level 1 studies. It is notable that no studies display a research design involving randomized controlled trials (level 4) or meta-analyses (level 6). Consequently, the field shows a lack of studies adhering to the optimal research designs in terms of strength of evidence.

Table 4.10: Distribution of literature by areas of interest and ranking in the general evidence hierarchy

	General evidence hierarchy					
	1	2	3	4	5	6
Economic performance	1	11	3	-	-	-
Innovation processes	3	41	5	-	-	-
Networking/ collaboration	1	11	2	-	-	-
Other*	2	5	-	-	3	-

Note: Publications with more than one effect tag will appear more than once in the table.

*Other include relevant studies which fall outside the 3 areas of interest, e.g. literature reviews, a study on perceived barriers to collaboration and studies that examine the optimal functions of RTOs.

Looking at the identified literature according to the empirical study evidence hierarchy (Kongsted, 2018), there is a similar pattern: most studies are placed at the lower levels of the hierarchy. In addition, there is a significant number of studies which cannot be placed in the hierarchy, because the hierarchy concentrates on quantitative approaches to research. Consequently, studies with exclusively qualitative research designs are categorized as n/a in table 4.11. 24 studies are situated at level 1 (see Appendix A, table A.2), as they have no control group – i.e. these studies show no attempt at establishing a counterfactual. In contrast, 11 studies do attempt at establishing control groups, for instance by applying Difference-in-Differences designs or Balancing (OLS, matching), and are therefore placed at level 3. Most studies examining economic performance are situated at this level of the hierarchy (table 4.11). Conversely, the studies focusing on networking/collaboration are predominantly placed as n/a or at the lower levels of the hierarchy. The distribution of the studies focusing on innovation processes has a more mixed character.

Table 4.11: Distribution of literature by areas of interest and ranking in the empirical study evidence hierarchy

	Empirical study evidence hierarchy					
	n/a	1	2	3	4	5
Economic performance	1	6	-	6	2	-
Innovation processes	18	16	3	10	2	-
Networking/ collaboration	9	4	-	1	-	-
Other*	8	2	-	-	-	-

Note: Publications with more than one effect tag will appear more than once in the table.

*Other include relevant studies which fall outside the 3 areas of interest, e.g. literature reviews, a study on perceived barriers to collaboration and studies that examine the optimal functions of RTOs.

Among the identified literature included in the review, especially the studies on firm perspectives use explicitly defined effect indicators in their analysis, i.e. a quantitative research methodology. The studies on RTO perspectives were more often case- and interview-based and without explicitly defined indicators, i.e. a qualitative research methodology. Therefore, the majority of empirical effect indicators have been found in the firm perspective studies, c.f. Table 4.12, which is a summary of the indicators listed for each study in Table A.3. The indicators are split by firm/RTO perspectives but also by effect types.

The literature on economic effects showed a large internal overlap among the indicators used, which is natural when considering the field's tradition for the use of certain variables, e.g. productivity, turnover and employment among others. Similarly the literature on innovation effects had a large internal overlap among the indicators used in these studies, primarily stemming from the innovation literature, e.g. product and process innovation, novelty and capacity. Conversely, the literature on networking/collaboration effects was less generous in the use of indicators as it seems to be a more diverse field with a larger fraction of case studies that more often uses case-specific, tailormade, intangible indications, e.g. through interviews.

Table 4.12 shows a summarized list of the found effect indicators but does not show how often the indicators have been used in the literature. However, the list provides an overview of indicators that have been used with some success in the literature, and therefore could be used in future studies of firm effects of RTO collaboration. The explicit definition and use of the relevant indicators can be found in the literature through search in the tables in section 5, Table A.1 and especially Table A.3, and finally accessed through the literature links under References.

Table 4.12: Summarized list of collected effect indicators by perspective and effect types*)

	Economic	Innovation	Networking/ collaboration
Firm Perspective studies	Private and social rate of return Sales, exports, production costs, profits, productivity, employment, number of clients Productivity, turnover, export, profit, value added, and innovative sales growth Average growth of SMEs' turnover or total factor productivity Turnover and productivity per employee Human capital or employment growth	Introducing new or improved goods, technologies, services, processes and logistics Applying new patents; applied and granted Market novelty of new products: New-to-the-firm innovation, new-to-the-market innovation, world-first innovation Turnover or share of total sales due to new products Innovation speed; time-to-market Developing new products with superior quality User satisfaction Process innovation; unit cost reduction, materials cost reduction, and production flexibility and capacity increase Innovation expenses, firm R&D activities, project performance (cost, time and quality) Development activities Innovation barriers, and information sources Firms' attitude towards RTOs technology transfer Innovation culture: encouraging new ideas, internal	Intangibles: Cognitive capacity such as ability to teamwork, knowledge share, relationship creation and utilization of external knowledge Importance attributed to RTOs (and others) in establishing links with universities Additional firm network and competence building User satisfaction

		collaboration, and participatory decision-making	
RTO Perspective studies	Productivity, turnover, export, and profit growth Turnover per employee Number of deals, profiles produced and promoted, and of new clients Cumulative number of business incubators	Innovation intensity and speed; new products and time-to-market Absorptive capacity, employment of qualified personnel, R&D activities Success factors for RTOs' service offering to private firms	

Note: *) A complete list of effect indicators by study is in Table A.3. No indicators are provided for the studies that did not contain exact wording, e.g. qualitative case studies examining a few or more units in order to gain a more in-depth understanding of how effects appear or which framing that characterizes best performing RTOs.

5. RTO effects found divided into sub-themes

Section 5 analyzes a selected subset of the most prominent literature's contribution to empirical evidence on RTOs' effect on firms' economic performance, subsection 5.1, innovative activity, subsection 5.2, and networking capacity, subsection 5.3, i.e. the three research questions. Even though, the literature significantly concludes that RTO interactions do benefit (SME) firms' innovation activity, networking ability and economic performance, the number of identified contributions, and especially contributions high on the evidence hierarchy scale, is scarce. Therefore section 5 also includes a subsection 5.4 on identified literature on what characterizes RTOs that most efficiently contribute to collaborating firms' demanded innovation activities. Especially this latter subsection focuses on selected literature within the RTO perspective. As section 5 primarily analyzes studies with measurable effects indicators, it does therefore not include all literature accounted for in Section 4 and Table A.1 in Appendix A, e.g. system or case studies without explicit use of indicators, cf. Table A.3.

Since national innovation systems as well as RTO types vary across countries it has proven difficult to collect evidence that fits perfectly with a Danish framework with a GTS-like RTO context. Instead, evidence from close approximations is used. Therefore, the 'Most Similar Sys-

tems Design', MSSD, approach best describes the methodology behind the collection of literature and analysis in the present review. In this approach, only literature analyzing aspects measured in similar contexts or contexts very close to the GTS-like context are included.[4]

Due to this lack of common ground or common context, the results found in the identified literature is difficult to transfer directly to the Danish GTS-like innovation policy framework. Therefore, sections 5.1 – 5.4 also present results that may seem less transferable to the Danish context, see also section 5.5. They are, however, following the MSSD approach, included as examples of effect studies where we judge that the evidence do have some value for UFS' innovation policy work, e.g. both Japanese and Chinese studies are referred to, although we know they operate in other policy contexts.

As RTO is not a monopolistic term for the kind of organizations we are interested in, the studies examined in this section uses a wide variety of categories such as bridging organizations (Garengo, 2019), innovation intermediaries (Guo & Guo, 2013; Matschoss & Heiskanen, 2018; Kanda et al., 2018), technology intermediaries (Spithoven & Knockaert, 2012), and knowledge intermediaries (Cantù et al., 2015).

5.1. Economic effects of RTO-cooperation

Improved economic performance must be assumed to be a central motivation for firms when they initiate cooperation with RTOs. This section will examine whether firms actually benefit economically from RTO-cooperation by looking into the contemporary pool of knowledge regarding the economic effects of collaborating with RTOs.

The economic aspect of RTO-cooperation has only been investigated in around a handful of studies. However, a number of reports also contribute with knowledge on the topic, thereby adding weight to the conclusions of this section.

As it appears in Table 5.1, there is a pronounced geographical skewedness in the articles and reports on the economic effects of RTO-cooperation, as they are almost exclusively founded on Northern European data. Methodologically, regression analysis is the dominant approach in this branch of the literature.

[4] This method consists in comparing very similar cases which only differ in known ways. A benefit of this strategy is that it keeps irrelevant literature out of the analysis by selecting comparable cases, i.e. cases with a number of common elements.

Table 5.1: Overview of literature on the economic effect of RTO-cooperation*)

Author	Context	Data	Empirical focus	Economic effect of RTO-collaboration	Indicator
Fukugawa (2018b)	Japan	Financial data from the Basic Survey of Business Activities by the Ministry of International Trade and Industry collected between 1992 and 1995.	Japanese SMEs in the manufacturing sector.	Innovation intermediaries help SMEs improve productivity.	Regression analysis of how different types of intermediaries impact total factor productivity of firms.
Comin et al. (2019)	Germany	Data from Fraunhofer's project database were coupled with data from the Community Innovation Survey to provide a sample of 4.495 firms.	German firms cooperating with Fraunhofer.	The results indicate a strong causal effect between collaborating with Fraunhofer and turnover and productivity growth.	Regression analysis of Fraunhofer expenditure and turnover and productivity growth.
Barge-Gil & Modrego (2011)	Spain	Survey among 257 Spanish firms collaborating with either TIs or PROs.	Firms featuring in the Official Innovation Survey in Spain.	The most positive impact on sales followed by profits, number of clients and productivity.	Companies were surveyed about the impact of RTO-collaboration on several economic parameters.
Kaiser & Kuhn (2012)	Denmark	Register data containing 4.549 observations on 217 unique DIC member firms and 173 unique control group firms.	Firms participating in the Danish Innovation Consortium program.	No statistically significant relationship between RTO-led support scheme and value added.	Regression analysis of support scheme participation and value added.

Forsknings- og Innovationsstyrelsen (2011)	Denmark	Statistics on research and innovation, accounting and education from around 20.000 Danish firms in the period between 1997 and 2008	Danish firms registered as GTS-clients.	RTO-collaboration increases the productivity by 40.000 DKK per employee, equivalent to 7.100.000 DKK per company	Average productivity per employee in relation to firms' investment in RTO collaboration
Arnold et al. (2010)	Spain	Literature review (recapitulating the results from Modrego & Barge Gil, 2009)	n/a	Collaboration with RTOs resulted in increased turnover (on average by 4% on an annual basis), profits (before taxes) and number of clients for a considerable number of businesses. It also enhanced the productivity and exports of some and reduced production costs.	n/a
Pesonen et al. (2008)	Finland	Survey data from firms collaborating with VTT coupled with turnover figures from these firms to measure collaboration intensity and firm growth.	Finnish SMEs with a significant collaboration with VTT.	An inverse relationship between collaboration intensity and firm growth is discovered.	Collaboration intensity and firm growth were compared.
Forsknings- og Innovationsstyrelsen, DAMVAD & Center for forsknings-analyse (2010)	Denmark	Statistics on research and innovation, accounting and education from 12.252 Danish firms in the period between 1997 and 2005	Danish firms registered as GTS-clients.	Firms collaborating with public knowledge institutions experience a productivity growth of 71.000 DKK per employee compared to non-collaborating	A comparative descriptive analysis of the productivity of firms with RTO-cooperation and without RTO-cooperation.

				firms, a 15% difference in productivity growth.	
Iris Group (2016)	Denmark	Survey among Danish firms collaborating with RTOs	Danish firms registered as GTS-clients.	Two out of three firms experience some level of effect of RTO-collaboration on productivity and turnover.	Likert-scale measure, where firms assess the impact of RTO-collaboration on productivity, turnover, export and profitability.
Styrelsen for Forskning og Uddannelse (2017)	Denmark	The study is based on the 2010 assessment of Danish firms' investments in research, development and innovation from Statistics Denmark as well as data on productivity growth from Statistics Denmark's FIRM statistics producing a sample of 3.497 firms.	Danish firms featuring in the FUI-statistics in 2010.	Firms that cooperate with RTOs have a 1.5 percent point higher productivity growth than firms without cooperation.	A regression analysis of investment in RTO-collaboration and productivity growth.
Frietsch et al. (2018)	Germany	n/a	German firms cooperating with Fraunhofer.	No direct effect from cooperation with Fraunhofer for large companies, but a significantly positive effect on operating income and earnings before interest and taxes for small and medium-sized companies.	n/a

The impression emanating from the literature is rather unambiguous, as a clear majority of research shows that RTO-cooperation affects the key economic figures of firms in a positive way.

A number of Danish reports written within the last decade find that firms increase their productivity by cooperating with RTOs (Forsknings- og Innovationsstyrelsen, DAMVAD & Center for Forskningsanalyse, 2010; Forsknings- og Innovationsstyrelsen, 2011; Iris Group, 2016; Styrelsen for Forskning og Uddannelse, 2017). Three of these reports compare the productivity of firms who cooperate with a RTO with firms that do not. They all found that the collaboration contributes positively to the productivity of firms, but to varying degrees (Forsknings- og Innovationsstyrelsen, DAMVAD & Center for Forskningsanalyse, 2010; Forsknings- og Innovationsstyrelsen, 2011; Styrelsen for Forskning og Uddannelse, 2017). A report from the Danish Agency for Higher Education authored in 2010 thus showed that firms increased their productivity with 69.000 Danish kroner per employee when they cooperated with public knowledge institutions (Forsknings- og Innovationsstyrelsen, DAMVAD & Center for Forskningsanalyse, 2010), while another report from the same ministry written a year later found that the productivity per employee was raised by around 40.000 Danish kroner because of RTO-cooperation (Forsknings- og Innovationsstyrelsen, 2011). A third and more recent report from the same institution found that firms experienced a productivity growth of 2,4 percent due to their RTO-collaboration (Styrelsen for Forskning og Uddannelse, 2017). In 2016, the consultancy Iris Group conducted a survey-based investigation of how firms perceived their collaboration with RTOs, which showed that 69 percent of the targeted Danish firms agreed that collaborating with RTOs had strengthened their productivity and efficiency (Iris Group, 2016). Further, RTO-collaboration had resulted in higher turnover for 67 percent of the firms (Iris Group, 2016). Another conclusion from the report regarded the correlation between collaboration intensity and user satisfaction. It appeared that the firms who collaborated the most with RTOs, also perceived themselves to reap the biggest benefits from their RTO-involvement (Iris Group, 2016).

However, a study based on panel data with firms involved in the Danish Innovation Consortia (DIC) support scheme blurs the picture slightly (Kaiser & Kuhn, 2012). The study compared how the firms in the support scheme, a program aimed at strengthening technology transfer between public research institutions and industry, fared against similar firms outside the scheme. No statistically significant effect of DIC-participation on value added was detected, although the participating firms had a 2,5 percent faster employment growth in the year after entering the program compared to non-participating firms (Kaiser & Kuhn, 2012).

The link between RTO-cooperation and firms' economic performance has also been examined in contexts proximate to the Danish. In a 2018 assessment of their own contribution to the German innovation system, the German research organization Fraunhofer concluded that

large firms did not benefit from cooperating with them, whereas small and medium-sized firms experience a significantly positive impact on operating income and earnings before interest and taxes (Frietsch et al., 2018). The impact of the Fraunhofer Society in Germany was also investigated in a paper from the same year (Comin et al., 2019). Here the correlation between firms' expenditure on services from Fraunhofer and growth in turnover and productivity was used as an indicator on the economic effect of RTO-collaboration. It was found that a 1% increase in Fraunhofer expenditure led to a 1 percent increase in the firms' annual growth rate equivalent to approximately 16 percent of the total average growth in the sample consisting of 4495 German companies (Comin et al., 2019). The effect on productivity growth was found to be 0,7 percent, which led the authors to conclude that the results indicate a strong causal relationship between Fraunhofer involvement and growth in turnover and productivity (Comin et al., 2019). A Finnish study also examined the impact of a particular RTO, VTT, on the growth rate of firms. The study employed figures from 848 Finnish firms, which was then correlated with data from VTT's customer database on collaboration intensity. Interestingly, it was found that the firms, who collaborated the least, the so-called daters, had more growth than the so-called maters (Pesonen et al., 2008).

Although the economic impacts of RTO-cooperation for firms have mostly been studied using Northern European data, evidence on the beneficial economic effects can also be found elsewhere. In a survey with 257 Spanish firms, Modrego and Gil enquired into the economic impact of collaborating with a RTO and found that a majority reported a positive effect on sales, while profits, number of clients and productivity were also positively affected for around half of the firms in the sample (Barge-Gil & Modrego, 2011). The duration and intensity of the collaboration were also found to positively influence the economic impact (Barge-Gil & Modrego, 2011). Another study by the same researchers referenced in a 2010 report from Technopolis Group showed that RTO-collaboration results in a 4 percent increased annual turnover on average as well as enhanced productivity and exports (Arnold et al., 2010). Further, a study on the collaboration between small- and medium-sized enterprises and innovation intermediaries in Japan showed that the relationship resulted in improved productivity for the firms. The productivity growth could be reached in different ways depending on the type of intermediary, as some intermediaries facilitated cost sharing through joint logistics, while others helped the firms with joint R&D (Fukugawa, 2016).

As previously mentioned the literature generally conveys the message that RTO-collaboration has a positive economic impact for firms. It has been shown to improve productivity, turnover

and employment growth. Collaboration intensity appears to be an important background factor influencing the economic effect of firms' cooperation with RTOs. It seems that firms gain more economically when their collaboration with RTOs is more intense, although a contrary finding also exists (Pesonen et al., 2008).

5.2. Innovation effects of RTO-cooperation

Before summarizing the literature that investigates the existence and extend of the impact RTO collaborations have on SME innovativeness, we begin by describing the mechanism that drives such effects.

SMEs' closeness to their customer base puts them in a good position to come up with viable innovation ideas (Roessl et al., 2010). However, they often lack internal innovation capacity to implement these ideas themselves and knowledge that would allow them to connect to relevant external partners is often not available in-house. As such, lack of absorptive capacity in SMEs is often cited as the reason why RTO-intermediaries are able to increase the innovation performance of their SME-clients. Collaboration with an RTO constitutes an alternative to internal knowledge build-up for SMEs aspiring to engage in inbound open innovation (see Spithoven et al., 2010 for descriptive evidence on the case of Belgian Collective Research Centers). Garengo (2019), in a cross-case analysis of 6 Italian bridging organizations, points out that bridging organizations help SMEs to leverage external networks in order to innovate. The evidence points to RTOs acting as bridging organizations that leverage their in-house knowledge and external networks to serve their clients in their innovation efforts. In a context of open innovation, the RTOs can then be seen as: 1) knowledge brokers, and; 2) catalysts for the SMEs search for potential collaborators.

In their function as knowledge brokers transferring knowledge to their clients, RTOs typically take on specific 'roles'. Gassmann et al. (2011) argues that, in order to facilitate the innovation process, intermediaries use analogies to transfer knowledge from one industry to another, thereby taking on specific 'roles' depending on how close or distant the analogy is. Also Landry et al. (2013) finds that for Canadian knowledge and technology transfer organizations (KTTOs) different types of KTTOs are needed to provide different types of services. Kanda et al. (2018, 2019) find that in the case of eco-innovation, intermediaries (in Sweden and Germany) take on 'roles' comparable to the "conventional" innovation case. They specifically stress the im-

portance of RTOs mobilizing their network and leveraging their funding and technological expertise to serve their clients. Guo & Guo (2013) come to comparable findings for a textile industry intermediary in China.

As catalysts for firms seeking collaboration with RTOs, Klewitz et al. (2012) find that the major benefits of participating in the German Ecoprofit eco-innovation programme were related to forging connections with external consultants, local authorities and other SMEs. Klerkx & Leeuwis (2009) provide a description of the different types of innovation brokers in the Dutch agricultural sector and emphasize that *"finding suitable collaboration partners"* is central to success.

As-such RTOs' absorptive capacities can be seen as knowledge pools, which can be proxied by the client-SMEs to 'obtain' upfront technological knowledge in order to find suitable collaboration partners in implementing their open innovation efforts. More evidence on the effectiveness of this mechanism is found in the limit case where SMEs want to connect to basic research conducted at universities. By first connecting to an RTO, it may become easier for the SME to form ties with universities, since the universities find it easier to collaborate with an RTO than with SMEs directly (Goduscheit & Knudsen, 2015).

The rest of this section deals with literature that is able to address the second research question: *Do aspiring innovators that interact with RTOs benefit from increased innovative performance?* The scope of considered literature is constrained to articles where the results are deemed transferable to the Danish context. As such, we expect the found effects to be relevant for policies surrounding the functioning of GTSs in Denmark.

Though the literature investigating the link between collaboration with RTO-like institutes and innovation performance of the SMEs is rather limited in volume, it does identify positive effects in several dimensions. Successfulness of innovation can be measured in several ways. The empirical literature reflects this multi-facetted nature of innovation outcomes.

- *Technological invention* is commonly measured by the volume and characteristics of the firms' patents. Although not all inventions are patented, and maybe not all patents are 'true' inventions. Patent (applications) proxy fairly well technological progress made by firms. Kaiser & Kuhn (2012) find that firms participating in the 'Danish Innovative Consortia' (a research venture support scheme) have a significantly higher number of patent applications both in the short and the long term,

indicating the technological benefits an SME might achieve from an RTO-like collaboration.

- *Cost, speed and quality* of innovation are important measures of firm innovation at the project level. Dietsch & Khemiri (2018) find that knowledge gained through third party intermediation impact these performance measures positively. Knockaert & Spithoven (2014) find, for Belgian clients of collective research centers, that the intensity of RTO-SME interaction positively affects innovation speed.
- The *novelty* of innovations is usually measured by making a distinction between market-novelties and innovations only new-to-the-firms. Fudickar & Hottenrott (2019) find evidence in a German sample that firms that collaborate with Public Research Institutes are introducing more 'novel' innovations.
- Another way of measuring innovative performance is indirectly through firm *productivity*. Fukugawa (2018a) finds in the Japanese context that cooperative associations are helping SMEs to uplift productivity through enabling of cost sharing (e.g. joint ventures) and knowledge sharing (e.g. joint R&D)
- *Innovation sales*-performance is a frequent measure of innovation success. Robin & Schubert (2013) find a positive effect of PRO-firm collaboration on the firms' product innovation sales in German and French Community Innovation Samples.
- Innovation 'volume' at the firm level can also be measured by counting *the number of innovation projects* or processes initiated. A study by the Forsknings- og Innovationsstyrelsen and Oxford Research A/S (2010) finds that 1055 private users of the Danish GTS services are exhibiting higher innovation 'volumes' than 300 private non-users.

Table 5.2: Overview of the innovation effects of RTO-cooperation*)

Author	Context	Data	Empirical focus	Innovation effect of RTO-collaboration	Indicator
Fukugawa (2018a)	Japan	Financial data of SMEs and inter-firm organizations among SMEs from the Basic Survey of Business Activities by the Ministry of International Trade and Industry	Innovative SMEs of 50 employees and more Representative for the economy with regard to NACE sector	Cooperative associations are helping SMEs to uplift productivity through enabling of cost sharing	Estimated productivity

Robin & Schubert (2013)	German	Community innovation survey	Cross section of firms representative for the economy in terms of size and NACE sector, consisting of both innovators and non-innovators.	Positive effect of PRO-firm collaboration on the firms' product innovation sales	Innovation sales-performance
Kaiser & Kuhn (2012)	Denmark	DIC/Experian data complemented by information on all patent applications to the European Patent Office (EPO)	Medium and large sized incorporated businesses which are part of the DIC No further selection based on NACE sectors.	Firms participating in the 'Danish Innovative Consortia' (a research venture support scheme) have a significantly higher number of patent applications both in the short and the long term	Number of patent applications
Forsknings- og Innovationsstyrelsen and Oxford Research A/S (2010)	Denmark	Survey data	1055 private users of GTS-services and 300 private non-users of GTS-services	Private users of the Danish GTS services exhibit higher innovation 'volumes' than private non-users	Number of innovation projects
Fudickar & Hottenrott (2019)	German	Firm-level data of German technology-based firms established between 2001 and 2006. The data had been collected as part of the ZEW High-tech Survey using computer-aided telephone interviews (CATI)	Sample of new technology based start ups, stratified by sector and founding year. Both R&D and non-R&D performing firms are represented.	Firms that collaborate with Public Research Institutes introduce more 'novel' innovations	Making a distinction between market-novelties and innovations only new-to-the-firms
Dietsch & Khemiri (2018)	n/a	Survey of 360 individuals involved in innovation projects	n/a	Knowledge gained through third party intermediation impact cost, speed and quality	Cost, speed and quality of innovation

				of projects measures favorably	
Knockaert & Spithoven (2014)	Belgium	Own collection of data by the collective research centres in Belgium	Both R&D and non-R&D performing firms of representative size for the population from all sectors served by the CRCs.	Intensity of RTO-SME interaction positively affects innovation speed	Innovation speed

Notwithstanding that generally positive effects are identified, some studies stress the *conditionality* of the effects on other factors. Upfront knowledge and capabilities seem to be an important modifier of effect of RTO-collaboration on innovation. Lin et al. (2016, 2020) find in a sample of Chinese manufacturing firms that positive innovation performance effects are tied to knowledge management capacity (Lin et al., 2016) and the firms' dynamic capabilities (Lin et al., 2020) and that intermediaries complement rather than substitute internal capacity. Having already thought through the required innovation efforts is also positively moderating positive effects. Olmos-Peñuela et al. (2017) show for a sample of firms that collaborate with the Spanish National Research Council (the country's largest PRO) that firms having formal innovation plans are more likely to benefit from a collaboration with a PRO in terms of their innovation performance. As such, it is natural that involving intermediaries in their own (formal) design phase for product development can have positive effects on SME innovation (Lasagni, 2012). Frietch et al. (2018) find that collaboration with the German Fraunhofer is particularly beneficial for innovative companies, for companies with a complex product portfolio, and especially for SMEs.

Other studies find *heterogeneous effects* across their samples. Robin & Schubert (2013) find that collaboration with a PRO has positive effects on product innovation (i.e. on the sales of innovative products) but not on process innovation. Giannopoulou et al. (2019) find that firms perceiving RTOs as more important collaboration partners than universities are less likely to develop new-to-the-market innovations but are more likely to develop service innovations. Furthermore, these firms invest less in internal R&D.

5.3. Networking effects of RTO-cooperation

With their central placement in the innovation system and diverse affiliations, RTOs could possibly be key actors in firms' network formation and interaction with external knowledge

sources. This section will provide an overview of what the contemporary literature can tell us about the extent to which this potential has been fulfilled.

It is evident from the literature search that the link between RTO-cooperation and added network capacity for firms has received scarce scholarly attention hitherto. Nonetheless, around two handfuls of papers shed light on the subject.

The papers are mainly based on data from European countries, although the networking effect of RTO cooperation has also been studied in China (Guo & Guo, 2013). Methodologically there is a clear qualitative inclination in the studies with interviews being a frequent way of eliciting data on the subject.

Across different geographical contexts and methodological approaches, the studies point toward that cooperating with RTOs help firms improve their networking capacity and ability to use external knowledge sources.

Table 5.3: Overview of the networking effect of RTO-cooperation*)

Author	Context	Data	Empirical focus	Networking effect of RTO-collaboration
Barge-Gil & Modrego (2011)	Spain	Survey among 257 Spanish firms collaborating with either TIs or PROs	Firms featuring in the Official Innovation Survey in Spain	Improved utilization of other knowledge external sources
Spithoven & Knockaert (2012)	Belgium	Interview with managers of the collective research centres (CRCs) followed by a survey among the member firms of the Belgian CRCs	The twelve collective research centers studied cover industrial sectors such as wood, ceramics; machinery, roads, construction; cement; textile, diamond, coatings and paintings, metallurgy, welding, and packaging	CRCs connect firms to networks of technological expertise
Knockaert et al. (2014)	Belgium	Interview with managers of the collective research centres (CRCs) followed by a survey among the member	The twelve collective research centers studied cover	Engaging in R&D activities with the CRCs resulted in network additionality for the average firm

		firms of the Belgian CRCs	industrial sectors such as wood, ceramics; machinery, roads, construction; cement; textile, diamond, coatings and paintings, metallurgy, welding, and packaging	
Cantù et al. (2015)	Italy	A qualitative case study on technological hubs (THs) in Northern Italy based on interviews with key referents from the THs and key referents from their primary collaboration partners (e.g. universities and incubators)	Italian high-tech firms from the ComoNExT network	In the interconnection between innovation process, political process and market process, THs are considered not only as knowledge intermediaries but also as knowledge mediators and network orchestrators of inter-sectoral innovation
Malik (2012)	Great Britain	An in-depth case study involving semi-structured interviews with managers in four British based organizations	UK manufacturing firms	Consultant KBX managed the interface between Glass STH and its university contacts by firstly carrying out an audit of what interactions Glass STH managers had with universities and for what reasons. From gathering this information the consultant was able to match Glass STH's list of core competencies for the whole business process to establish which universities might be able to provide the expertise not currently found within Glass STH
Guo & Guo (2013)	China	Single case study on a Chinese innovation intermediary, Zhejiang Institute of Modern Textile Industry, employing interviews with senior management	Zhejiang Institute of Modern Textile Industry (ZIT), an innovation intermediary in the Shaoxing Textile industrial cluster in China	ZIT integrates innovation resources by linking clients with other organizations and cooperating with actors both inside and outside the industrial cluster itself

		staff at as well as archive material (annual reports and newspaper articles) and participant observation		
Kivimaa (2014)	Finland	Case study on two Finnish intermediaries, Motiva and Sitra, featuring interviews with ten employees and six stakeholders to the organizations, printed or electronic publications as well as websites and news releases by the case organizations	Two Finnish intermediaries within the energy sector	The empirical data reveals similarities and differences between the two organisations: Motiva, a government-owned company promoting efficient use of energy and resources, and Sitra, a foundation to promote sustainable well-being in Finland. The similarities relate to a strong role given in internal interviews to sustainability aims (A4) and, in that context, neutral arbitration (O1) and creation of new networks (N1)
Kanda et al. (2018)	Germany and Sweden	A case study on five German and four Swedish intermediaries resting on interviews with key staff in the organizations and documentation analysis of websites and reports	German and Swedish intermediaries within the eco-innovation sector	Fostering networking and partnerships outside the traditional boundaries of firms is a common intermediation activity among the studied cases
Matschoss & Heiskanen (2018)	Finland	A case study on the collaboration between the Finnish energy company, Helen, and the innovation intermediary, FVH, using participant observation and interviews to generate data	A large Finnish energy company, Helen, and the innovation intermediary, FVH	FVH as an intermediary organisation can offer the energy company new opportunities for networking with actors that they are not likely to meet through their established collaboration channels
Garengo (2019)	Italy	Six Italian bridging organizations were investigated by way of in-depth interviews with five people at	Six Italian bridging organisations with different profiles	In managing networking activities, bridging organisations drive enterprises to learn about acquiring

		each case organization		knowledge on and understanding of their position in the business network and perceiving the advantages of possible changes

In a study of the cooperation between SMEs and intermediaries in selected regions of Sweden and Germany, Kanda finds that intermediaries commonly assist firms in fostering network and partnerships outside their traditional boundaries (Kanda et al., 2018). A similar conclusion is reached in a Finnish case study on the cooperation between an innovation intermediary and an energy company (Matschoss & Heiskanen, 2018), while a survey-based study with 309 Spanish firms concludes that cooperation with RTOs improves the firms' ability to utilize knowledge external sources (Barge-Gil & Modrego, 2011). Likewise, a series of studies on the collaboration between small and medium sized firms and the collective research centers (CRCs) in Belgium provide evidence that the cooperation results in enlarged networks for the firms (Knockaert & Spithoven, 2009; Knockaert et al., 2014), which also benefit from being connected to technological expertise by the CRCs.

5.4. RTO perspective on innovation effects

The previous sections have dealt with studies that make inferences about the effect of RTO collaborations on firms in a direct manner, i.e. the firm (SME) as the unit of analysis. There is however also literature taking the perspective of the RTO, amongst other things inquiring about the roles an RTO should play in order to serve their (SME) clients well. A general observation by Spithoven et al. (2010), who examine the activity of collective research centres in Belgium, places emphasis on these organizations' role to help build absorptive capacity within their client-firms by providing knowledge intelligence, agency and repository services. Indeed, firms in the more traditional industries confronted with an ever more 'open' way of innovating might have trouble building these capacities internally. As such, RTOs provide a viable alternative and a way to source these capacities externally. To effectively achieve this role of 'knowledge broker', RTOs might need to possess certain characteristics, tied to the environment in which they operate, the nature of their clientele, etc. In this section, we summarize the literature on optimal RTO characteristics and focus on innovation effects since innovations are usually the central objective in these collaborations. These studies address the contingencies of RTO-firm collaborative innovation performance from the viewpoint of the RTO.

Albors-Garrigós et al. (2010) take a regional perspective and analyze which strategies are conducive to better performance of RTO R&D units in the Basque Country in Spain. They find that financial indicators such as sales performance are not to be a clear independent objective for RTOs but rather a means of survival. In order to achieve alignment between RTO and client-firm, emphasis should be placed on implementing organic organizational structures and achieving strategic fit with the served sector. Interestingly, they do not find an effect of technology transfer management on the RTO R&D units' innovation performance. This surprising result is attributed to the fact that the RTO R&D units in their analysis serve specific and distinct sectors, which have diverse technology transfer requirements.

Landry et al. (2013) analyze the business models of 81 publicly supported Canadian KTTOs and find that KTTOs devise specific types of business models that are fit to activities along different stages of the value chain. They conclude that KTTOs should tailor their business model and offer customized solutions to their client base in order for the collaborations to deliver maximum value. This, in turn, could increase the value captured by the RTOs and allow them to become less dependent on governmental funding.

In an empirical study on 27 RTOs in regions Valencia and the Basque country (Spain), Rincón-Díaz & Albors-Garrigós (2017) focus on identifying the strategies RTOs use to be able to adapt flexibly to their environments. Based on the results of a cluster analysis and under the approach of contingent theory they find that RTOs "can cope with the turbulence of the environment through a contingent relation between their organizational structure and their strategy" (p. 194). They further identify implementation of mixed RTO-client teams and getting to know the clients' innovation strategy as best practices conducive to the RTOs' (financial) performance. Although several types of financial and conceptual barriers (such as tensions between innovation cultures, risk perceptions) to RTO-firm collaboration are identified, encountering one or the other is not found to have a differential impact on RTO performance.

In a sample of 67 Russian RTOs, Thurner and Zaichenko (2015) find that high tech and low tech clients of RTOs have different needs. Whereas for high tech clients, the use of patents and intake of scientist are vital for successful technology transfer, low tech clients benefit when RTOs have their own basic research to offer them.

The literature thus generally stresses the need for tailored RTO business models, strategies or organizational structures as vital to success of RTO-firm collaborations. The firm innovation performance effects (from section 5.2) should thus be viewed against this backdrop, since they

seem to realize to a larger or smaller extent, depending on the fit between the firm and the RTO.

Table 5.4: Overview of the RTO perspective innovation effects of RTO-cooperation*)

Author	Context	Data	Empirical focus	Indicator
Landry et al. (2013)	Canada	81 publicly supported Canadian KTTOs	RTOs' business models	Indicators from factor analysis on survey data
Rincón-Díaz & Albors-Garrigós (2017)	Spain	27 RTO in regions Valencia and the Basque country	RTOs organizational structure & strategy, barriers to collaboration, collaboration best practices	Indicators built from factor analysis on survey data
Albors-Garrigós et al. (2010)	Spain	RTO R&D units in the Basque Country	Strategies of the RTOs' R&D units	Financials, strategy indicators built from factor analysis on survey data
Thurner & Zaichenko (2015)	Russia	Sample of 67 Russian RTOs	Strategic fit of RTO high tech vs. low tech clients	Patents, scientific employees
Spithoven et al. (2010)	Belgium	Population of collective research centres in Belgium	Knowledge brokering role of the RTO	Indicators from survey responses

5.5. Limitations and proposed solutions

As demonstrated in the evidence hierarchy tables in section 4, e.g. tables 4.9, 4.10 and 4.11, the identified literature lies low in the hierarchies, meaning that the studies in general display lower levels of reliability and generalizability. Especially the case studies are often tailormade to specific research questions and difficult to generalize. The many qualitative single case or quantitative cross section survey studies give, on the one side, low transferability to a Danish context, but also, on the other side, a larger number of studies pointing in the same direction, i.e. common evidence patterns. This means that even though the individual conclusions drawn in the present review are less robust than wanted, the overall judgement is still that the results are robust, usable and representing general tendencies as shown in sections 5.1 – 5.4. Hence, while the effects are positive and present, it is much more difficult to judge how large these effects are in general.

The overwhelming and diverse use of case studies reflects two challenges in the identified effect studies. The first challenge is to isolate an effect from other factors that may cause the same kind of effects. Only a small number of studies compare 'treated' firms or cases (collaborating with an RTO) with similar 'non-treated' firms or cases by matching, which suggests that this solution is apparently too difficult (cf. table 4.11). The second challenge is that performing methods high on the empirical evidence hierarchy requires large data sets, e.g. register data, which rarely exists and often is collected for other purposes and thus lacks nuances in the available measures. Here, case studies may instead offer a large palette of knowledge tailor-made to the concrete aims of the study, and may therefore be able to identify and describe effects with a high level of detail. However, the drawback is a lower statistical generalizability.

Even with the MSSD approach in mind, the identified studies investigate to fragmented issues to allow robust conclusions on many of the interesting policy dimensions, e.g. whether studies higher on the evidence hierarchy revealed lower effect sizes than studies lower on the evidence hierarchy or whether non-R&D collaborating firms become R&D firms afterwards. Such questions could be answered if enough literature was identified, i.e. through an effect size meta-analysis known from e.g. the health literature and more seldom from the social sciences literature. However, the present review is not able to perform such an analysis as to few studies use sufficiently identical measures in similar contexts. This is the case for both qualitative and quantitative studies. As we have only found very few larger empirical studies that are situated high on the empirical evidence hierarchy (e.g. performing randomized (pseudo-)controlled trials, balanced or longitudinal studies) future research using these techniques and methods would contribute to future recommendations build on more robust and statistically reliable studies. Such studies are scarce and therefore also limited in the present review.

Future studies situated high on the evidence hierarchy could inform the discussion on whether case studies (lower on the evidence hierarchy) consistently find larger effects than quantitative controlled trials approximated studies, e.g. a case study bias caused by selection of prominent cases. However, the identified literature in the lower end of the evidence hierarchy did to a large extent support the causal hypothesis suggested in referenced studies showing similar results (parallel evidence), thereby securing a minimum of coherence, replicability and similarity. Contrarily, the more direct and experimental-like studies (higher on the evidence hierarchy, securing unbiasedness from hidden confounding influences) have been scarce among the identified literature and have usually analyzed different measures (cf. table A.3), which makes a meta-analysis difficult and close to impossible based on the identified and included studies in the review.

The question regarding whether non-R&D firms become R&D firms is also difficult to determine from the collected literature in the present review. However, Som et al. (2015) show that both non-R&D and low R&D intensive firms successfully utilize external knowledge sources in their innovation, e.g. are potential RTO clients. They find that such firms demand 'practical' innovative knowledge closer to their own value chains or markets compared with R&D intensive firms, i.e. sector specific or regional RTOs have a market among non- or low-R&D intensive firms. Furthermore Moilanen et al. (2014) also show that there exists a relationship between insourcing external knowledge (from e.g. RTOs) and the firms' absorptive capacity as input to increase their innovation performance. However, they find that an effect through the absorptive capacity is not the case for non-R&D firms where solely the external knowledge has a direct effect on the firms' innovation performance. One could therefore argue, that these results justify an innovation system where firms may approach knowledge mediators such as RTOs without prior R&D or innovative competences.

Similarly, an interesting result for the present review could be whether different types of initial firm-RTO collaboration gives different effect types and sizes. A thorough reading of the identified literature however reveals that not all of the literature does explicitly distinguish or mention whether e.g. the firm-RTO collaboration was part of a commercial program (firms buy knowledge), part of a publicly financed program (free of charge or reduced price for the firms) or something third, i.e. inconclusive collaboration types. Without being close to fully accountable, it seems that more studies involve commercial based than public financed collaborations. However, the results, the context and the methodologies are also so diverse that common or general conclusions on effect sizes across collaboration types are not possible or robust, i.e. meaningful. Hence, while the included literature does not contain enough information to decide which collaboration type that creates the largest effects, such a question could be interesting to answer in future studies.

In a Danish context, Guerrero (2020) investigated whether firms that collaborate with external knowledge providers become more likely to collaborate with universities afterwards. He finds that firms based in peripheral and metropolitan regions with universities that collaborated with RTOs were more likely to collaborate with universities afterwards. However, this was not the case for firms in non-metropolitan university regions. Knowing that most, or almost all, R&D performing SMEs with highly educated employees are situated in the metropolitan areas, the

effect found may rely on absorptive capacity, cf. Moilanen et al. (2014), more than on geographical placement. Hence, there seems to be a role for RTOs in all areas but different roles, depending on the firm (and RTO) characteristics.

6. Discussion and conclusion

The role played by the RTOs differs depending on the client they are collaborating with. Larger and R&D heavy organizations might require specific R&D services, whereas smaller R&D light or non-R&D firms might in the first place need help to find out what they might be able innovate and which partners can help them do so. Since these smaller non-R&D active firms often do not have the required knowledge base to make direct interaction with other actors in the innovation system, RTOs then perform the role of bridging organizations. The focus of this report is on RTOs in this role of match-maker between SMEs that aspire to innovate and potential knowledge providing parties, and to summarize the existing empirical literature on the matter.

This study categorized three types of effects RTO-collaborations might have on the firms contracting with them: effects on economic performance, effects on innovation capacities and networking effects. Although there is heterogeneity in the size of the effect found in the literature, most of the identified studies point towards the presence of positive effect 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.

We find that evidence on the firm level effects of RTO collaboration is scarcer opposite to, for example, the large literature on TTOs' collaboration with firms. However, on this smaller scale, similar positive effects seem to be expected or obtained. Strong empirical evidence is difficult to obtain since SMEs are vulnerable economic units in open economies where they encounter multiple changes over time. Hence, it is difficult to identify and measure their effects of collaboration with RTOs. Many of the currently existing studies are thus based on cases and qualitative methods, with only few quantitative studies identifying firm level effects on larger samples. The liability and generalizability of future empirical evidence could therefore benefit from studies confronting these statistically and methodologically weaknesses by e.g. analyzing larger samples over time with control groups etc., i.e. semi-natural experiments with less risk of biases, thereby delivering more robust policy relevant advices.

Several options exist to meaningfully broaden the current strand of the literature. First, longitudinal studies on additionallity over time are lacking. For instance, it could be interesting to find out to which extent the effects of a current RTO-collaboration cause additional investments after the collaboration ends. Investigating the effect on firms' future innovation capacities, e.g. measured by employee educational levels or R&D-like investments is another interesting route in this regard. Also studies addressing effects on firm innovativeness and placement on the technological frontier — non-R&D firms becoming R&D-firms (e.g. measured by collaboration with science institutions as in Guerrero, 2020), or pushing R&D firms further towards the technological frontier, e.g. measured by firms shifting from purely 'new to firm innovations' (incremental innovation) to 'new to market innovations' (more radical innovations) — is warranted.

Second, the current literature is rather silent with regard to the difference in the effects of commercially vs. fully or partly publicly financed collaboration. More transparency is warranted to inform the public policy debate on government intervention to address innovation market failures. In order to become able to gauge the efficacy of current policy, it remains to be studied whether and to what extent such differences in effect or perceived value exist. Relatedly, to study possible interference between several public interventions, it would be interesting to find out what the effects are on firms that enter into a mixed set of policy-programs. Fourth, there exits opportunities to study firm-RTO interactions in specific areas of (policy) interest studies, for example, the broader societal impact of RTOs on climate change and the digital transformation (industry 4.0).

As evidence based policy requires studies with high reliability, i.e. high evidence hierarchy scores, basically any kind of statistically robust studies high on the evidence hierarchy, and focusing on these subjects would increase the present knowledge base allowing a better foundation for evidence based policy. Such studies are still lacking in numbers, and would be advisable to have in planning for optimal innovation system conditions, i.e. infrastructure, in the Technology Service policy areas. For now, the evidence is significantly in favor of positive effects of collaboration with RTOs, but is mainly based on smaller scale and fragmented studies from which the magnitude of the widespread effects is difficult to determine.

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Appendix A: Characteristics of the reviewed literature

Table A.1: Overview of reviewed literature

Reference (author, year, journal, publisher)	Purpose/Topic/Focus/RQ	Design/method Analysis period Evaluation unit	Country/population/setting	Evidence Hierarchy[5]	Transferability[6]	Tags	Primary findings
Albors-Garrigós, J., Zabaleta, N., & Ganzarain, J. (2010) *R & D Management, 40*(5), 435-454.	Proposes a model to identify organizational factors in RTOs that affect performance and strategic alignment between RTOs and their clients	Personal interviews Questionnaire (mostly closed questions) Dependent variables: R&D unit's turnover and innovation RTOs divided into clusters with different characteristics	22 managers of R&D units in the Basque Country in Spain Regional	2/3	Less	RTO perspective; economic performance; innovation processes; mixed method	• Both dependent variables (turnover and innovation) are significantly different within different RTO clusters • No findings of interest regarding client firms. Focus lies on the R&D units' turnover and innovation
Arnold, E., Brown, N., Eriksson, A., Jansson, T., Muscio, A., Nählinder, J. & Zaman, R. . (2007). *VINNOVA Report: The Role of Indus-*	Report on the Swedish Research Institute System Analyzes the roles of six applied research institutes in Sweden and how these differ	Interviews	Six selected applied research institutes (ACREO, IVF, SIK, The Swedish Foundry Association and SP) and their clients Sweden	2/na	Yes	RTO perspective; qualitative	• Differences in firms' decisions on using the institutes: *The SMEs decided on a rather ad hoc basis, buying projects as and when needed. Foreign-owned multinationals tended to have a central*

[5] See Appendix B

[6] 'Transferability' to a Danish GTS-like context means that the study, its results or purpose contributes with evidence suitable in the present Danish innovation policy framework for the Danish GTS-system. A 'Less' means that the literature deals with broader evidence of e.g. national innovations systems or sectors not covered by the GTS-like System, or illustrates mechanisms behind collaboration effects using data from less comparable countries or innovation systems. The evidence can deal with firm as well as RTO system perspectives.

Note: direct quotes from the publications are italicized

trial Research Institutes in the National Innovation System. VINNOVA.	from the role of universities (chapter 5) Includes a section on the clients and how they use the research institutes.		National				*decision-making process for R&D, but it was possible to make use of the resulting R&D budgets to some degree* • *For some of the customers, university or scientific knowledge was too remote to access. The institutes provided a very useful bridge that allowed them to benefit from scientific knowledge that they could not themselves have exploited directly.*
Arnold, E., Clark, J. & Jávorka, Z. (2010). *Impacts of European RTOs - A Study of Social and Economic Impacts of Research and Technology Organisations - A Report to EARTO*. EARTO.	Begins by discussing and defining RTOs and estimating the size of the sector – including how RTOs are different from universities. Contains a review of previous studies of the impacts of European RTOs.	A literature review supplemented by own survey are used to conclude on the economic impacts of the RTOs	38 EARTO members Denmark, other Nordic and other European countries Multinational	3/1	Yes	Firm perspective; economic performance; quantitative	• Contains the EARTO definition of RTOs and their functions • Chapter 4 discusses the methodology and findings on previous studies on the economic impacts of RTOs • Conclusions on the macro-economic impacts • Identifies spill-over effects: *The presence of spillovers implies that social rates of return will exceed private rates* • *Conventional estimates of the magnitude of the private rate of return (from firm-level econometric studies) suggest something in the region of 15-25%. Econometric studies suggest that industry rates of return (where spillover*

							benefits to other firms in the same industry are also taken into account) are about double this
Barge-Gil, A., & Modrego, A. (2011) *Journal of Technology Transfer, 36*(1), 61-83.	Investigates the impact of collaboration with RTOs on firm competitiveness PROs vs. TIs	Quantitative survey 2003-2005 Empirical model for impact determinants	257 Spanish firms collaborating with TIs or PROs National	3/3	Yes	Firm perspective; Innovation processes; networking/collaboration; economic performance; quantitative	• *TIs have more economic impact than PROs* • The percentage of staff with a university degree is linked to economic impact • Relationship characteristics between RTO and firm affect impact • *Technical motivations affect economic impact, the impact on investments and the general satisfaction*
Barge-Gil, A., Santamaría, L., & Modrego, A. (2011) *European Planning Studies, 19*(2), 195-215	*investigates the different roles played by universities and technology institutes (TIs) as innovation partners of firms.* Describes the characteristics of firms working with TIs vs. firms working with universities	Descriptive analysis: two-sample t-test and x^2 test Econometric analysis to check the robustness of the descriptive analysis: Random effects probit model to observe the influence of various firm characteristics on their probability to cooperate only with TIs or only with universities 2003-2004	8720 Spanish firms collaborating with TIs or universities Information on both the general characteristics of firms and the innovation processes of firms National	3/2	Yes	Firm perspective; innovation processes; quantitative	• *Firms collaborating with universities are bigger, have higher internal capabilities and are less dependent on their external relationships* • *Firms collaborating with TIs are smaller, have weaker internal capabilities but are more open to their environment and thus more reliant on external sources.* Thus, smaller firms need help in their innovation processes • Firms collaborating with TIs are more dynamic in terms of organization *in the sense that they are more likely to achieve manage-*

							rial and strategic innovations. Universities tend to focus more on the technological or scientific arena
Batterink, M. H., Wubben, E. F. M., Klerkx, L., & Omta, S. W. F. (2010) *Entrepreneurship and Regional Development, 22*(1), 47-76	How do innovation brokers successfully orchestrate innovation networks of SMEs?	In-depth case studies	Four case studies in the agri-food sector from different countries: the Netherlands (2003, 2005), Germany (2001) and France (2001) 4-5 interviews per case study Multinational	2/na	Less	RTO perspective; innovation processes; qualitative	• Innovation brokers orchestrate innovation initiation by incorporating the actual innovation needs of SMEs in the innovation project, by being strongly embedded in the social and business networks of the SMEs, by enhancing transparency and by facilitating interaction between network members • Innovation network composition can be successfully orchestrated when innovation brokers maintain a large and diverse network • When orchestrating network composition, innovation brokers take the lead in setting up the coordination mechanisms • Innovation brokers should take the lead in handling conflicts that accompany the inter-organizational processes, thereby orchestrating the actual innovation process
Cantù, C., Ylimäki, J., Sirén, C. A., & Nickell, D. (2015)	How can technological hubs (THs) help firms connect with horizontal networks	Longitudinal case study of an Italian technologic hub, ComoNExT, that	70 semi-structured interviews with key referents of ComoNExT combined	3/na	Yes	RTO perspective; networking/collaboration; qualitative	• In the shift from outsourced innovation to co-managed innovation, firms need to select and involve both

Journal of Business and Industrial Marketing, 30(8), 951-961	and how can THs assist firms on finding suppliers and customers from the vertical network with whom to collaborate?	aims to improve the competitiveness of its local economy	with secondary data gathered from the firm's website, reports, trade press and other company documents Italy Local				vertical (i.e. suppliers and customers) and horizontal (i.e. universities and research centers, public organization and knowledge intermediaries) relations in innovation development • THs facilitate and support relationships among actors belonging to different positions but characterized by the same relational proximity
Clayton, P., Feldman, M., & Lowe, N. (2018) *Academy of Management Perspectives, 32*(1), 104-124	To improve our understanding of intermediaries in the commercialization of science	Literature review for each type of intermediary: providing a definition and considering the contribution of the intermediary and the related policy implications	Five types of intermediaries: - university technology transfer and licensing offices (TTOs) - physical space providers? - professional services providers; - networking, connecting, and assisting organizations - finance providers For each category an extensive literature search using a variety of keywords through online searches of bibliographic databases was performed	5/na	Yes	RTO perspective	• Definitions and descriptions of primary role in scientific entrepreneurship for all the different intermediary types (see table 1, pp. 108) • *Incubators, accelerators, and co-working spaces offer firms and entrepreneurs varying levels of support with one common feature: the provision of a laboratory and/or workspace* • *The ability of TTOs to accumulate stocks of human, network, and technological capital make them important players in ecosystems*

			European as well as non-European cases Multinational				
Colombo, G., Dell'Era, C., & Frattini, F. (2014). *R&D Management*, *45*(2), 126-146.	Develops a typology which helps to distinguish between different innovation intermediaries in terms of their different contributions to handling clients' new product development (NPD) problems	Multiple case study Interviews innovation intermediaries' founders and senior managers Interviews with client firms Across-case matrix	4 innovation intermediaries and 12 clients European as well as non-European cases Multinational	2/na	Yes	RTO perspective; innovation processes; qualitative	• *Innovation intermediaries should be distinguished into four classes, labeled* broker, mediator, collector *and* connector, *based on how they* access *their sources of knowledge and* deliver *value to their clients*
Comin, D., Licht, G., Pellens, M., & Schubert, T. (2019). *Do companies benefit from public research organizations? The impact of the Fraunhofer Society in Germany*. Discussion paper.	Analyzes *whether project interaction with Fraunhofer affects the performance and strategic orientation of firms.*	*Using instrumental variables that exploit the scale heteroscedasticity of the independent variable (Lewbel, 2012), we identify the causal effects of Fraunhofer interactions on firm performance and strategies* 1997-2014	Firms interacting with the Fraunhofer society Germany National	2/4	Yes	Firm perspective; economic performance; quantitative	• *strong, positive effect of project interaction on growth in turnover and productivity… one percent increase in the size of the contracts with FhG leads to an increase in growth rate of sales by 1.3 percentage points, and to an increase in the growth rate of productivity by 0.8 percentage points in the short-run* • *considerable long-run effects accumulating to 18% growth in sales and 12% growth in productivity over the course of 15 years*
Department for Business Innovation and Skills, UK. (2015). *Research*	*This paper is a preliminary empirical account of what RIOs do to support innovation*	Case studies, surveys, interviews and site visits	16 Research and Innovation Organizations in the UK National	2/na	Yes	RTO perspective; innovation processes; qualitative	• Identifies three broad *innovation-related activities: : (1) Support to industrial innovation, involving scien-*

and Innovation Organisations in the UK: Innovation Functions and Policy Issues.							*tific development of industry knowledge bases, problem solving and advice, and in-house product and process development, (2) Infrastructure creation and maintenance, involving provision of specialised or large-scale capital goods, instruments and equipment, and storage of scientific and/or industrial materials and data, and (3) Public policy development and implementation, involving contributions to policy development and implementation, contingency planning and monitoring for accidents and natural disasters, and social and health innovation.*
Dicecca, R., Pascucci, S., & Contò, F. (2016) *British Food Journal, 118*(8), 1857-1882	Exploring *how innovation intermediaries engage with smallholder farmers and provoke value chain reconfigurations*	Systematic literature review of case studies	Inclusion criteria: literature dealing with smallholder farmers, innovation and intermediaries Cases from both Africa, Europe and Asia Multinational	5/na	Less	RTO perspective; System view	• Identifies 3 types of intermediaries: consultants, KTOs, and broker organizations • Each type facilitates change in the value chain in different ways (different types of innovation processes)

Dietsch, D., & Khemiri, R. (2018) *International Journal of Innovation Management, 22*(6)	Examining the relationship between knowledge acquisition (e.g. knowledge transfer) and performance of innovation projects. Examines the role of innovation intermediaries in innovation projects.	Survey study Performance of innovation projects is measured in cost, time and quality Interviews with innovation directors.	360 individuals engaged in innovation projects 10 innovation directors. France National	2/1	Yes	Firm perspective; innovation processes; mixed method	• Knowledge obtained through third parties positively impacts the performance of innovation projects in terms of *cost, time and quality*
Dornbusch, F., Lehmann, H., Pohle, A. & Radic, M. (2018). *The Significance of the Fraunhofer-Gesellschaft for the German SMEs with which it Cooperates*. Fraunhofer Society. Study summary.	*The objective of this study is to empirically examine the significance of the Fraunhofer-Gesellschaft for German SMEs as cooperation partners. It also discusses the approaches available for improving collaboration.*	Online survey and interviews A 2-page summary – does comment on the methodology	SMEs cooperating with the Fraunhofer Society Germany National	2/na	Yes	Firm perspective; innovation processes; qualitative	• *Collaboration between Fraunhofer and SMEs is considered positive and extremely important for both sides. The results from the company survey show that it is primarily SMEs with a strong focus on R&D and innovation that collaborate with Fraunhofer* • *the majority of companies consider "product and technology development" to be an important field for collaboration with Fraunhofer.* • *In contrast, the fields of "industrial property rights, norms, standards," and "market-related services and training programs" are deemed by SMEs to be less relevant for collaboration, which also applies to the field of "R&D services*

							and knowledge-based consulting."
Fernández-Esquinas, M., Merchán-Hernández, C., & Valmaseda-Andía, O. (2016) *European Journal of Innovation Management, 19*(3), 424-442	Comparing the effectiveness of TTOs, science parks and regional innovation agencies in establishing connections with universities. RQ1: *What kind of firms use Triple Helix organizations and for what purposes?* RQ2: *How are the effects of these relationships perceived by the firms?* RQ3: *Do different interface organizations have a specific role in promoting knowledge transfer between universities and firms considering the wide range of collaboration channels?*	Triple Helix Approach Questionnaire Descriptive analysis Regression analysis Dependent variables: Importance attributed to TTOs/research parks/the regional innovation agency (considering their role in establishing links to universities)	800 innovative firms in Andalusia, Spain Regional	2/1	Less	Firm perspective; networking/collaboration; quantitative	• Generally, research parks and innovation agencies show greater effectiveness than TTOs • Different organizations have different roles in the knowledge transfer taking place between firms and universities – it depends on *firms' absorptive capacity and the type of links that firms establish with universities* • Most significant differences are found in *the type of activities carried out in cooperation with universities*
Forsknings- og Innovationsstyrelsen (2009). *A Step Beyond: International Evaluation of the GTS Institute System in Denmark*.	Report evaluating the Danish GTS-institutes and their role in the Danish innovation system Recommendations for best use of the	Based on 4 previous reports User survey on the performance of the GTS-institutes (reference to a survey by Oxford Research in 2008)	GTS-institutes and GTS-users Denmark National	2/1	Yes	Firm perspective; innovation processes; quantitative	• Central recommendation: the GTS-institutes should do more R&D *to be able to support increasingly sophisticated companies in their innovation effort* • *Customer satisfaction is very high: 93% are either*

	GTS-system's capabilities and for what they can do to keep their services up to date with the most recent developments within technological service. Contains a thorough description of the GTS-system						*completely or partly satisfied with the service they obtained. Some 84% of customers are repeat customers, indicating that this level of satisfaction is real* (section 3.5) • *GTS customers are markedly more innovative than a control group and are more engaged in international markets* (section 3.5) • *The main activities are given as 'transferring knowledge' and 'solving specific technical problems'* (section 3.5) • Section 5 places the Danish GTS-system in an international context
Forsknings- og Innovationsstyrelsen (2011). *Økonomiske effekter af erhvervslivets forskningssamarbejde med offentlige videninstitutioner.*	How does knowledge collaboration affect firm productivity? Examines effects of collaboration with: universities, GTS-institutes, and both universities and GTS-institutes Discusses the influence of different factors on the impact of the knowledge collaboration and the	Survey study Treatment group vs. control group Effect indicator: productivity per employee Difference-in-difference method applied OLS regression 1997-2008	Treatment group: 547 firms collaborating with public research institutions Control group: 547 firms that do not collaborate with public research institutions Denmark National	2/3	Yes	Firm perspective; economic performance; quantitative	• Suggests that there is a statistically significant, positive causal relation between collaboration with public knowledge institutions and productivity per employee • Section 4 is on economic effects of the collaboration

	probability of participating in knowledge collaborations: employees' level of education, industry type, competence level						
Forsknings- og Innovationsstyrelsen, DAMVAD & Center for Forskningsanalyse (2010). *Produktivitetseffekter af erhvervslivets forskning, udvikling og innovation*.	How does investing in R&D activities impact firm productivity?	Econometric models Effect indicator: productivity per employee 1997-2006	12.252 firms (both R&D investors and non-R&D investors) Denmark National	2/1	Less	Firm perspective; economic performance; quantitative	• Firms collaborating with public knowledge institutions have a 15% higher productivity per employee (section 2.3) • Firms investing in R&D activities show 9% higher productivity per employee than innovative firms who do not invest in R&D – the effect is significant across industries but highest in the manufacturing industry
Forsknings- og Innovationsstyrelsen & Oxford Research A/S (2010). *Brugerundersøgelse af GTS-institutterne 2010*.	Examines: 1) GTS-users' innovativeness compared to non-users, 2) firm's satisfaction with their collaboration with the GTS-institutes, 3) non-users' familiarity with the GTS-institutes and their services	Survey study Treatment group vs. control group	1055 private users of GTS-services and 300 private non-users of GTS-services Denmark National	2/3	Yes	Firm perspective; innovation processes; quantitative	• Firms using GTS-services are more innovative than the control group • GTS-users perform more development activities and initiate more innovation processes and projects than non-users • The firms change knowledge provider depending on the specific development task (GTS-institute, university or private consultant). Private consultants are the firms´ first choice followed by the GTS-institutes

							• 95% of the GTS-users are very or somewhat satisfied with the collaboration • 2/3 user-firms state that they are very likely to repeat collaboration with the GTS-institutes • Control group firms show low familiarity with the GTS-institutes – 82% are not familiar with the GTS-institutes
Frietsch, R., Lutz, J., Neuhäusler P., Schubert, T., Lerch, C., Bethke, N., Rothengatter, O. . (2018). *Contribution to the German Innovation System - Fraunhofer Gesellschaft*. Study summary	*The objective of this study is to address Fraunhofer's contributions to Germany's success as a location for business and innovation and to demonstrate and measure the contributions*	*The study uses a systemic perspective that combines approaches based on innovation economics, micro- and macroeconomics*. Qualitative interviews A 2-page summary – does not say much on the methodology	Technology experts (interviews) SMEs collaborating with Fraunhofer Germany National	1/na	Yes	Firm perspective; economic performance; innovation processes; mixed method	• *The results showed that cooperation with Fraunhofer is of particular significance for innovative companies, for companies with a complex product portfolio, and especially for small and medium-sized enterprises (SMEs).* • *there was a significantly positive effect on operating income and EBIT (earnings before interest and taxes) for small and medium-sized companies.*
Fudickar, R., & Hottenrott, H. (2019) *Journal of Technology Transfer, 44*(2), 326-358	Examines whether collaboration with PRIs increase new-to-the-market product innovation in new technology-based firms	Questionnaire Outcome variable: market novelty. Control variables: firm characteristics. Correlation analysis: does interaction with PRIs correlate with market novelty?	German technology-based firms National	2/1	Less	Firm perspective; innovation processes; quantitative	• Firms collaborating with PRIs introduce more new-to-the-market products and services • However, the effect depends on the *interaction persistency, internal R&D and the founders' academic background*

Fukugawa, N. (2016) *Scientometrics, 109*(3), 2303-2327	Examines the characteristics and activities of the Japanese Kosetsushi (public institutes for testing and research). Compares Kosetsushi and universities as the collaboration partners of SMEs regarding technology transfer	Quantifies technology transfer activities using different databases on researchers and patent applicants. Spearman rank-order correlation coefficients between technology transfer channels and location quotients of the SMEs 2000-2009	Data from Japanese Kosetsushi, universities and SMEs Regional	2/1	Yes	RTO perspective; quantitative	• *Local SMEs' technological portfolio […] indicate a better fit with those of the Kosetsushi than with those of the local universities* • The characteristics of Kosetsushi are comparable to the characteristics of the Danish GTS-network
Fukugawa, N. (2018a) *Journal of Small Business Management, 56*, 297-322	*Identifies different channels through which different intermediaries could improve productivity effects of SMEs and assesses how these channels affected productivity growth differently.* Compares productivity effects between two types of intermediaries: cooperative associations vs. voluntary groups.	1992-1995 Switching regression model Dependent variable: annual average growth rate of SMEs' total factor productivity	Includes both participating and non-participating SMEs in innovation intermediary programs. Japan National	2/4	Yes	Firm perspective; economic performance; innovation processes; quantitative	• Cooperative associations helped SMEs improve their productivity through cost sharing (e.g. joint logistics) • Voluntary groups helped SMEs improve their productivity through knowledge sharing (e.g. joint R&D)
Fukugawa, N. (2018b) *International Entrepreneurship and*	Investigates what characteristics that affect business incubators' (BIs) perfor-	Survey data 2004-2006	Japanese business incubators within the high-tech sector (some established by local authorities,	2/1	Less	RTO perspective; economic performance; quantitative	• Physical factors of incubators (e.g. size and location) have no effect on performance

Management Journal, 14(2), 457-478	mance in their technology transfer (TT) function	Two-way error component regression model. Dependent variable: performance measure (cumulative number of incubatees that "graduated" business incubators) Control variables: Business incubator characteristics	some established by universities) National				• Different organizational factors are required for creation and growth of startups depending on the sector • Incubators which are successful in creating electronics startups use managers with diversified professional experience • In contrast, creation of biotechnical startups is affected by specialization in technological skills • Human resource factors are *insignificant in the early growth stage* • *Openness to foreign entrepreneurial firms facilitates the creation and growth of startups in electronics* • Results suggest that BIs should focus on designing a TT process that fits with sectoral innovation patterns and growth stages of startups
Fukugawa, N. (2019) *Scientometrics, 120*(3), 1475-1498	Examines the Japanese public research institutes, the Kohsetsushi, and how these institutes affect agricultural innovators and farmers	Measuring innovation output: data from registration of new plants developed by agricultural Kohsetsushi 2004-2016	National	3/4	Less	Firm perspective; innovation processes; quantitative	• *The results show that agricultural Kohsetsushi are found to act as a significant source of agricultural product innovations in the regional agricultural innovation system, with knowledge resources allocated in different levels of efficiency across products.*

Garengo, P. (2019) *Technology Analysis and Strategic Management, 31*(4), 477-491	Addresses the following RQ: *What activities could bridging organizations carry out to promote technology transfer in SMEs?*	Qualitative, explorative approach. Empirical investigation of 6 bridging organizations: interviews. Cross-case analysis.	6 bridging organizations operating in the North-East of Italy Regional	2/na	Yes	RTO perspective; networking/collaboration; innovation processes; qualitative	• Bridging organizations help SMEs to promote three abilities: *networking, integration and absorptive capacity* • The positive impact on the networking capacity promotes innovativeness in SMEs • Bridging organizations assist SMEs in turning knowledge into innovation
Gassmann, O., Daiber, M., & Enkel, E. (2011). *R&D Management*, *41*(5), 457-469.	Examines the role of intermediaries *in the cross-industry innovation process.* *The aim of this paper is to show which capabilities are required by an intermediary when the job of that intermediary is to transfer existing solutions from one industry to another by using analogies.*	Methodology in 3 stages: 1) initial interviews with 4 German and Swiss-based intermediaries, 2) Survey (based on initial interviews), 3) 6 case studies	107 European manufacturing firms (Switzerland, Germany, Austria and Lichtenstein) + 6 *collaborative cross-industry innovation projects* Multinational	2/1	Less	RTO perspective; innovation processes; mixed method	• 3 types of intermediaries are identified • Innovation broadener: *is able to realize an innovative idea from a very distant context, the role of* innovation broadener *in the adaption or implementation phase remains minor* • Innovation leverager: *can realize innovation by applying an analogy within its field of corporate experience or within its employee's personal background* • Innovation multiplier: *acts within a narrower technological field of expertise but can lead innovation projects further into the adaption phase*
Giannopoulou, E., Barlatier, P. J., & Pénin, J. (2019) *Research Policy, 48*(1), 223-233	Examines *the innovative characteristics […] of firms that collaborate with RTOs versus universities*	Statistical analysis of Community Innovation Survey micro-data (2012)	Data based on 30.000 firms (SMEs and MNEs) in 8 European countries: Belgium, Spain, Italy,	2/3	Yes	Firm perspective; innovation processes; quantitative	• RTOs and universities have significantly different innovation impacts

		Dependent variables: (1) new-to-the-firm innovation, (2) new-to-the-market innovation, (3) world-first innovation	Luxembourg, Portugal, Finland, Sweden and Norway Multinational				• Firms that perceive RTOs as more important collaboration partners than universities are less likely to develop new-to-the-market innovations but are more likely to develop service innovations. Furthermore, these firms invest less in internal R&D
Goduscheit, R. C., & Knudsen, M. P. (2015) *Creativity and Innovation Management, 24*(1), 29-54	Examines the specific role of RTOs as intermediaries in the collaboration between SMEs and universities and the barriers which impede this collaboration	2011-2012 Questionnaires for each partner type: SMEs, RTOs and universities Factor analysis Independent means t-test regarding perceived barriers	151 SMEs, RTOs and universities Data from Denmark, Norway, Finland, Estonia, Latvia and Lithuania Multinational	2/1	Yes	Firm perspective; RTO perspective; quantitative	• *Universities experience lower barriers when collaborating with RTOs than with SMEs* • *SMEs perceive greater barriers in the collaboration with universities than with RTOs* • SMEs with experience from publicly funded research projects perceive higher barriers to collaboration with knowledge institutions (RTOs and universities) than SMEs without experience • SMEs are regarded as very important collaboration partners by the knowledge institutions • The SMEs, however, do not perceive knowledge institutions as equally important collaboration partners
GTS-foreningen. (2020). *GTS-institut-*	Focus on the financial performance of the GTS-institutes, the	Presents key figures from the GTS-institutes in 2020	GTS-institutes and GTS-users	2/na	Yes	RTO perspective; innovation	• GTS-services purchased by the firms: 4% sale of goods; 13% education, 40% test,

ternes performanceregnskab 2020: Banebrydende teknologi til dansk erhvervsliv.	central activities of the institutes, and their collaboration with firms. Firm cases present the benefits of collaboration with the GTS-institutes	Overview of 4 types of GTS-services purchased by the firms Firm cases Descriptive (no analysis)	Denmark National			processes; qualitative	development and calibration, 43% consulting services and commercial R&D • Positive feedback on the collaboration with GTS-institutes from the firms, whom report big effects of the collaboration (qualitative) • Specific examples of the nature of the collaboration
Guo, J. J., & Guo, B. (2013) *Asian Journal of Technology Innovation, 21*, 31-49	Examines the roles of innovation intermediaries in industrial clusters in the emerging economy of China. Considers intermediaries' functions at the different stages of the innovation process.	Case-based qualitative analysis Data collection: interviews, archives and observations	Case study of a textile industry intermediary in China Local	2/na	Yes	RTO perspective; innovation processes; networking/collaboration; qualitative	• Intermediary roles identified in the case study: *technology gatekeeper, technology spanner, technical problem solver and innovation resource integrator.* Each role is relevant at different stages in the innovation process. • Technology gatekeeper: supports knowledge flow between firms and external sources • Technology spanner: *accumulates knowledge about diverse clients* and *transfers tacit knowledge from one firm to another in an informal way* • Technical problem solver: creates value for firms by supporting the innovation process through *problem identification* and *specialized solutions*

							• Innovation resource integrator: links firms with other organizations
Iris Group. (2016). *Analyse af GTS-nettets teknologiske ydelser set fra et brugerperspektiv*	The aim of the report is to create an overview of the GTS services and their users, as well as the users' perception of the benefits of the GTS services provided	35 qualitative interviews and workshops with GTS-users Qualitative interviews with the 2GTS-institutes (about target groups, services and strategy) Questionnaire (active GTS-users) Analysis of existing data sets 2015-2016	GTS-users and GTS-institutes Denmark National	2/1	Yes	Firm perspective; RTO perspective; economic performance; innovation processes; mixed method	• Chapter 6 is particularly relevant – discusses the benefits of collaborating with the GTS-institutes from the perspective of the users • 54% of the firms state that the GTS-institutes are very significant or somewhat significant to their innovation and business development (ch. 6) • 69% of the firms state that the GTS-services have a positive impacts on their productivity and efficiency (ch. 6) • Over 60% of the firms believe that the GTS-institutes have a very significant or somewhat significant impact on knowledge transfer, solutions to technical issues, higher security in terms of complying to regulations, and higher product and service quality (ch. 6)
Kaiser, U., & Kuhn, J. M. (2012) *Research Policy, 41*(5), 913-927.	Examines the short- and long-term effects of membership of a research joint venture support	Causal effect study – treatment group vs. control group. Performance is operationalized as pa-	Treatment group: firms that have been members of a DIC Control group: firms that have not been members of a DIC	3/3	Less	Firm perspective; economic performance; innovation processes; quantitative	• Participation in a DIC has a statistically and economically significant effect on number of patent applications per year (both short- and long-term effects)

	scheme (Danish Innovative Consortia) on firm performance.	tent counts, employment and added value growth Difference-in-differences estimation is performed Data from 1990-2007	(matched with treatment group firms) Denmark National				• No short-term effects on employment, but positive effects on employment are detected the year after a DIC was joined • No statistically significant relationship between participation in a DIC and value added
Kanda, W., Hjelm, O., Clausen, J., & Bienkowska, D. (2018) *Journal of Cleaner Production, 205*, 1006-1016	Analysis of the different roles intermediaries take to facilitate eco-innovation in firms. Explores how the *roles of intermediaries in eco-innovation differ from the roles of intermediaries in "conventional" innovation.*	Exploratory study based on interviews and documentation analysis 2012-2016	Eco-innovation intermediaries in Sweden and Germany Multinational	2/na	Yes	RTO perspective; networking/collaboration; innovation processes; qualitative	• Roles identified: 1) *forecasting and road mapping*, 2) *information gathering and dissemination*, 3) *fostering networking and partnerships,* 4) *prototyping and piloting,* 5) *technical consulting*, 6) *resource mobilization, 7*) *commercialization*, and 8) *branding and legitimation* • The roles of eco-innovation intermediaries resemble the roles of "conventional" innovation intermediaries, though some characteristics were found especially relevant to eco-innovation intermediaries, e.g. *validating the environmental benefits*
Kanda, W., Río, P. D., Hjelm, O., & Bienkowska, D. (2019)	Develops an approach for analyzing the role of intermediaries in terms of supporting eco-innovation and developing	Iterative development of the analytical approach using literature, expert discussions and empirical case	Case examples of eco-innovation intermediaries in Sweden and Germany Multinational	1/na	Yes	RTO perspective; innovation processes; collaboration/networking; qualitative	• Finds that intermediaries support the development of the technological innovation system in terms of guidance of the search,

Journal of Cleaner Production, 227, 1136-1148	the technological innovation system functions in firms.	studies on intermediaries The analytical approach is employed on two example cases					market formation, legitimation and resource mobilization • Intermediaries support innovation by providing *test beds* for firms to test and evaluate products in the early stages of innovation (entrepreneurial experimentation) • Intermediaries contribute to the branding of eco-innovations – supporting *publicity* and *building public trust* in new innovations • Resource mobilization was identified as an important intermediary role in terms of providing in-house resources (funding, networks and technical experience)
Kivimaa, P. (2014) *Research Policy, 43*(8), 1370-1380	Creates an analytical framework for examining the role of government-affiliated intermediaries in socio-technical transitions. Furthermore, intermediaries' role as catalyst for sustainability transitions is explored.	Interviews with intermediary employees and mapping of the intermediaries' project portfolio. In addition, stakeholders were interviewed about their perception of the intermediary's role. 2011-2012	Empirical case study of Motiva and Sitra - two Finnish national-level intermediaries in the energy regime. Local	2/na	Less	RTO perspective; networking/collaboration; qualitative	• Finds differences and similarities in terms of the two intermediaries' functions. • Significant functions identified in both intermediaries relate to networking, knowledge accumulation and knowledge dissemination • Sitra is more focused on identifying societal needs and creating investments in new businesses • Motiva is more focused on *gate-keeping and brokering, provision of advice*

							and support, and policy implementation
Klerkx, L., & Leeuwis, C. (2009) *Technological Forecasting and Social Change, 76*(6), 849-860	Provides a *description of the emergence of different types of innovation brokers in the Dutch agricultural sector, and an analysis of their embedding*	Descriptive analysis Typology of different innovation brokers and their characteristics Data comes from the authors' previous studies	Innovation brokers in the Dutch agricultural sector National	2/na	Yes	RTO perspective; innovation processes; qualitative	• Creates an overview of the different innovation brokers in the Dutch agricultural sector, describing their functions, coverage, funding and innovation focus • Finds that innovation brokers *act as innovation catalysts, by fulfilling the tasks of demand articulation […], finding suitable cooperation partners in innovation processes […] and forging a connection with these actors, and facilitating interaction during the innovation process.* • Identifies some challenges to the innovation brokers' catalyzing activities: clients have difficulties in grasping *the nature and value of their activities* • The conclusion presents implications for policy (e.g. the role of the government in relation to the innovation brokers)
Klewitz, J., Zeyen, A., & Hansen, E. G. (2012) *European Journal of Innovation Management, 15*(4), 442-467	Identifies *the role intermediaries can play in an small to medium-sized enterprise's (SME's) pursuit*	Qualitative interviews Iterative approach Thematic analysis	Seven German metal and mechanical engineering SMEs participating in Eco-profit (an intermedi-	2/na	Less	Firm perspective; innovation processes; qualitative	• Finds that *a complex intermediary may strengthen an SME's absorptive capacity for eco-efficiency innovation*

	for corporate sustainability with a focus on eco-innovation	Examining the long-term effectiveness of program participation: interviews conducted years after participation	ary based eco-innovation program) before 2005. National				• *being directly assisted by external consultants, actively supported and approached by local authorities and then linked to other SMEs during the one-year Ecoprofits programme were the major benefits of participation* • Findings *indicate that Ecoprofits will be able to trigger long-term effects if businesses are involved in concrete follow-up programmes*
Knockaert, M., & Spithoven, A. (2014) *Regional Studies, 48*(8), 1391-1403	Examines under which conditions firm-technology intermediary interaction results in enhanced innovation speed	Data collection in 2 stages: (1) personal interviews on the CRCs' *activities, location drivers and their resource base,* (2) CEOs of the CRC member firms responded to an online questionnaire on *R&D-related activities with the CRCs* Dependent variable: innovation speed Independent variables: absorptive capacity at firm- and intermediary level	12 Collective Research Centers (CRCs) and their clients in Belgium National	2/1	Yes	Firm perspective; innovation processes; mixed method	• Did not *find that absorptive capacity at the technology intermediary level affected innovation speed positively* • *it is found that the intensity of interaction positively affects innovation speed (except in the case of low acceleration additionality)*

		and intensity of interaction					
Knockaert, M., Spithoven, A., & Clarysse, B. (2014) *Technological Forecasting and Social Change, 81*, 376-387	Examines *the conditions under which technology intermediaries contribute to knowledge and networking outcomes generated by the firms that call upon them.*	Interview with managers of the collective research centres (CRCs) Questionnaire on member firms' engagement with CRC-related activities, including questions on cognitive capacity Dependent variable: cognitive capacity additionality (measured as firm network and competence additionality) Independent variables: absorptive capacity of member firms, absorptive capacity the TI, and intensity of interaction	Firms collaborating with the Collective Research Centers (CRCs) in Belgium National	2/1	Less	Firm perspective; networking/collaboration; mixed methods	• Finds that, *both for R&D and R&D related activities, cognitive capacity additionality is positively affected by the intensity of use of the services offered by the technology intermediary, pointing to a significant learning effect* • *Interaction with TIs is mediating the effect of absorptive capacity at firm level and cognitive capacity additionality, with more R&D intensive firms calling more frequently upon the technology intermediary's services* • *Did not find absorptive capacity of the technology intermediary to positively affect the cognitive capacity additionality generated by the firms (except for competence additionality through R&D related activities), and even found a negative impact for the impact of absorptive capacity of the CRC on cognitive capacity additionality of the member firm in case of R&D related activities*

Landry, R., Amara, N., Cloutier, J. S., & Halilem, N. (2013) *Technovation, 33*(12), 431-449	Examines the roles of different types of knowledge and technology transfer organizations (KTTOs) at different points in the value chain of firms. Focuses on KTTO business models.	Quantitative survey study Dependent variables: *factors underlying the stages of service offerings by KTTOs* Econometric models	212 publicly supported KTTOs in Canada National	2/3	Yes	RTO perspective; innovation processes; quantitative	• Finds that *different types of KTTOs are specialized in differently emphasizing the provision of services at the different stages of the knowledge value chain* • *different types of KTTOs devise different types of business models that are centered on services linked to different stages of the value chain*
Lasagni, A. (2012) *Journal of Small Business Management, 50*(2), 310-339	Addresses 2 RQs: 1) *Whether SMEs that are proactive in strengthening their relationships with innovative suppliers and customers are more likely to achieve positive results in the innovation of products or services.* 2) *Whether innovative SMEs are more likely than other SMEs to take advantage of linkages with R&D laboratories and universities.*	Survey study Econometric models Dependent variable: Innovation performance Independent variable: External relationships for innovation 2008-2009	Managers working in SMEs in Austria, Germany, Italy, Hungary, Poland, and Slovenia (approx. 600 SMEs) Multinational	2/1	Less	Firm perspective; innovation processes; quantitative	• Finds that *innovative SMEs involve their customers and suppliers in the design process more than other firms* • Results suggest *that when the formulation and design stage of new products is accompanied by interaction with suppliers and customers, the innovation performance of SMEs can be improved.* • In addition, *the results of this paper confirm that having internal R&D resources (produced or acquired) is a significant point of strength for innovative SMEs*
Loikkanen, T., Rilla, N., Deschryvere, M. & Lehenkari, J. . (2013). *Roles, effectiveness, and im-*	*The aim of this study is to investigate the roles, legitimacy, and socio-economic im-*	*Case-study analysis of seven individual innovations involving a VTT contribution*	VTT in Finland Local	2/2	Yes	RTO perspective; innovation processes; mixed method	• Section 4 contains a toolbox for impact and effectiveness assessment • *VTT is an important collaboration partner for companies that have developed*

pact of VTT: Towards broad-based impact monitoring of a research and technology organisation. VTT	*pacts of VTT – Technical Research Centre of Finland.* Presents *a toolbox of methodologies for exploring VTT´s impact*	*Quantitative analysis of innovations in the SFINNO database concerning VTT´s contribution* Innovations from 1985-1998					*innovations and then launched them commercially. During 1985-2009, VTT collaborated in around 34% of all observed innovation projects (section 8.2)* • *As a collaborative partner and provider of expertise and know-how, VTT's role is considered especially important in the development of highly complex innovations, and VTT's significance is deemed higher in the context of developing more novel innovations (section 8.2)*
Lin, H., Zeng, S. X., Liu, H. J., & Li, C. (2016) *Journal of Business Research, 69*(11), 4831-4836	*This study proposes and empirically tests a theoretical framework for understanding the effects of intermediaries on corporate innovation performance.*	Survey study Measures: *innovation performance, ties with intermediaries, absorptive capacity* and *eight factors to measure the external environment*	289 Chinese manufacturing firms (top managers) Regional	2/1	Less	Firm perspective; innovation processes; quantitative	• *A successful transformation of these external advantages into substantive innovation requires effective and efficient knowledge integration. Firms need to invest to develop their absorptive capacity to track, evaluate, assimilate, and apply external knowledge*Finds that *firms' capacity plays a critical role in the processes when external knowledge leads to substantive outcomes. Intermediaries only play the role of a complement, rather than a substitute, for internal activities of*

							knowledge management. The outcomes of innovation search are context-dependent
Lin, H., Zeng, S. X., Liu, H. J., & Li, C. (2020) *Technovation, 94-95*.	RQ1: *do stronger ties with intermediaries actually lead to better innovation performance by building dynamic capability?* RQ2: *how do organizational strategies influence the path from ties with intermediaries to innovation performance?*	Survey study Dependent variable: innovation performance	289 Chinese manufacturing firms Regional	2/1	Yes	Firm perspective; innovation processes; quantitative	• *The empirical results showed that ties with intermediaries had a significant positive impact on firms' innovation performance* • *Dynamic capability, focusing on the sensing and reconfiguring processes, acted as a mediator in the relationship between ties with intermediaries and innovation performance* • *Firms' ties with intermediaries may enable firms to search the broader scope of organizations and the deeper depth of knowledge, but it is not sufficient to simply acquire outside knowledge. A successful transformation of these external advantages into substantive innovation requires effective and efficient knowledge integration*
Lin, M., & Wei, J. (2018) *Physica A: Statistical Mechanics and its Applications, 502*, 21-28	Examines *the effect of innovation intermediary on knowledge transfer by studying a simple model of technology*	Simulation impact study based on a proposed model of how RTOs influence firms' knowledge base in open innovation processes	Simulated data illustrating changes in impacts No geographical categorization	1/na	Less	Firm perspective; innovation processes; quantitative	• Finds that *the existence of innovation intermediary is conducive to the growth of knowledge. Interestingly, the scale of the innovation intermediary has little effect on the system knowledge growth*

	innovation and diffusion process on networked systems. Furthermore, *the study investigates the selection strategies of intermediary members*						• *The innovative ability selection strategy outperforms all the other strategies in promoting the system's average knowledge level.* • *Intermediaries help firms choose technology providers with a high level of knowledge enhancing the efficiency of knowledge transfer and eventually improving the knowledge growth of the whole system* • the *study provides a theoretical basis for the role of intermediaries in improving the efficiency of knowledge transfer*

Malik, K. (2012) n *2012 IEEE 6th International Conference on Management of Innovation and Technology, ICMIT 2012 \IEEE Int. Conf. Manage. Innov. Technol., ICMIT* (pp. 273-278)	*The paper provides an overview of the different functions of 'knowledge brokers' that have emerged to assist firms with innovation by connecting clients with external partners with a view to better informing the 'search and scanning' activities of the client firms*	Exploratory case study Semi-structured interviews with managers	4 UK organizations National	2/na	Less	RTO perspective; networking/collaboration; innovation processes; qualitative	• *Finding a solution to a technology/ business problem via an intermediary organization is part of the larger process of scanning, selection, adoption and exploitation* • *When adopting solutions from other industry sectors […] companies often rely on the intermediary organization to help reduce uncertainties frequently found during the fuzzy front end of innovation* • The case studies *confirm that the functions of an intermediary organization are more numerous, diverse and knowledge intensive than previous studies have implied. Intermediaries and their clients discover new needs and requirements for their intermediary roles*
Martínez-Vela, C. (2017). *Benchmarking Research and Technology Organizations (RTOs): A Comparative Analysis*. MIT Industrial Performance Center.	Comparative analysis between the SENAI Innovation Institutes (ISIs) in Brazil and RTOs (European and others)	Case analysis	Primary cases: The Fraunhofer Institutes in Germany and the Netherlands Organization for Applied Scientific Research Brazil Multinational	2/na	Yes	RTO perspective; qualitative	• Section 5 identifies key challenges faced by RTOsand key factors of success • *ISIs have the potential to become significant players in the Brazilian economy and potentially catalysts for change.*

Matschoss, K., & Heiskanen, E. (2018) *Technology Analysis and Strategic Management, 30*(12), 1455-1469	RQ1: *How does the collaboration of the intermediary and the local energy company unfold?* RQ2: *What are the impacts of the intermediary work on the local energy company in terms of enactment of transition pathways and what are the mechanisms causing the impact?*	Case study Semi-structured interviews Participant observation 2015-2016	Finnish energy company based in Helsinki: Helen Ltd. Local	2/na	Less	Firm perspective; networking/collaboration; innovation processes; qualitative;	• *The intermediaries can contribute to the transitions through disturbing existing structures, practices and behaviours from two levels: niche creation and regime destabilization* • Identifies *the role of networking between niches and regimes in the destabilisation of the existing regimes*
Mei, L., Zhang, T., & Chen, J. (2019) *Technological Forecasting and Social Change, 144*, 118-128	This paper studies *the effects of inter-firm linkages on the open innovation of small- and medium-sized enterprises (SMEs) from an innovation ecosystem perspective.* Two types of firm linkages are studies: *the Linkages of a SME with its Prominent Organizations (LPO) and the Linkages of the SME with its Service Intermediaries (LSI)*	Firm level Questionnaire 420 SMEs	Zhejiang Province, China Regional	2/3	Yes	Firm perspective; innovation processes; quantitative	*LSI played a dual role in the innovation activities of a focal SME in an innovation ecosystem. Apart from positively influencing the innovation performance of the focal SME, they had a positive effect on LPO, representing the bridge enabler to leverage the effectiveness of knowledge transfer in the SME's innovation ecosystem.*
Memon, A. B., & Meyer, K. (2017)	Identifies the roles and functionalities of innovation laboratories and how they	Methodology in three stages: 1) Web-based re-	35 innovation labs (mostly in developed countries but also a few in the BRIC	2/1	Less	RTO perspective; innovation processes; mixed methods	• Findings show that *the InnoLabs are helpful to business organizations in 1) increasing the novelty of*

International Journal of Service Science, Management, Engineering, and Technology, 8(1), 32-49	contribute to the innovation processes of business organizations	search (investigating characteristics of specific innovation labs), 2) Online survey with innovation labs, 2) In-depth expert interviews with innovation lab practitioners	countries – no further specification) European as well as non-European innovation labs Multinational				*ideas, 2) building human capacities, 3) acquiring knowledge and technical expertise, 4) dissolving management barriers for innovation, 5) reducing initial costs of new businesses, 6) accessing the complimentary assets, 7) reducing risks associated with the innovation, 8) sharing costs for the innovation projects, 9) lowering time to market, 10) alleviating dearth of resources, 11) integrating technology, 12) collecting the feedback, 13) applying the systematic innovation methodologies, 14) learning emerging trends, innovation-related problems, and their solutions, and 15) financing the innovation projects*
Miller, S. (2014) *Regional Studies, Regional Science, 1*(1), 145-151	*RTO functions must be tailored to their environments, but there has been little research into how these functions can be systematically deduced using the regional innovation system model as a normative reference. This paper examines the optimal functions*	*The methodological approach used draws upon Tödtling & Trippl (2005) in that an RIS with known weaknesses is taken as a starting point for 'remedial' prescription. RTOs, as a form of innovation interme-*	Scotland Strathclyde Technology and Innovation Centre (TIC) Local	1/na	Less	RTO perspective; qualitative	• *The RIS framework can be employed as a means of ex ante RTO evaluation.* • *Contemporary RTOs are increasingly flexible and varied in their roles.*

	of a new RTO in Scotland. *An ex ante analysis based on three thematic areas (linkages, themes and services, and strategic capability) is used to consider how this RTO can optimally function in an innovation system with recognized structural weaknesses.* RIS (i.e. regional innovation system)	*diary, occupy an influential position within the system.*					
Olmos-Peñuela, J., García-Granero, A., Castro-Martínez, E., & D'Este, P. (2017) *European Planning Studies, 25*(11), 2001-2020	*The purpose of this paper is to explore whether collaborating with public research organizations (PROs) contributes to strengthening the innovation culture of small and medium sized enterprises (SMEs).* *.. examining to what extent their innovation culture is reinforced by collaborations with research organizations and investigate the type of*	Survey of firms that collaborate with the largest Spanish PRO, the? Spanish National Research Council (CSIC). 1891 Spanish firms that established at least one formal research contract	Spain National	2/1	Less	Firm perspective; innovation processes; quantitative	• *… results indicate that SMEs differ greatly in their capacity to strengthen their innovation culture through collaboration with research organizations. We show also that firms with formal innovation plans that develop internal and external search strategies are more likely to improve their innovation culture as a result of collaboration with PROs.*

	organizational strategies that enhance this effect of collaboration.						
Parker, R., & Hine, D. (2014) *European Planning Studies, 22*(5), 1048-1061	Examines how *participation in intermediary knowledge transfer programmes can contribute to the development of firm capabilities for problem-solving and learning.*	Two case study intermediary programs 66 face-to-face semi-structured interviews ranging in length from 20 min through to over 2 h	Rural, regional and metropolitan Queensland in Australia Regional	2/na	Less	Firm perspective; innovation processes; networking/collaboration; qualitative	• *Our data show that knowledge intermediaries affect organizational learning capabilities by impacting on firms' network relationships, internal and external communication channels and internal learning processes which in turn affect the ability to interpret and use knowledge within the firm. This suggests that the role of knowledge intermediaries might be greater than facilitating interactions in the innovation system, as knowledge intermediation may affect the ability of firms to learn and absorb knowledge from their environment.*
Pesonen, P., Van Der Have, R., Saarinen, J., & Rilla, N. (2008) *VTT Technological Research Centre of Finland. Research Nores No. 2423* (pp. 3-36)	*In this paper, we … study SMEs and their collaboration activity with a large research and technology organisation (RTO) in Finland, VTT.* *We base our analysis on a comparison of two different collaboration strategies;*	Descriptive (correlation) analysis.	Finland 1 RTO – VTT VTT customer database + firm level administrative data + finish patent data Local	2/1	Yes	Firm perspective; economic performance; innovation processes; quantitative	• *We discover that the consecutive collaborators are, compared to the occasional ones, more often larger in firm and project size, have subtle growth, are active in patenting, are relatively older and are more R&D experienced. While the occasional collaborators are more often experiencing high growth,*

	maters and daters. Half of the collaborating SMEs are conducting consecutive RTO cooperation (i.e. maters), while the other half have a more occasional relationship with the RTO (i.e. daters).						*the consecutive collaborators dominate in the group of patenting and growing firms. VTT's role in the Finnish innovation system is significant as it serves a relatively large share of SMEs from various sectors and across different size classes.*
Rincón-Díaz, C. A., & Albors-Garrigós, J. (2013) *Direccion y Organizacion, 50*, 74-84.	*The objectives of this paper are to propose a contingent model linking context, organizational and performance variables, and to identify barriers that Research and Technology Organisations have to overcome to work with companies*	(theoretical) modelling	Study of 14 Research and Technology Organisations in the Valencian Community and 13 Research and Technology Organisations in the Basque Country. Regional	1/na	Less	RTO perspective; qualitative	• *The study identifies certain factors which could improve their performance to address properly changes in their environment and become more competitive*
Rincón-Díaz, C. A., & Albors-Garrigós, J. (2017) *European Journal of Management and Business Economics, 26*(2), 180-198	*Proposes a contingent model that facilitates knowledge of the strategies followed by the research technology organizations (RTOs), to adapt to the turbulence of their environment.*	Applying the proposed model in... factor analysis hierarchical cluster analysis based on a questionnaire of 50 questions covering eight areas of operation of the RTOs	27 RTOs of Valencia and the Basque Country, Spain Regional	2/3	Less	RTO perspective; economic performance, innovation processes, quantitative	• *The technological policy must consider the characteristics of each region to propose more efficient and equitable mechanisms that allow the RTOs to face new challenges.*
Robin, S., & Schubert, T. (2013)	The research *evaluates the impact of cooperation with*	(IV) regression analysis	France & Germany Multinational	2/4	Less	Firm perspective; innovation	• Finds *that cooperating with public research in-*

Research Policy, 42(1), 149-166	*public research organizations on firms' product and process innovations*	Community Innovation Survey data 2004 & 2008				processes; quantitative	*creases product innovation, but has no effect on process innovation, which depends more on firms' openness* • The *increase in product innovation is much higher in Germany than in France.*
Roessl, D., Kessler, A., & Fink, M. (2010) *The International Journal of Entrepreneurship and Innovation*, *11*(3), 199-207	*In this paper, we attempt to answer whether statefunded programmes aimed at stimulating SMEs to conduct technical feasibility studies together with RTOs are able to facilitate the interaction and instigate the transfer of external R&D knowledge between SMEs and RTOs* Identifies *prerequisites for SMEs to tap the full potential of their interaction with RTOs*	Examining SMEs' research proposals *Comparison of feasibility projects leading to follow-up projects and feasibility projects not leading to follow-up projects* Questionnaire examining 1) *the motivation of SMEs applying for the programme,* 2) *the attitude of SMEs towards RTOs,* 3) *perceived benefits to and satisfaction of SMEs concerning in the programme* 2002-2003	Examines 183 research proposals that were evaluated in the 'Feasibility Studies Program' of the Austrian Industrial Research Promotion Fund (RPF) Austria National	2/1	Less	Firm perspective; innovation processes; quantitative	• *The attitudes towards additional cooperation with the designer of the study as well as towards the assignment of further feasibility studies on new topics were very positive, which can be regarded as a sign of a long-term change of attitude* • *first-time applicants were remarkably successful: 14% of the feasibility studies resulted in follow-up projects, whereas in the group of SMEs that had done similar studies before, only about 9% of the studies were carried out via follow-up projects*
Roxas, S. A., Pirolic, G., & Sorrentinod, M. (2011) *Technology Analysis and Strategic*	*This paper aims at modelling a proper production function for the TT brokers, providing insights on*	Regression analysis Survey data	24 countries (Nordic, European and non-European)	2/3	Less	RTO perspective; economic performance; in-	• *Results showed how brokers can pursue more productive and targeted strategy in order to increase their impact and improve*

Management, 23(1), 7-24	*how to compare their performance and investigating the influence of external factors on their efficiency, in order to draw useful managerial and policy implications.*	63 responses at the organization level Ouput measures: *the number of deals (signed and under negotiation), technology profiles produced and promoted and number of new clients*	51 NUTS level 2 regions Multinational			novation processes; quantitative	*their performance (inter alia, by taking into account a 'pull' approach to technology and the need of a long-lasting relationship with the clients – small and medium sized enterprises (SMEs) in particular).* • Feasibility studies' impact on decisions: *we were able to prove a slightly significant correlation between the technical evaluation of the results and the intended continuation of the project* – particularly for smaller firms
Spithoven, A., Clarysse, B., & Knockaert, M. (2010) *Technovation, 30*(2), 130-141.	*This paper focuses on the role of collective research centres in building absorptive capacity at the inter-organisational level.*	Descriptive statistics interviews with CEOs of the CRCs and their member firms analysed in combination with secondary data.	CRCs in Belgium National	2/1	Yes	RTO perspective; innovation processes; mixed method	• *The paper demonstrates that the openness of the innovation process forces firms lacking absorptive capacity to search for alternative ways to engage in inbound open innovation. The paper highlights the multiple activities of which absorptive capacity in intermediaries is made up; defines the concept of absorptive capacity as a pre-condition to open innovation; and demonstrates how firms lacking absorptive capacity collectively cope with distributed knowledge and innovation.*

Spithoven, A., & Knockaert, M. (2012) *Innovation: Management, Policy and Practice, 14*(3), 375-387.	This paper positions collective research centres (CRCs) in the innovation system. *Further, it provides an insight into how collective research centres help firms, many of which are low tech SMEs, to build absorptive capacity for R&D activities.*	Descriptive statistics OECD R&D survey 1993-2005 12 face to face interviews with the CRCs' CEOs	Belgium/ 12 CRCs National	2/1	Less	RTO perspective; networking/collaboration; mixed method	• The researchers *find that collective research centres are unique actors in the innovation system, engaging in both R&D and technology transfer activities to an extent that depends on their size, R&D budgets and number of members and aiming at strengthening the members' absorptive capacity*
Styrelsen for Forskning og Uddannelse (2017). *Erhvervslivets investeringer i forskning og udvikling i Danmark 2017*	The report presents an overview of the key figures and trends regarding Danish businesses and their investments in internal research and development. Section 5 investigates the correlation between firms' use of public research in 2010 and their productivity growth from 2010-2014 Section 5.3 and 5.4 comments specifically on firms' collaboration with GTS-institutes	Correlation analysis Section 5: data from 2010-2014 Variables: 1) number of university educated employees, 2) firms' collaboration with Danish universities and other public knowledge institutions, 3) productivity growth	3.497 R&D active firms Denmark National	2/1	Yes	Firm perspective; economic performance; quantitative	• Firms that collaborated with a Danish university had a 3,5% productivity growth on average (section 5.3) • Firms that collaborated with a GTS-institute had a 2,4% productivity growth on average (section 5.3) • Firms that did not collaborate with either had a 0,9% productivity growth on average (section 5.3) • Higher productivity growth in firms with higher education intensity (section 5)
Tann, J., Platts, A. E., & Stein, J. (2002) *Technology Analysis and Strategic*	*This paper explores the roles and services provided by RTOs, together with the*	Semi-structured interviews with RTO CEOs	9 RTOs (all but one were AIRTO members)	2/na	Less	RTO perspective; qualitative	• *Interviews with RTOs revealed that an unsupported market for knowledge services to*

Management, 14(2), 241-249	*measures being taken to assist small firms that, for many RTOs, form a new and challenging market.*	Question themes: *services to clients, service development, relationship structures adopted in technology transfer, services to supply chains, services targeted at SMEs, and the management of intellectual property rights (IPR).*	UK National				*SMEs has potential mechanisms for failure.* • *The reluctance of some SMEs to join alliances and their inexperience of leadership inhibits the development both of SME–SME networks catalysed by RTOs as well as SME–RTO collaborations* • Identified RTO-roles: *Expert, Independent Third party, Network Developer, Sector Focus, and Trainer and Documenter*
Thurner, T. W., & Zaichenko, S. (2015) *International Journal of Innovation Management, 19*(1)	Purpose: *to gain a better understanding of how RTOs serve industries with different degrees of absorptive capabilities* – i.e. *whether RTOs would fine-tune their approach to technology transfer in line with their customer's mode of innovations* *Tests whether Research and Technology Organisations (RTOs) that provide technology transfer to firms follow one or the other mode in correspondence to their customer's needs.*	Survey study Testing *for correlations between industries and certain aspects of transfer regimes*. 2011	67 Russian RTOs (providing services to both high- and low tech manufacturing firms) National	2/1	Less	RTO perspective; innovation processes; quantitative	• *Although we found no differences between the groups of RTOs in the number of patents they hold, we did indeed find that only for RTOs servicing high-tech industries, such patents are connected with radical innovation transferred into companies* • *In high-tech industries, a high share of business enterprise sources in the RTO's R&D expenditure implies higher technology transfer revenues per R&D staff. Also, private business partners engage with the RTO at a rather early level and co-finance their research activities already. Such connections were not*

							visible in the low- and medium manufacturing industries.
Tran, Y., Hsuan, J., & Mahnke, V. (2011). *R&D Management*, *41*(1), 80-91.	Examines how the capabilities of innovation intermediaries *add value in creative NPD processes.* *Compares instances of intermediary value creation that are contingent of strategic choices made by a fashion firm.* *Suggests an integrative framework on how and when innovation intermediaries add value*	Inductive case study Interviews with intermediary and clients (*investigating the value-added inputs of the innovation intermediary from both perspectives*) 2006-2008	Case company in the fashion industry (FlexTex), one intermediary and 3 intermediary clients European Local	2/na	Yes	RTO perspective; Firm perspective; innovation processes; qualitative	• Identifies *five key factors influencing when and how innovation intermediaries add value to clients' NPD processes* • 1) Innovation intermediary involvement points – different stages in the innovation process when intermediaries may be involved • 2) Value-added dimensions - *including (a) decreasing costs of product development; (b) improving hit-and-miss rate of collections; (c) reducing product development risks; (d) enhancing product attributes; (e) improving fashion actuality; and (f) increasing product development speed.* • 3) NPD speed • 4) Innovation intermediary capabilities - *(1) value creation through best-cost capabilities, (2) value creation through timing capabilities, (3) value creation through product solution capabilities, and (4) value creation through market response capabilities.*

Tremblay, D. G., & Dossou-Yovo, A. (2015) *International Journal of Technology Management, 69*(1), 1-19	Investigation of *the role of the intermediary actors of a given territory and their relation to the innovation process in small businesses.*	Qualitative (interviews) 17 interviewees -> 7 used 2003 & 2005	Canada, Montreal ICT sector Regional	2/na	Yes	RTO perspective; innovation processes; qualitative	• *The main contribution of this article is to identify the precise intermediation functions that the intermediary organisations fulfil for example, for learning, product development, and the search for venture capital, human resources, or knowledge.* • *The results also showed that the intermediary organisations thus contribute mainly to the knowledge base of the businesses, in part as concerns tacit knowledge, which is not always easily transferable and where intermediary organisations can play a crucial role.*
Vivas, C., & Barge-Gil, A. (2015) *Journal of Economic Surveys, 29*(5), 943-964	*This study summarizes the main conclusions from a systematic review of the empirical literature regarding the impact on firms of the use of knowledge external sources.*	Systematic literature review	Global Includes studies from Nordic, European and non-European countries Multinational	5/na	Less	Firm perspective	*Several recommendations for future research emerge.* • *First, to take in greater consideration methodological issues so that potential biases in the results caused by sample selection and endogeneity are handled properly.* • *Second, to pay more attention to heterogeneous outcomes.* • *Third, to use continuous indicators of depth and breadth of links allowing for non-linear relationships*

							• *and fourth, to extend evidence for developing countries and service industries.*
VTT (2017). *Impact of VTT 2017*.	Presents the VTT evaluation model. Four dimensions: *benefit to society, benefit to customers, excellence of operations and balanced finances. Each target dimension is represented by three indicator baskets in the model.* Results refer back to a VTT customer survey from 2017 Presents examples of VTT's research results	Survey study 2017	VTT customers Finland National	2/1	Yes	Firm perspective; innovation processes; networking/collaboration; quantitative	• Very short presentation of survey results from a 2017 customer survey: • *40% confirmed that a new or improved process was created* • *58% reported that their competitiveness improved¨* • *51% thought that their VTT project promoted international networking* • *88% reported that their knowledge base and expertise improved*
Wu, J. B., & Xu, M. Z. (2013) *Asian Journal of Technology Innovation, 21*, 7-19	*Examines the innovation effects of technology intermediaries on different types of innovation and the roles they play in different sectors at a regional level.*	Panel of data for 31 Chinese provinces Empirically testing the relationship between numbers of technology intermediaries and regional innovation performance. 2003-2011	China 31 provinces/regions National	3/3	Yes	Firm perspective; innovation processes; quantitative	• *Technology intermediaries have positive and significant contributions to product-related innovation in all regional industries.* • *More positive and significant effects of technology intermediaries on both knowledge-related innovation and product-related innovation of high-tech industries, meaning that technology intermediaries play a more important role in high-tech industries.*

Table A.2: Distribution of literature by research design

	Systematic review	Quasi-experimental[1]	Non-experimental[2]	Case study[3]	Other[4]	Level of evidence hierarchy
Albors-Garrigós et al. (2010)		X				2/3
Arnold et al. (2007)				X		2/na
Arnold et al. (2010)			X			3/1
Barge-Gil & Modrego (2011)		X				3/3
Barge-Gil et al. (2011)			X			3/2
Batterink et al. (2010)				X		2/na
Cantù et al. (2015)				X		3/na
Clayton et al. (2018)	X					5/na
Comin et al. (2019)		X				2/4
Colombo et al. (2014)				X		2/na
Department for Business Innovation and Skills, UK. (2015)				X		2/na
Dicecca et al. (2016)	X					5/na
Dietsch & Khemiri (2018)			X			2/1
Dornbusch et al. (2018)					X	2/na
Fernández-Esquinas et al. (2016)			X			2/1
Forsknings- og Innovationsstyrelsen, DAMVAD & Center for Forskningsanalyse (2010)			X			2/1

Forsknings- og Innovationsstyrelsen & Oxford Research A/S (2010)		X				2/3
Forsknings- og Innovationsstyrelsen (2009)					X	2/na
Forsknings- og Innovationsstyrelsen (2011)		X				2/3
Frietsch et al. (2018)					X	1/na
Fudickar & Hottenrott (2019)			X			2/1
Fukugawa (2016)			X			2/1
Fukugawa (2018a)		X				2/4
Fukugawa (2018b)			X			2/1
Fukugawa (2019)		X				3/4
Garengo (2019)				X		2/na
Gassmann et al. (2011)			X			2/1
Giannopoulou et al. (2019)		X				2/3
Goduscheit & Knudsen (2015)			X			2/1
GTS-foreningen (2020)				X		2/na
Guo & Guo (2013)				X		2/na
Iris Group (2016)			X			2/1
Kaiser & Kuhn (2012)		X				3/3
Kanda et al. (2018)				X		2/na
Kanda et al. (2019)				X		1/na
Kivimaa (2014)				X		2/na
Klerkx & Leeuwis (2009)				X		2/na
Klewitz et al. (2012)				X		2/na

Knockaert & Spitho-ven (2014)			X			2/1
Knockaert et al. (2014)			X			2/1
Landry et al. (2013)		X				2/3
Lasagni (2012)			X			2/1
Lin et al. (2016)			X			2/1
Lin et al. (2020)			X			2/1
Lin & Wei (2018)					X	1/na
Loikkanen et al. (2013)			X			2/2
Malik (2012)				X		2/na
Martínez-Vela (2017)				X		2/na
Matschoss & Heiskanen (2018)				X		2/na
Mei et al. (2019)		X				2/3
Memon & Meyer (2017)			X			2/1
Miller (2014)				X		1/na
Olmos-Peñuela et al. (2017)			X			2/1
Parker & Hine (2014)				X		2/na
Pesonen et al. (2008)			X			2/1
Rincón-Díaz & Al-bors-Garrigós (2013)				X		1/na
Rincón-Díaz & Al-bors-Garrigós (2017)		X				2/3
Robin & Schubert (2013)		X				2/4
Roessl et al. (2010)			X			2/1
Roxas et al. (2011)		X				2/3
Spithoven et al. (2010)			X			2/1

Spithoven & Knockaert (2012)			X			2/1
Styrelsen for Forskning og Uddannelse (2017)			X			2/1
Tann et al. (2002)				X		2/na
Thurner & Zaichenko (2015)			X			2/1
Tran et al. (2011)				X		2/na
Tremblay & Dossou-Yovo (2015)				X		2/na
Vivas & Barge-Gil (2015)	X					5/na
VTT (2017)			X			2/1
Wu & Xu (2013)		X				3/3

Note: 1) In the review, a broad understanding of quasi-experimental research designs is applied. Thus, quasi-experimental research designs cover several types of *quantitative* designs, such as natural experiments (DID and RDD), designs with instrumental variable techniques, matching and balancing. Quasi-experimental designs identify a comparison group that is as similar as possible to the treatment group in terms of baseline (pre-intervention) characteristics. Alternatively, a quasi-experimental design may consist of several treatment groups and no control group, which enables the assessment of relative effects.

2) Non-experimental research designs cover types of *quantitative* designs with no attempt at establishing a counterfactual situation. Non-experimental research is usually descriptive or correlational, which means that you are either describing a situation or phenomenon simply as it stands, or you are describing a relationship between two or more variables, all without any interference from the researcher. Instead of using a comparison group these designs operate e.g. with establishment of control variables and 'before and after' comparisons.

3) Case studies are *qualitative* studies of one or few units, which seeks a more in-depth understanding of the investigated cases.

4) Other includes study summaries and simulations studies.

Table A.3: Overview of the effect indicators used in the literature and whether the effects are measured through RTOs or measured at firms.

Author	RTO persp.	Firm persp.	Economic	Innovation	Networking/coll.
Albors-Garrigós et al. (2010)	X		Turnover per employee	Innovation intensity (number of patents, new products, new spin-off firms and scientific publications per employee in the last 3 years)	
Arnold et al. (2007)	X		-	-	-
Arnold et al. (2010)		X	Private rate of return, social rate of return		
Barge-Gil & Modrego (2011)		X	Sales, exports, production costs, profits, productivity, employment, number of clients	Technical results (new or improved goods, services, processes and new logistic innovations)	Intangible results (enhanced ability to teamwork and knowledge sharing, improved relationships between firm's R&D and other departments, improved utilization of other knowledge external sources)
Barge-Gil et al. (2011)		X		Innovation expenses, internal firm R&D activities, barriers to innovation activities, sources of information	
Batterink et al. (2010)	X		-	-	-
Cantù et al. (2015)	X		-	-	-
Clayton et al. (2018)	X		-	-	-
Comin et al. (2019).		X	Turnover growth, productivity growth, change in innovative		

			sales, change in human capital		
Colombo et al. (2014)	X		-	-	-
Department for Business Innovation and Skills, UK. (2015)	X		-	-	-
Dicecca et al. (2016)	X		-	-	-
Dietsch & Khemiri (2018)		X		Innovation performance of projects (cost, time and quality)	
Dornbusch et al. (2018)		X	-	-	-
Fernández-Esquinas et al. (2016)		X			Importance attributed to TTOs/research parks/the regional innovation agency (considering their role in establishing links with universities)
Forsknings- og Innovationsstyrelsen, DAMVAD & Center for Forskningsanalyse (2010)		X	Productivity per employee		
Forsknings- og Innovationsstyrelsen & Oxford Research A/S (2010)		X		User satisfaction, development acitivities innitiated	
Forsknings- og Innovationsstyrelsen (2009)		X		User satisfaction	
Forsknings- og Innovationsstyrelsen (2011)		X	Productivity per employee		
Frietsch et al. (2018)		X	-	-	-

Fudickar & Hottenrott (2019)		X		Market novelty	
Fukugawa (2016)	X		-	-	-
Fukugawa (2018a)		X	Annual average growth rate of SMEs' total factor productivity		
Fukugawa (2018b)	X		Cumulative number of incubatees that "graduated" business incubators		
Fukugawa (2019)		X		New products (number of new plant varieties)	
Garengo (2019)	X		-	-	-
Gassmann et al. (2011)	X		-	-	-
Giannopoulou et al. (2019)		X		New-to-the-firm innovation, new-to-the-market innovation, world-first innovation	
Goduscheit & Knudsen (2015)	X	X	-	-	-
GTS-foreningen (2020)	X		-	-	-
Guo & Guo (2013)	X		-	-	-
Iris Group (2016)	X	X	Productivity growth, turnover growth, growth in export, profitability growth	Innovation speed, new products, time-to-market	
Kaiser & Kuhn (2012)		X	Employment, added value growth	Number of patents	
Kanda et al. (2018)	X		-	-	-
Kanda et al. (2019)	X		-	-	-
Kivimaa (2014)	X		-	-	-
Klerkx & Leeuwis (2009)	X		-	-	-

Klewitz et al. (2012)		X	-	-	-
Knockaert & Spithoven (2014)		X		Innovation speed	
Knockaert et al. (2014)		X			Cognitive capacity additionality (measured as firm network and competence additionality)
Landry et al. (2013)	X			Five factors underlying the stages of service offerings by KTTOs to private firms	
Lasagni (2012)		X		Range innovativeness, turnover from new product	
Lin et al. (2016)		X		Introducing new products, applying new patents, and developing new technology or processes	
Lin et al. (2020)		X		Introducing new products, applying new patents, and developing new technology or processes	
Lin & Wei (2018)		X	-	-	-
Loikkanen et al. (2013)	X		-	-	-
Malik (2012)	X		-	-	-
Martínez-Vela (2017)	X		-	-	-
Matschoss & Heiskanen (2018)		X	-	-	-
Mei et al. (2019)		X		Introducing new products, being first in new product introductions, quickly launching new products, developing new	

				products with superior quality	
Memon & Meyer (2017)	X		-	-	-
Miller (2014)	X		-	-	-
Olmos-Peñuela et al. (2017)		X		Innovation culture (encouraging new ideas, creating inter-departmental working teams, encouraging employees to participate in decision-making)	
Parker & Hine (2014)		X	-	-	-
Pesonen et al. (2008)		X	Average turnover growth, average personnel growth	Number of patent applications, number of patents granted	-
Rincón-Díaz & Albors-Garrigós (2013)	X		-	-	-
Rincón-Díaz & Albors-Garrigós (2017)	X		Turnover per employee	Innovation intensity	-
Robin & Schubert (2013)		X		Product innovation (percent of total sales due to new products) Process innovation (extent of unit cost reduction, extent of cost reduction in materials, increase in production flexibility and capacity)	
Roessl et al. (2010)		X		Firms' Attitude towards RTOs	
Roxas et al. (2011)	X		Number of deals, profiles produced and promoted, number of new clients		

Spithoven et al. (2010)	X			Absorptive capacity, employment of qualified personnel, R&D activities	
Spithoven & Knockaert (2012)	X		-	-	-
Styrelsen for Forskning og Uddannelse (2017)		X	Productivity growth		
Tann et al. (2002)	X		-	-	-
Thurner & Zaichenko (2015)	X			Technology transfer	
Tran et al. (2011)	X	X	-	-	-
Tremblay & Dossou-Yovo (2015)	X		-	-	-
Vivas & Barge-Gil (2015)		X	-	-	-
VTT (2017)		X		User satisfaction	User satisfaction
Wu & Xu (2013)		X		New product output, number of patent applications, number of patents granted	

Appendix B: Evidence hierarchies elaborated

In general, design of the study and how information is measured affect the evidence strength. In top of the hierarchy, i.e. the optimal evidence type, lie meta-analyses, systematic reviews (e.g. Cochrane like), followed by randomized controlled trials (RCT), observational and case studies. Expert opinion and anecdotal experience are situated at the bottom level of evidence quality. Additional to this ranking, many scholars have suggested additional sub-rank categories typically fitting specific purposes or scientific fields.

The many versions and suggested evidence hierarchies mirror a broad critique of the various rankings that prioritizes statistical robustness and reliability over research integrity and ethical behavior. Support comes primarily from health and natural science research cultures while critique comes from human and social science cultures.

An evidence hierarchy in social science research studies, and especially in literature on e.g. firm effects of RTO services, needs to prioritize and rank the typical evidence types in such field-defined studies. Therefore, the number of categories and their content in the present evidence hierarchy used in this review are designed to fit the purpose to rank evidence in social science studies, as opposed to e.g. vital health-related medical studies.

The following table explains and illustrates the evidence hierarchy used in the present review. It is chosen in a version that fits social science studies like the literature behind this review. Hence, even though the hierarchy includes RCT studies, the review did not find any fitting this evidence level. However, it identified reviews and other quasi-like or approximate studies.

Table B.1: Evidence hierarchies used in the present review of RTO firm effects.

Level of Evidence	**Source: Karolinska Institutet University Library (2020)**		Level of Evidence	**Source: Kongsted (2018) based on the Scientific Maryland Scale (Hünermund, 2016)**
General evidence hierarchy			**Empirical study evidence hierarchy**	
6	Meta-analyses		5	Randomised controlled trials, 'Natural experiments', No self-selection into sample
5	Systematic reviews		4	Instrumental variable techniques or regression discontinuity design, Proper balancing (OLS, matching), Self-selection discussed but not addressed
4	Randomised Controlled Trials		3	Difference-in-Differences, Balancing (OLS, matching), Uncontrolled differences likely remain
3	Cohort Studies		2	'Before and after' comparison, A comparison group without balancing of covariates
2	Case Reports/ Cross-sectional Studies		1	Correlation analysis, No control group, No attempt at establishing a counterfactual
1	Background Information / Expert Opinions			

Note: The hierarchy proposed by Kongsted supplements rank 2, 3 and 4 by Karolinska Instituttet. Hence, it functions as sub-dimensions of the general evidence hierarchy.

The hierarchy suggested by Kongsted (2018, https://ufm.dk/publikationer/2018/filer/) is methodologically classifying literature by the robustness of its empirical methods as proposed by Paul Hünermund (2016, https://phuenermund.wordpress.com/2016/) and recommended in Alslev et al. (2014, https://ufm.dk/publikationer/2014/filer-2014/).

The other hierarchy is suggested by the Karolinska Institute Library (2020, https://kib.ki.se/en/search-evaluate/) and covers the full spectrum of research literature types

in most scientific fields. Both hierarchies assign the highest reliability to studies on the highest level. As table B.1 shows, the hierarchy proposed by Kongsted can be used to supplement the ranking by the Karolinska Institute's rank 2-4. Hence, the hierarchy proposed by Kongsted deepens the build-in methodological knowledge in the Karolinska Institute hierarchy through a judgement of the internal validity of the found effects, i.e. whether the found firm effect is judged to equal the true effect of collaborating with an RTO.

Especially the hierarchy proposed by the Karolinska Institute (2020) is commonly suggested although other intuitive variants are proposed by e.g. TheScientificParent.Org (2017, https://twitter.com/TheScieParent/), Crescitelli et al. (2019, https://www.researchgate.net/publication/) or C. J. Blunt (2020, http://cjblunt.com/hierarchies-evidence/. However, the hierarchy proposed by Kongsted (2018) concentrate on the quality, robustness and inter-reliability of the identified evidence rather than the research method in itself. Both hierarchies seem to be of importance in the overall judgement of firm effects found in studies of firm and RTO collaborations.