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Impacts of European RTOs

A Study of Social and Economic Impacts of Research and Technology Organisations

A Report to EARTO

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Summary

This is an independent report on the impacts of European RTOs. It has been commissioned by EARTO and performed by a team from the Technopolis Group. It is based on a study of secondary sources, information provided by 38 EARTO members and a piece of simple economic modelling intended to complement the qualitative and micro descriptions of impact contained in the existing literature with a more macroeconomic perspective.

Research and Technology Organisations (RTOs) play major roles in the European Innovation System, in making progress towards creating a European Research Area and the new Innovation Union. They increase the rate of innovation in industry by developing and helping implement new technology platforms, enabling companies and other producers to go beyond the limits of their internal technological capabilities, bringing both new and existing knowledge to bear by solving problems in the context of application.

Yet, what they do is to a large extent undocumented and misunderstood. RTOs have been systematically ignored in ERA development and discussions, despite their key nodal role in the Framework Programmes. Key elements of the current research and innovation policy discussion at European level concern the need to link innovation with research, to mobilise coalitions of major stakeholders and tackle the Grand Challenges such as climate change, ageing, nutrition, energy and water supplies and HIV-AIDS and to build scale and scope in European research and technological capabilities in order to win in global competition. This is the home territory of the RTOs. Improved policy can unleash their power to make significantly larger contributions than they already do.

RTOs have a range of different origins – some as Research Associations; others as 'technology-push' institutes to promote industrial development; yet others as services-based organisations focusing on testing and technical services; some comprise elements of more than one of these. EARTO defines RTOs broadly as organisations "which as their predominant activity provide research and development, technology and innovation services to enterprises, governments and other clients". This distinguishes them from universities, whose main mission is education, and from enterprises that produce goods and many types of services. A narrower definition would restrict RTOs to subsidised institutes that develop technical capacities based on state subsidy and then use these capacities to de-risk and speed up industrial innovation by helping companies tackle technological problems that would otherwise not be within their reach. Most RTOs (narrowly defined) thus operate with an explicit or implicit innovation model that involves

- Exploratory research and development to develop an area of capability or a technology platform
- Further work to refine and exploit that knowledge in relatively unstandardised ways, often in collaborative projects with industry
- More routinised exploitation of the knowledge, including via consulting

There are no useful official statistics about the RTO sector or indeed the research institute sector more broadly. Probably, the institute sector as a whole turns over well above €30 billion. We estimate that RTOs in Europe turn over €18.5 billion (on a narrow definition) and €23 billion (on a broad one). A few large organisations dominate turnover and employment.

In discussions about research, there is often confusion about whether there are overlaps or even duplication between RTOs and universities. Data about what these organisations actually do make it clear that their activities are complementary.

Universities focus on more or less fundamental research and teach. RTOs do more applied research and exploit the resulting knowledge in industrial innovation and development projects. They have industry-relevant skills and a professionalism that is absent in the university sector. Their work is often more interdisciplinary. They can efficiently deliver services and focused research. Many companies have both RTOs and universities as cooperation partners – but they are very careful about allocating different types of task to each.

However, RTOs and universities are increasingly strongly linked, through joint projects, PhD training, co-publication, joint appointments, joint research centres and in some cases co-location. While their activities remain complementary, there is also an increasing element of productive overlap. There is a significant amount of knowledge spillover from RTOs' work – not only in the parts where they cooperate with universities but even in their industrial work, which leads also to a lot of publication.

RTOs tend to work with the more technologically progressive companies and to establish partnerships with many of these over time. They have many SME customers but often the larger ones provide the majority of the work. Their customer base is primarily national and is internationalising only slowly. Despite the ambitions of ERA, under present arrangements RTOs have limited incentives to operate trans-nationally.

RTOs do, however, play a pivotal role in the Framework Programme. They coordinate about a third of the projects and they create major European networks of participants. In many cases, they are involved in very large numbers of projects.

Most attempts to quantify economic impacts of RTOs focus on a sub-set of their activities that directly supports innovation projects in firms. Typically, the rewards from such innovation activities are highly skewed: some projects make a lot of money; many make little or nothing. Where it is possible to identify impacts, however, these can be quite high.

The second, more macroeconomic approach to understanding the economic impact of RTOs tackle all of their activities but suffer from inability to account in detail for the mechanisms of impact. Both approaches are therefore problematic. Rather than placing faith in a particular set of numbers, we note that whatever approach is used the impacts appear to be **significant** in size. This is also consistent with the survey and case-based evidence. The RTOs themselves have in a number of cases tried to estimate their own economic impacts, typically by asking customers about the effects of projects on their turnover and profitability. They find quite high ratios between subsidies and turnover – in some cases finding that a Euro of subsidy invested at the RTO yields as much as 25 Euros of turnover.

We set out a simple model, based on work by Oxford Economics for AIRTO in the UK. We considered four categories of 'impact'

- A 'direct' component, representing the contribution of RTOs to GDP, i.e. their contribution to value added (equals output minus input values, or wages plus salaries plus profits)
- An 'indirect' component which incorporates the dependence on the RTOs of their (upstream) suppliers and (downstream) users of their outputs, normally calculated from estimated flows of inputs and outputs
- A component representing Keynesian-type 'multiplier' effects, whereby expenditures by RTOs and their employees stimulate activity in other sectors ('induced' impact)
- Social returns to investment in R&D activities, comprising private returns to RTOs and client organisations and 'spillovers' to other sectors of the economy

The estimates resulting are shown below. Of course they are subject to large uncertainties, but they do indicate that – however you count – the RTOs are a collective force in European innovation that is of considerable size.

Estimated economic impact of European RTOs – central estimates[1]

	Wide definition (€bn)	Narrow definition (€bn)
Direct	**12.2**	**9.8**
Indirect	**10.8**	**8.7**
Induced	**+/- 4.6**	**+/- 3.7**
Social returns	**12.9**	**10.4**
TOTAL	**31.3-40.5**	**25.2-32.6**

On the basis of the Oxford Economics methodology, therefore, the overall annual impact of European RTOs is estimated to be in the range €25-40bn.

We believe, however, that this may represent a considerable underestimate, in particular, by neglecting long-term dynamic effects of R&D. The social returns are estimated with a simple 1-year time horizon, while returns to R&D are normally assumed to extend well into the future, abating over time according to a discount rate. Using the UK Treasury's working assumption of a discount rate of 3.5% yields a total social return of the order of €100bn with a 10-year time horizon, on the basis of the above figures.

Much larger figures than those in the above table are also suggested by econometric work on the relationship between R&D and productivity and GDP. Work by Guellec and van Pottelsberge, for example, suggests that a 1% increase in business R&D increases national productivity/GDP by around 0.13%.

The RTOs are affected by drivers of change that include technological convergence, growing links within the Knowledge Triangle, globalisation, increased pressures for commercialisation and policy drivers such as the ERA.

In the light of the ERA objectives, which are ultimately to build a healthy 'research ecology' at European level, objectives for EU-level policy for the research institute sector should be to optimise the research institute sector towards European needs by

- Integrating European knowledge markets to create a common market for knowledge and knowledge services
- Removing barriers to RTOs building globally competitive and naturally viable scale[2] through competition and specialisation
- Exploiting the capabilities of the RTOs to tackle the grand challenges, once these are defined and integrated into EU research and innovation policy
- Ensuring that Community provision of research infrastructure addresses not only the needs of basic research (ESFRI) but also of the RTO sector

[1] The 'Direct' component is the estimated 'value added' of RTOs, their contribution to GDP. Turnover is equal to the sum of direct and indirect components, the latter representing inputs from upstream suppliers

[2] Comparisons with the USA are often made in defining the aims of EU research and innovation policies. However, it is not self-evident that the scale or monolithic structure of key US government laboratories would be optimal for Europe. Rather, an evolutionary approach is needed to discover the scale and degree of competition that is appropriate in each European sector

- Supporting the self-organisation of the RTO sector at the European level via organisations such as EARTO and their connection to areas of developing policy need at European level
- Supporting developments in the institute sector that are **disequilibrating**, i.e. that combat existing lock-ins and enable new and existing institutes or groups of institutes to build positions in competition with others that overall strengthen the 'offer' of the European institute sector and its global competitiveness

An urgent need is proper statistics about the institute sector. The Commission should ask Eurostat to establish definitions and collect statistics about the RTOs and other research institutes, as is done for the university sector, and should encourage the OECD to act in a similar way.

The Commission should become more involved in the first stage of RTOs' activity – capacity development – as a way to help break down the lock-ins caused by national boundaries. This, and the creation of a true common market in knowledge services, will help them to realise their huge potential in delivering the ERA.

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Impacts of European RTOs

1. Introduction: Why are we interested in RTOs?

Research and Technology Organisations (RTOs) play major roles in the European Innovation System, in making progress towards creating a European Research Area and the new Innovation Union. They increase the rate of innovation in industry by developing and helping implement new technology platforms, enabling companies and other producers to go beyond the limits of their internal technological capabilities, bringing both new and existing knowledge to bear by solving problems in the context of application.

Yet, what they do is to a large extent undocumented and misunderstood. RTOs have been systematically ignored in ERA development and discussions, despite their key nodal role in the Framework Programmes[3]. A recent review of reforms in the public research base across the EU confirms that very little reform has taken place in the institute sector, except for changes to bring former Soviet-style academies into line with EU practice[4]. Unlike the universities, the institutes are barely present in official discussions of research policy, especially at the European level. There is a small 'grey' literature about them but very little in the 'white', peer-reviewed literature. They are "the neglected stepchild of public policy." [5] The neglect is less in Northern Europe and especially the Nordic area than elsewhere, whereas – with the exception of some work on Spanish RTOs – there is no literature dealing with Southern Europe. This necessarily affects this document: we can report on what has been researched, and not on that which has not been researched.

This neglect would not matter if RTOs were unimportant. But they are not. On our crude estimate (for there are no proper statistics), European RTOs collectively turn over about €18.5-23 billion and have an economic impact of up to €25-40 billion. However, their impacts go well beyond the economic. RTOs are at the centre of significant projects in areas such as sustainable energy, environment and health technology – often coordinating these on a European scale within the Framework Programme.

Key elements of the current research and innovation policy discussion at European level concern the need to link innovation with research, to mobilise coalitions of major stakeholders and tackle the Grand Challenges such as climate change, ageing, nutrition, energy and water supplies and HIV-AIDS and to build scale and scope in European research and technological capabilities in order to win in global competition. This is the home territory of the RTOs. Improved policy can unleash their power to make significantly larger contributions than they already do.

In this report we begin by discussing and defining RTOs and estimating the size of the sector. In the absence of official statistics, that is a considerable task. In Chapter 3, we discuss the characteristics and role of RTOs in the innovation system, showing that they play a vital role that is very different to that of the universities. In Chapter 4, we summarise others' efforts to assess RTOs' economic impacts and provide our own

[3] European Research Advisory Board, *Research and Technology Organisations (RTOs) and ERA*, December 2005

[4] Paul Simmonds, *Activities of the EU Member States with Respect to the Reform of the Public Research Base*, Report of the ERAWATCH ASBL, Brussels: European Commission, ERAWATCH service, 2008

[5] Michael Crow and Barry Bozeman, *Limited by Design: R&D Laboratories in the US National Innovation System*, New York: Columbia University Press, 1998

model, based on a methodology previously used by Oxford Economics in the UK for AIRTO, the UK association of RTOs. Finally we discuss the likely future for RTOs and set out some policy implications

We have prepared this report using a mixture of methods.

- A key element has been literature review – building both on previous reviews and about a hundred documents identified with the help of EARTO and its members.
- A second ingredient was a short survey of EARTO members. We sent out 98 questionnaires and received 38 completed responses, though these include the answers of most of the EUROTECH group of large RTOs within EARTO, so they cover a significant proportion of the sector.
- We complemented this survey with a search for data about RTOs from secondary sources via the Web. Chris Hull of EARTO kindly spent a long day with us sifting through data to identify an initial list of RTOs, which we subsequently extended. Thereafter, we looked for basic economic ad employment data about these RTOs. This allowed us to produce two different estimates of the size and economic importance of the RTO sector and finally to estimate their aggregate economic impact.

This study has been funded in its entirety by EARTO and undertaken independently by Technopolis. The findings, judgements and opinions of the authors – as well as any mistakes that may have survived a critical reading by key EARTO members – are entirely the responsibility of the authors and should not necessarily be attributed to EARTO.

2. What are RTOs?

2.1 Types of Institute

RTOs are an important part of the sector described in the German language as 'extra-university research organisations'. These are of three types

- Scientific research institutes, such as the Max Planck institutes in Germany, CNRS in France or the institutes of the national academies of science in various of the new member states. These largely do the same kind of research as universities and correspondingly get a high proportion of their income in the form of block grants
- Government laboratories (sometimes referred to as 'sector' institutes), which are generally owned by the state and whose main function is normally to deliver services and policy-relevant information to government. Examples include nuclear research, marine institutes (which mix counting fish stocks with more fundamental work in marine biology). Generally, the bulk of their income comes from the ministry, whose policy mission they support[6]
- Applied research institutes or Research and Technology Organisations, like VTT Finland, the Fraunhofer Society in Germany or TNO Netherlands. They focus on user- or problem-orientated research for the benefit of society and normally win the greater part of their funds competitively. Typically, their funding is a mixture of 'core' subsidy that lets them develop capabilities and industrial income that lets them exploit these capabilities for the benefit of industry

2.2 RTOs

Looking at the origins of RTOs internationally, there are at least three typical histories. Some RTOs conform to more than one

1. Research associations, which originally tackled common problems within one or more branches of industry and then became institutionalised in the form of institutes. Some of these are still membership based. Examples persist in the UK (e.g. PERA, formerly the Production Engineering Research Association and in the Swedish system, where the old Institut för Verkstadsteknisk Forskning persists as part of SWEREA in the IRECO group)
2. 'Technology push' institutes, set up in order to promote industrial development. SINTEF in Norway is an older example. The Fraunhofer Society in Germany has also been in this category since the early 1970s, when its original mission was transformed
3. Services-based institutes, generally focusing in their early years on measurement, testing and certification. These tend to have moved 'upstream' into research. SP (formerly Statens Provningsanstalt) in Sweden is a case in point. VTT, Finland is a mixed case where a policy decision was taken to transform a services-focused institute into a technology push institute

Other factors can also play a role in RTO development. In some cases (e.g. TNO), a defence mission was partly integrated. Sometimes, providing a home for nuclear energy research was a factor.

These ways of describing RTOs are **functional** in nature. RTOs may have different legal forms at different times and places. Some are foundations; others are limited liability companies that do not aim to distribute profits to shareholders. Others are associations or even state agencies. In some systems the institutes have changed their

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[6] Paul Simmonds, *Activities of the EU Member States with Respect to the Reform of the Public Research Base*, Report of the ERAWTCH ASBL, Brussels: European Commission, ERAWATCH service, 2008

legal form without changing their social and economic function. What matters is the function, not the form.

In this report, we use both a broad and a narrow definition of RTO. EARTO defines RTOs broadly as organisations "which as their predominant activity provide research and development, technology and innovation services to enterprises, governments and other clients". This distinguishes them from universities, whose main mission is education, and from enterprises that produce goods and many types of services. It does not, however, distinguish them from technology consultancies or contract research firms – whether these are for-profit organisations (like QinetiQ) or not-for-profit ones that have a societal mission but receive no subsidy (like PERA). The UK Association of Independent Research and Technology Organisations (AIRTO) describes its members as 'market-led, problem oriented, businesses and organisations serving all facets of technology transfer and innovation, and who secure their own ongoing existence and growth through success in this market place'.

The narrow definition is rooted in the economics of research and the idea that 'market failure' makes it difficult for companies to invest in general forms of knowledge. Since the overriding purpose of RTOs is to promote industrial competitiveness by technological means, they can only do their job if they in fact are technologically capable and can offer firms inputs that are in advance of or otherwise superior to those available on accessible commercial knowledge markets. The narrow definition of an RTO is that its societal role is recognised and it receives core or 'capability' funding from the state in order to fund this advantage. That funding represents a social investment and society expects to get returns through spillovers. That is, the institute's technological advantages are passed on to its customers whose performance improves, become more competitive, employ more people, pay more taxes, increase the quality of life, and so on.

Private companies operating without subsidy struggle to obtain such advantages. Where they do, it is irrational for them to share these advantages with others. Rather, they try to prevent spillovers. There is no market solution to the national need for RTOs. In fact, the nearest private sector equivalents to industrial institutes – engineering consultants – famously struggle to do any R&D at all. Even though such firms want to invest in new capabilities, price competition for new projects tends to squeeze this out. Clients are rarely interested in their suppliers' future ability to do work, and are certainly unwilling to invest in it. Human mobility is generally the most important external source of new capability for such firms.

Both this logic and practical experience – for example from the period when the UK government withdrew funding from the research associations – suggest that withdrawing core or capabilities funding from an RTO will over time turn it into a technical consultancy, as it is forced to obey the market's rules.[7] Of course, technical consultancies are good and useful things, but the state has no need to own or run them – the market organises that quite well without any help.

2.3 The RTO Innovation Model

Most RTOs (narrowly defined) thus operate with an explicit or implicit innovation model that involves

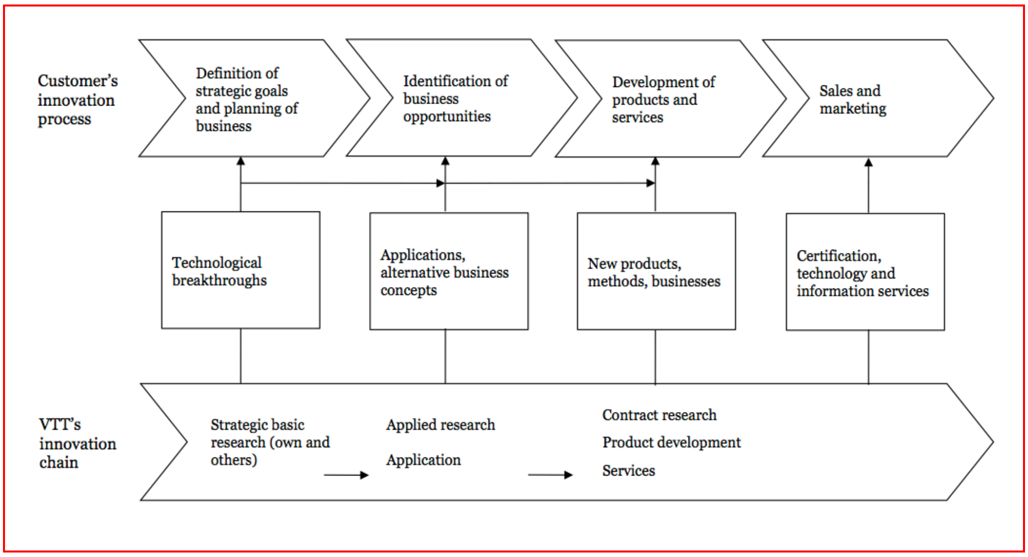
- Exploratory research and development to develop an area of capability or a technology platform
- Further work to refine and exploit that knowledge in relatively unstandardised ways, often in collaborative projects with industry

[7] See the case study of the privatisation of the UK Production Engineering Research Association (PERA) in Howard Rush, Michael Hobday, John Bessant, Erik Arnold and Robin Murray, *Technology Institutes: Strategies for Best Practice*, London: International Thomson Business Press, 1996

- More routinised exploitation of the knowledge, including via consulting, licensing, spin-off company formation

Figure 1 shows VTT's version of this model. In principle, RTO core funding is primarily intended to pay for the first, exploratory stage, where the RTO develops knowledge and capabilities needed to support its industrial customers. On the narrower definition, this is the key thing that distinguishes an RTO from a technical consultancy. The public money is used to create the capabilities the institute needs to take companies 'one step beyond' what they could otherwise do, thereby providing social returns by de-risking innovation[8].

Figure 1 VTT's Innovation Model



Source: VTT

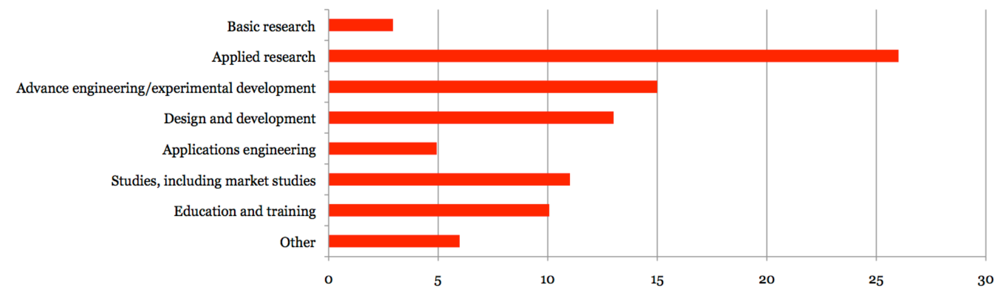
In principle, the more money an RTO can invest in research to produce capabilities, the further away from its customers' short-term needs it can search for technological opportunities and the more fundamental the research is that it can do. Some systems obtain a relatively high proportion of their income in the form of core funding. Thus Fraunhofer, TNO and VTT – which lie in the 30-40% core funding range – are able to do considerable amounts of applied (and even a small amount of basic) research, whereas others like GTS or the Swedish RISE system in the 10-15% range, have more focus on experimental development and services[9].

Our study of core funding in the Swedish RTOs offers an opportunity to understand what **type** of activities are covered by core funding. Many of the RISE RTOs leverage their close relationships with universities to engage in rather more capacity-building research than is paid for by their core funding. Three of the 37 project leaders surveyed claimed to be doing basic research, but most of the work was in applied research and in development.

[8] Sverker Sörlin (chair), Erik Arnold (rapporteur), Birgitte Andersen, Jørgen Honoré, Pia Jørnø/ Erkki Leppävuori and Ketil Storvik, *A Step Beyond: International Evaluation of the GTS Institute System in Denmark*, Copenhagen: Forsknings- og innovationsstyrelen, 2009

[9] Sverker Sörlin (chair), Erik Arnold (rapporteur), Birgitte Andersen, Jørgen Honoré, Pia Jørnø/ Erkki Leppävuori and Ketil Storvik, *A Step Beyond: International Evaluation of the GTS Institute System in Denmark*, Copenhagen: Forsknings- og innovationsstyrelen, 2009

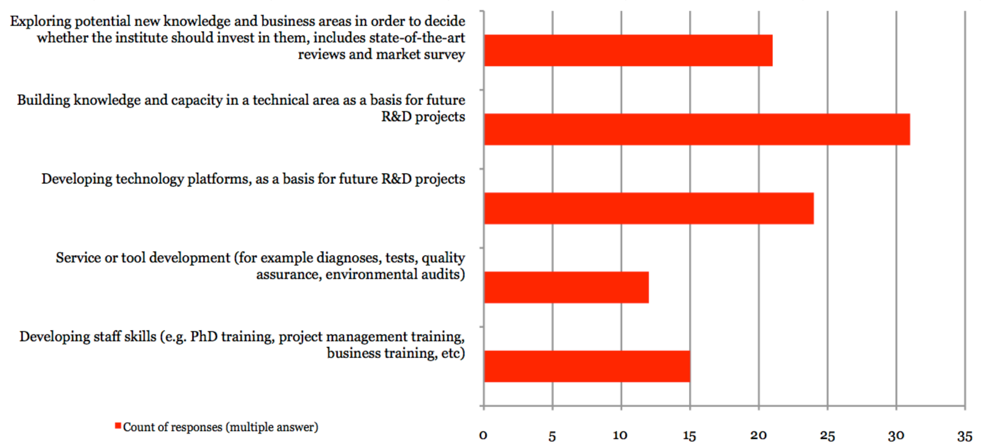
Figure 2 Nature of Work Done in Core Funded IRECO Projects



n = 37

Advanced engineering is the process of removing uncertainties in a technology, so that it is possible to do product or process development in the absence of known uncertainties. There was little applications engineering – in the sense of applying ready-packaged technologies to new applications. This pattern confirms that the core funds are being used for the intended kinds of activity: namely, making or acquiring new knowledge, understanding and codifying it so that it can be re-used as a basis for other activities within the institutes. It is interesting to note how many of the projects involved studies, education and training, suggesting that core funds are used not only for purely technical activities but also to integrate technology into the research institutes' overall business. The roles of the projects for the institutes focused on building knowledge and capacity, and to a lesser extent on building specific technology platforms to support future institute development (Figure 3). Quite a number had an exploratory character – so that they were not only concerned with developing capabilities but also with assessing the relevance of those capabilities to the business mission of the institute.

Figure 3 The Roles of the Projects for the IRECO RTOs



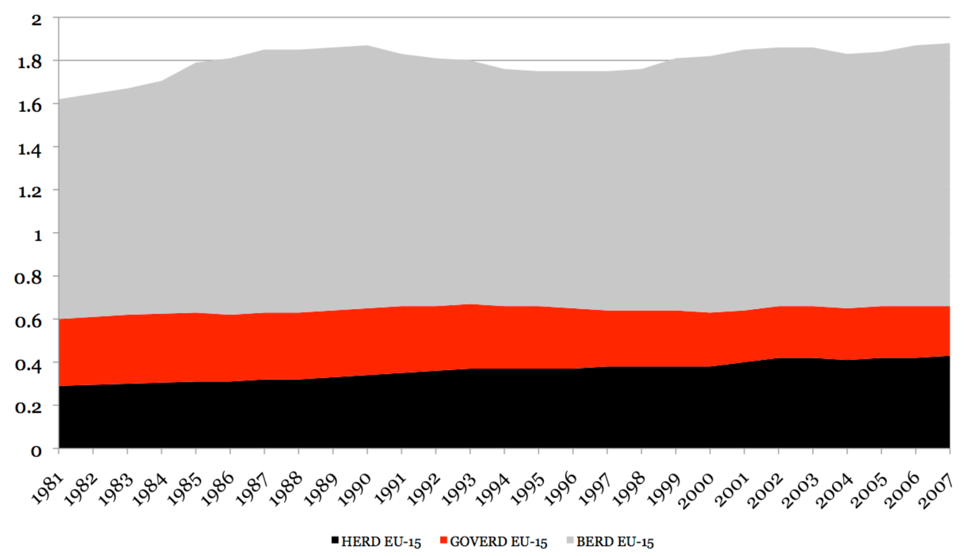
n = 37

2.4 Size of the Sector

2.4.1 The Research Institute Sector Overall

One of the reasons there is so little policy consideration of RTOs is that there are no proper statistics about them, and there are precious few about the wider Research Institute sector – that which in the German language is described as "extra-university research" – except at the most aggregated level. The closest proxy[10] for the institute sector in OECD statistics is Government Expenditure on R&D – the central stripe in Figure 4, which shows its share of GDP gently declining across a long period. According to EUROSTAT, there are about 340,000 full-time researchers in the EU-27 government research sector (EU-15 = 270,000), making up some 15% (EU-15 = 13%) of the working researcher population. A further 32% (EU-15 = 31%) work in higher education and the rest in business.

Figure 4 Higher Education, Other Government and Business Spending on R&D, EU-15, 1981-2007



Source: OECD Main Science and Technology Indicators

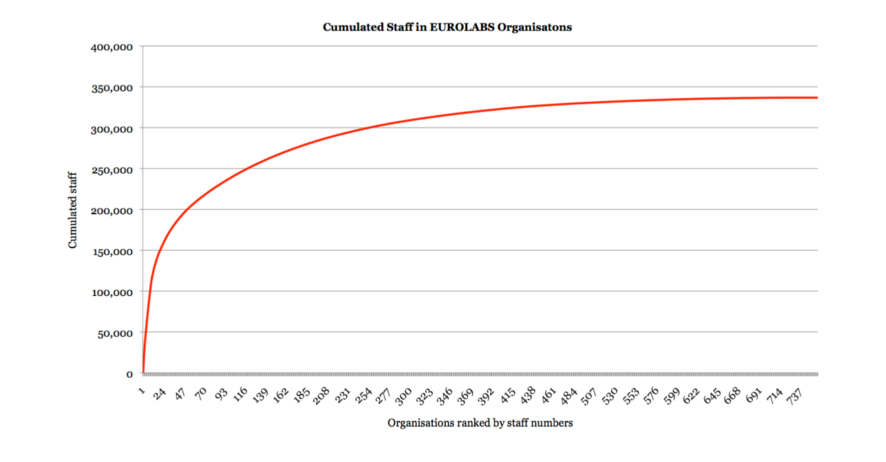
The largest inventory of research institutes ever taken in Europe in the EUROLABS project – was produced in 2002. Visual inspection of the data shows that they are patchy and the study did not attempt to estimate the turnover of the sector, but it did show that while the number of EU research institutes is large, employment is fairly concentrated to a modest number of major organisations. Figure 5 shows (on the vertical axis) the cumulated number of employees in the 754 institutes whose details are in the EUROLABS[11] database plotted against the number of institutes ranked by size. Some 50% of employment is within the 28 largest institutes while two thirds of the employment is contained within the 77 largest institutes.[12]

[10] How good a proxy is not clear. Some RTOs have the form of limited companies and may in certain countries be classified under 'business'

[11] PREST, *A Comparative Analysis of Public, Semi-Public and Recently Privatised Research Centres*, Manchester University: PREST, 2002

[12] In fact, EUROLABS does not treat Max Planck, TNO or VTT as single organisations. There have been important mergers since the EUROLABS data were collected, such as those creating Tecnalia and AIT. Hence EUROLABS tends to understate the degree of concentration in the institute sector.

Figure 5 Employment Pareto for Institutes in the EUROLABS Database, 2002



A more recent but unpublished survey[13] of 151 of the largest research institutes in Europe found that these had a total budget of some €31b and employed about 293,000 people.

2.4.2 RTOs

In estimating the size of the European RTO community, we have compiled a set of organisations whose activities can be broadly described in this way. From this we have compiled lists using 'wide' and 'narrow' definitions of RTOs

- The wider definition takes no account of organisations' sources of funding, or whether they seek to be profitable or whether their principal customers are from the public or private sectors. All EARTO members, some of which are, for example, for-profit organisations
- The narrower definition only covers organisations which receive public-sector subsidies and carry out contract research, and excludes private-sector organisations and bodies which primarily function as government laboratories

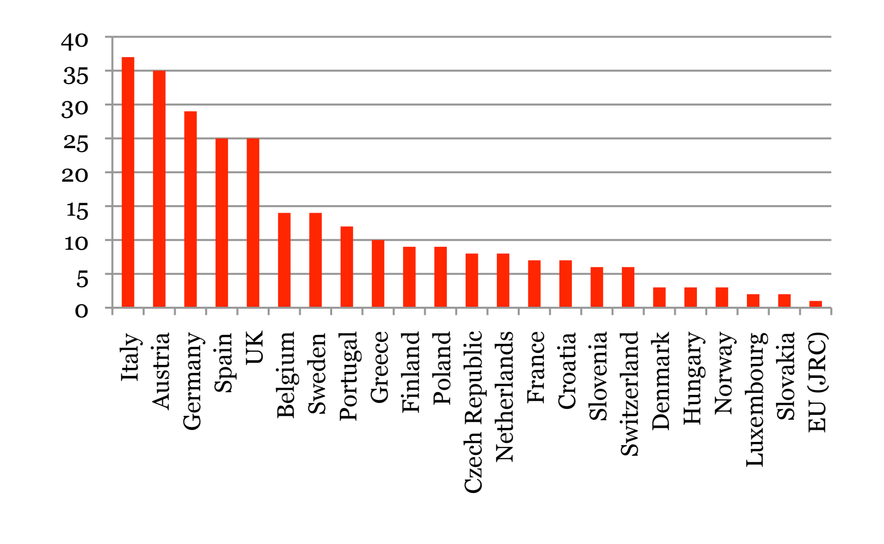
We have used three main sources to compile our set of European RTOs

- Members of the European trade association (EARTO)
- Participants in the EU's Framework Programme (FP7). Participants are described as Research Centres, Industrial Companies, Higher Education Establishments, or 'other'
- A survey of EARTO members, where respondents were asked to name three other RTOs in their country (in addition to details of inputs, activities and outputs in their own organisation)

With the help of EARTO, we have attempted to identify RTOs from among FP7 participants and, together with the other sources, have compiled a set of 275 organisations for inclusion under our wider definition, of which 168 are EARTO members. Figure 6 shows the distribution of these organisations by country.

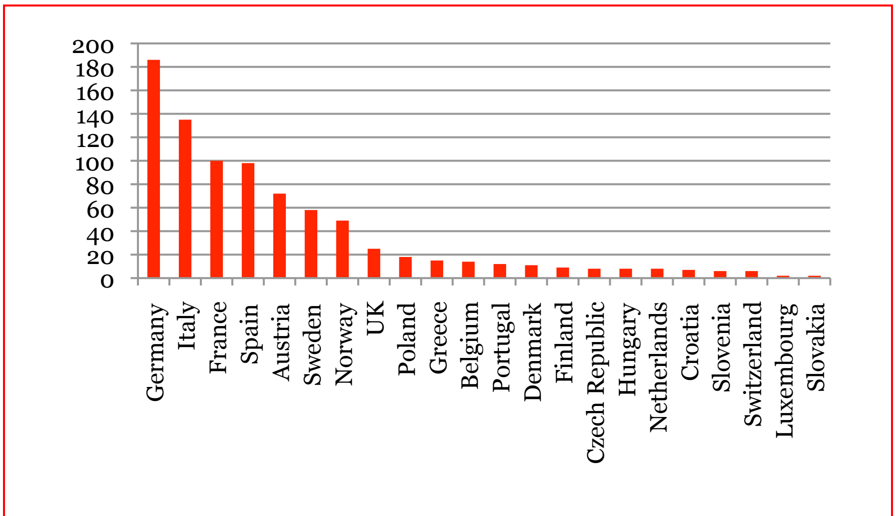
[13] COWI, Co-ordination and co-operation – non-university Research Performing Organisations, Lyngby: COWI, 2008

Figure 6 Number of RTO Organisations by Country



Many of these RTO organisation are 'associations' or groups, with several dozen separate institutes sometimes included within one association. In Spain, for example, the private non-profit organisation FEDIT encompasses 67 separate institutes, although FEDIT (and similar multi-institution organisations) is counted as a single organisation in the figure above. Figure 7 presents estimates of numbers of separate institutions by country, although it should be stressed that there is a degree of arbitrariness in defining what constitutes a 'separate institution'.

Figure 7 Number of RTO Institutes by Country



2.4.3 RTO Turnover

Turnover data provide better indicators of the relative importance of the RTO sector among countries, although these data are not immediately available for many of our identified RTOs. We have therefore adopted the following estimation procedure.

- For slightly less than half the organisations on the database, turnover data are available
- For around one-half of the remainder, numbers of employees are available. For each country individually, we have estimated average turnover per employee from

those organisations where we have figures for both variables. We have then multiplied the resulting ratio by number of employees for organisations where only the latter figure is available, to obtain an estimate of turnover for those organisations

- In the case of institutes where we do not have figures for either turnover or employment, we have taken an average of turnovers from a sample of institutes in the country, chosen to exclude outliers (essentially large institutes which are atypical of the whole). This average is then taken as an estimate of the turnovers of institutes where data are missing

Actual numbers used for turnover per employee, and for turnover of organisations with 'missing' turnover and employment data, are presented in Appendix 1.

Using these assumptions, we estimate that the size of the European RTO sector, in terms of turnover, is between about **€18.5bn** (narrow definition) and some **€23bn** (under the wide definition of an RTO). The country-by-country distribution of RTO turnovers is as shown in Figure 8 on the basis of our 'wide ' definition and in Figure 9 for the 'narrow' definition.

Figure 8 Estimated Size of Country RTO 'Sectors', Wide Definition (annual turnover, €m)

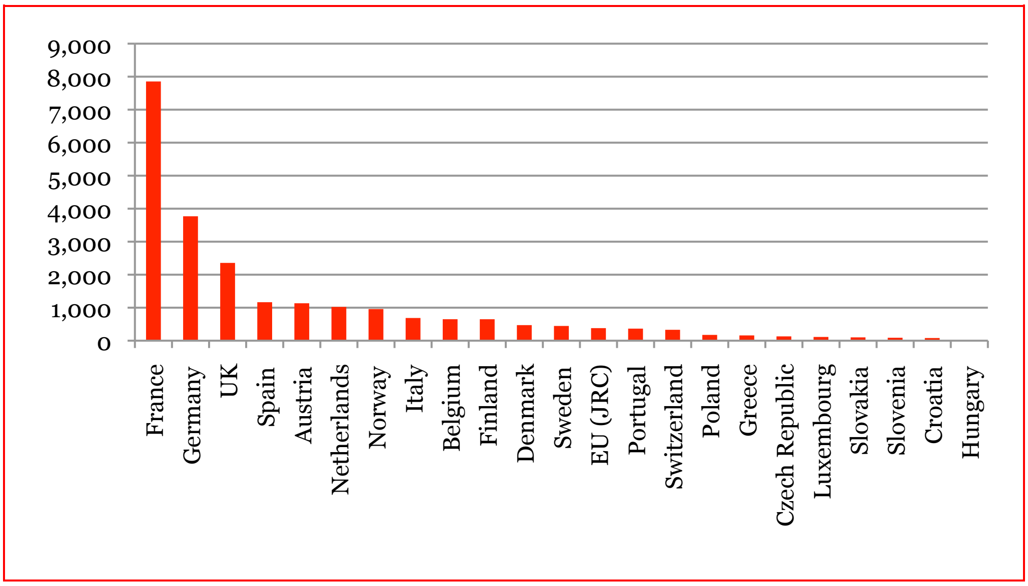
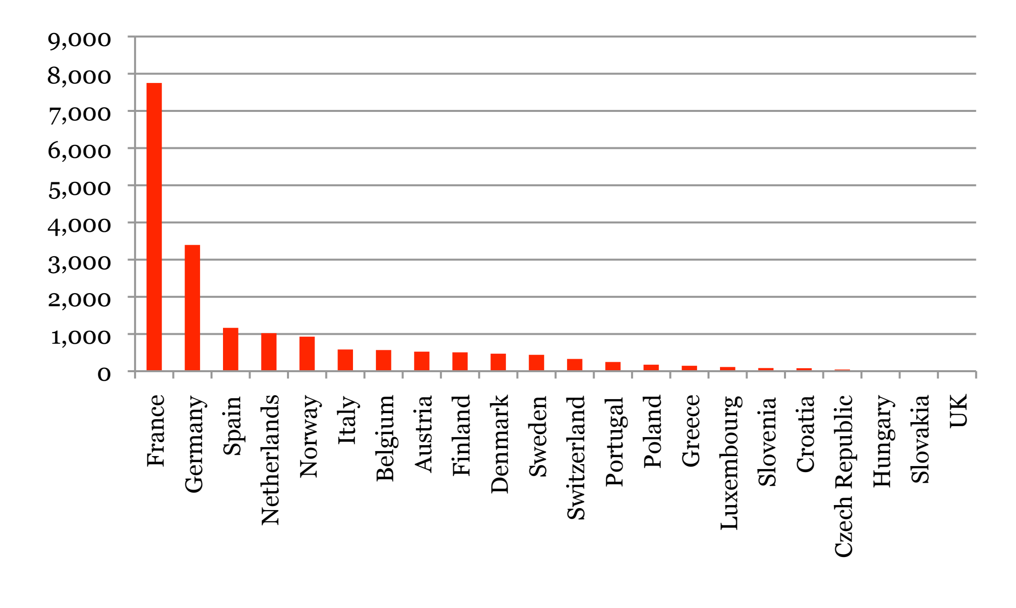


Figure 9 Estimated Size of Country RTO 'Sectors' , Narrow Definition (annual turnover, €m)



France and Germany clearly dominate the turnover statistics under both definitions. The major difference between the two distributions shown concerns the UK, which is shown as having the third largest RTO sector under the wide definition (dominated by QinetiQ) but which makes no contribution under the 'narrow' definition. This results from the fact that, following widespread privatisation in the 1980s, there are no core funded RTOs remaining in the country.

Other differences between the distributions (such as the shift in Austria's ranking) are due to large organisations contributing to the wide definition but not to the narrow – in the Austrian case, the engineering company AVL List GmbH accounts for most of the difference, contributing over half the total Austrian turnover under the wide definition but excluded from the narrow.

These estimates of turnover are later used to derive broader estimates of economic impact, following the methodology applied to the UK RTO sector by Oxford Economics[14].

[14] Oxford Economics, 'Study of the Impact of the Intermediate Research and Technology Sector on the UK Economy', May 2008.

3. What RTOs Do and Don't Do

This Chapter discusses the activities undertaken by RTOs. These activities are in fact rather diverse, including basic and applied research, advanced and applications engineering, design and development, studies, training, measurements and tests, providing information and advice, producing prototypes and even occasionally short production runs. Their activities can include non-technical studies and services such as foresights and road maps and help with technology management and innovation management. There are also examples of RTOs helping companies change business models, for example extending from conventional paper products to energy or new collaborative innovation models.

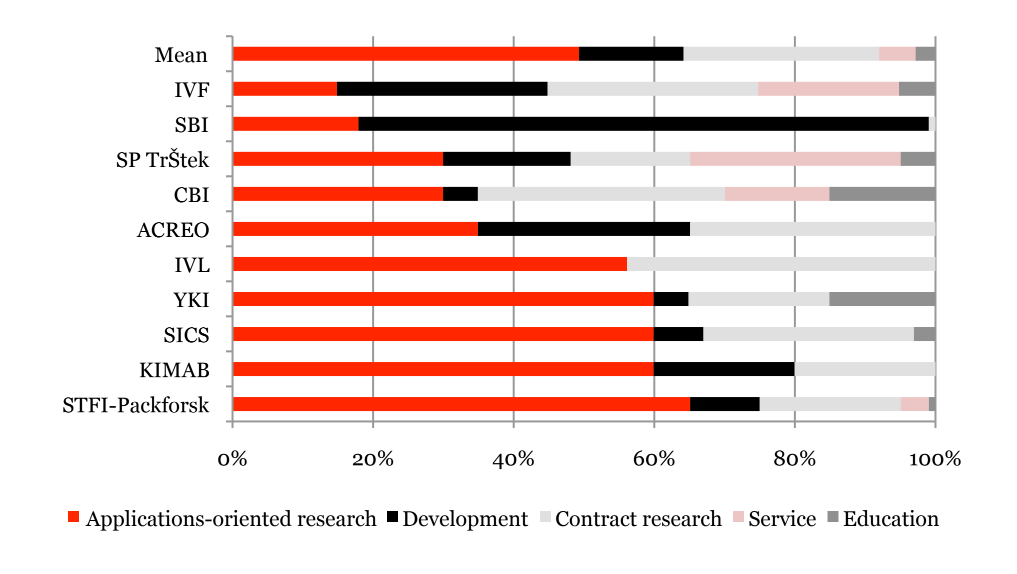
3.1 RTOs are Not Like Universities

A key difference between RTOs and many universities is the need to programme activities. This is partly caused by the need – which varies among RTOs – to obtain a financial return on expensive equipment, especially pilot scale facilities that allow the institute to tackle real industrial problems. Many act as 'knowledge bearers' for their branches, maintaining key databases, influencing standards and holding libraries of industry-relevant materials. The need to programme is also partly caused by the requirement to match customers' specific needs, rather than to generate new knowledge in areas chosen by the researchers themselves. In order to use knowledge to help others, institutes need to consider not only knowledge generation (or acquisition) but how to codify and exploit it at various scales.

Usefully, a study of the relationship between the Royal Institute of Technology (KTH) in Stockholm and the RTOs present on its campus included a survey of those institutes' **overall** activities, based on estimates by their managers (Figure 10). The differences among the institutes are striking and reflect differences in the characteristics of the branches and the technologies involved.[15] What the Figure cannot show is the set of RTO-specific skills such as project management and technology management that is absent from the universities.

[15] They probably also reflect some differences in the use of terminology, but that is difficult to control for

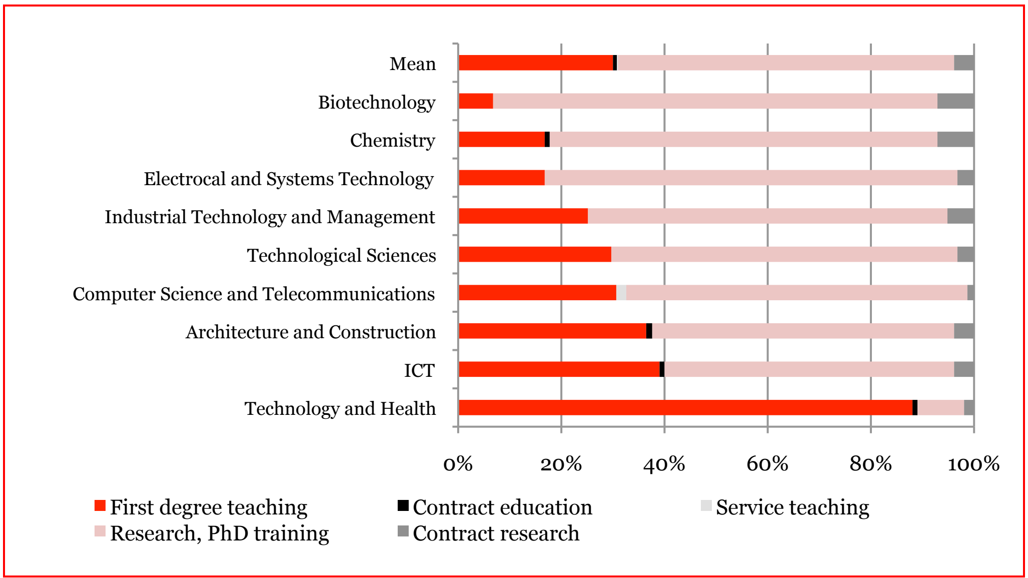
Figure 10 Self-reported Activity Profiles of RTOs based at KTH



Source: Lennart Eriksson and Lisa Ericsson, *Samarbete Mellan KTH och Kringliggande Industriforskningsinstitut – nuläge och utvecklingsmöjligheter*, VR 2005:10, Stockholm: VINNOVA, 2005; Technopolis calculations

Figure 11 shows the corresponding results for nine KTH Schools. Overall, they point out that about 3% of KTH's income comes from industry, which makes it clear quite how marginal any institute-like function is even in a Swedish technical university.

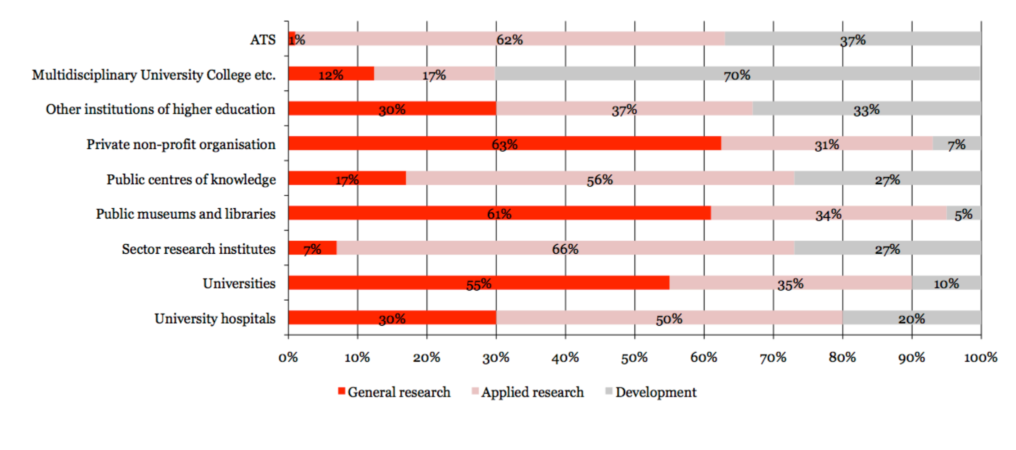
Figure 11 Self-reported Activity Profiles of a Sample of KTH Schools



Source: Lennart Eriksson and Lisa Ericsson, *Samarbete Mellan KTH och Kringliggande Industriforskningsinstitut – nuläge och utvecklingsmöjligheter*, VR 2005:10, Stockholm: VINNOVA, 2005; Technopolis calculations

The Danish example also shows clear differences between the applied institute and university systems in the overall pattern of R&D effort. Figure 12 shows this for Denmark[16], with the GTS institutes (in their R&D activities, i.e. excluding technological services) being strongly focused on applied research and development while the universities focus on basic and applied research.

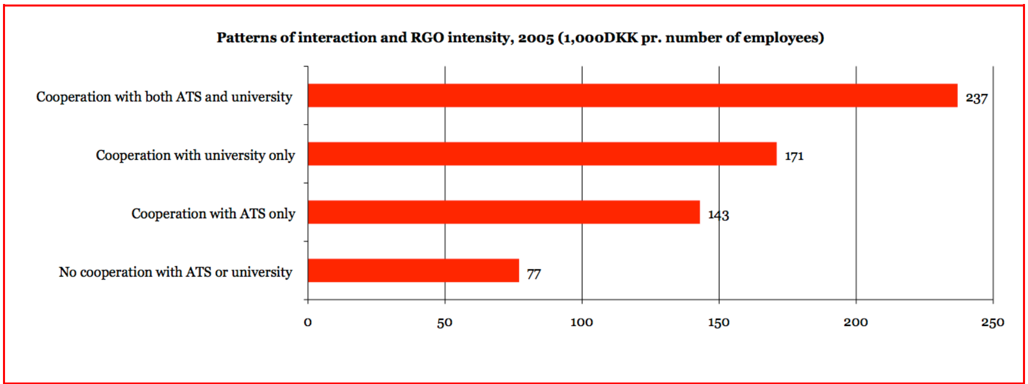
Figure 12 How R&D Activities Differ among Actors



Source: DAMVAD, Mapping of the Danish knowledge system, 2008, Customised data, CFA, 2008

In Denmark, companies employing more than 1000 people do 48% of business R&D. The share of companies under 250 employees doing R&D has risen from 27% in 1997 to 36% ten years later, indicating greater knowledge intensity even in the small-firm part of the economy. This increasing R&D intensity widens firms' opportunities to cooperate with the knowledge infrastructure. Figure 13 illustrates this quite dramatically and underlines that the **type** of interaction is different depending on whether the knowledge infrastructure partner is an institute or a university. R&D intensity and absorptive capacity are of course linked to size, but there are also many small companies with high R&D skills.

Figure 13 R&D Intensity and Cooperation Behaviour of Danish Firms



Source: Customised data, CFA, Forskningsstatistikken, 2008

16 See Erik Arnold, Neil Brown, Annelie Ericsson, Tommy Jansson, Alessandro Muscio, Johanna Nählinder and Rapela Zaman, *The Role of Research Institutes in the National Innovation System*, VA 2007:12, Stockholm: VINNOVA, 2007 for equivalent data on Sweden

Both the university and private consulting sectors in many countries, including Denmark, like to complain that the institutes somehow duplicate their work and that they somehow compete unfairly with them. In fact, customers of the Swedish institutes, GTS and Fraunhofer all say in recent surveys that they go to RTOs and universities for different things.

New ecological, biocide-free concept for an antifouling system

The YKI Institute of Surface Chemistry is part of the SP Group Sweden. It provides research and innovation expertise in a broad range of technology areas. Ekomarine contacted YKI in 2007 with ideas for a new ecological, biocide-free concept for an antifouling system. The paint that they wanted to develop encourages a biofilm to form, which comprises proteins that would act as a nutrient. This biofilm (or slime) would then prevent higher organisms, such as barnacles, from attaching, so creating true biological warfare inspired by nature. However, the entrepreneurs of Ekomarine lack the expertise of how to turn their revolutionary concept into paint. SMEs in general do not have the resources to carry out the research activities in house; therefore, RTOs play a significant role in supporting them to realise their goals and to elaborate their ideas such as Ekomarine's example shows.

Ekomarine needed help quickly to formulate the paint. They contacted YKI in the summer of 2007 and they expected the results by the end of the year. In Sweden YKI Institute of Surface Chemistry is well placed to provide the specific expertise needed with such a short deadline. YKI has the advantage compared to universities in that it was set up in a way that enables a quick response to the needs of businesses. They can work with tight deadlines and have broad experience in working with close to market projects.

YKI researchers worked with the Ekomarine team and brought crucial expertise to the project, turning the concept into a product that was launched for the Swedish yachting market in the spring of 2008. The product is the Neptune Formula, the only truly non-toxic solution in the market today. Since then, YKI and Ekomarine have worked together in a milestone-based collaboration to develop and improve the products further such as in reformulating the paint colours. An improved product was developed by YKI in 2008, and launched in 2009. As of now the company has developed a small range of the products and they keep improving and broadening their portfolio.

There were both social and economical benefits realised through the project. The private yachting market in Finland and in the Baltic parts of Sweden is estimated to be close to EUR 20 million, while the global antifouling market close to EUR 3000 million. Antifouling systems are essential, and particularly for commercial shipping, in order to reduce fuel consumption by up to 30-50 %. The Baltic Sea is under considerable environmental pressure from agricultural and industrial effluents, but the shipping and yachting industries also contribute significantly, particularly from toxic antifouling systems. A reduction of toxins from the yachting market is important, and steps have been taken by such means as prohibiting the use of copper oxides in yachting paints. However, all commercial solutions today contain significant amounts of organic toxins. Ekomarine's product, Neptune Formula, is the only truly non-toxic solution in the market today.

YKI has helped Ekomarine to enter the market with their product much more quickly than they would have been able to do without the contribution from the RTO; furthermore YKI's involvement in the development contributed in building the company's credibility.

"*YKI has proven crucial to Ekomarine in realising the concept: the first functional non-toxic antifouling system on the market today.*" (President of Ekomarine)

In a recent study of the Swedish institute system, customers who worked with both institutes and universities were able to be very clear that they went to universities for one set of things and to institutes for another (Figure 14). The other consideration in the division of labour between RTOs and others is efficiency. It is no doubt true, for example, that universities or even private companies could supply a number of the tests offered by RTOs institutes, but the institutes are set up to deliver these things dependably, in volume at a modest price and it is not at all clear that these other organisations could deliver the tests on similar terms. This is especially the case for low-unit-cost services to small firms, who tend to have a high cost-to-serve and who therefore are largely unattractive as customers.

Figure 14 Ideas Customers Associated with RTOs and Universities

RTOs	Universities
• Resources • Competence • IPR handled professionally • Confidentiality • Used to working with industry • Project management routines in place • Timeliness (mostly) • Can address focused research questions • Close to applications and products • Understand real industrial processes • Understand industrial customer needs • Less focus on publications than universities • A 'bridge' to scientific knowledge • Bring in university partners where that is useful • Proximity an advantage – especially when significant R&D projects are done together with an institute	• Developing human resources, especially PhDs • Basic and precompetitive research • No timetable • Difficult to steer or predict outcomes • Poorly equipped, compared to the institutes • May be opportunities to get additional state funding to carry on the project Note: In the special case of university-based competence centres, access to academic and industrial networks were also mentioned

Source: Erik Arnold, Neil Brown, Annelie Ericsson, Tommy Jansson, Alessandro Muscio, Johanna Nählinder and Rapela Zaman, *The Role of Research Institutes in the National Innovation System*, VA 2007:12, Stockholm: VINNOVA, 2007

The GTS user survey clearly indicates that RTOs are able to reach much smaller companies than universities. Most of GTS' customers employing 50 people or less only use the RTO sector, while many of those with more than 50 employees use both the universities and GTS[17].

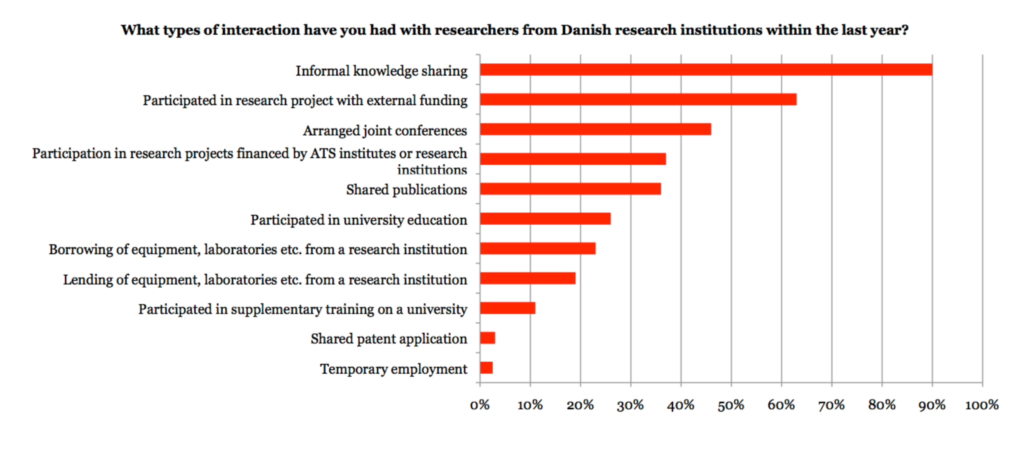
3.2 RTOs and Universities are Increasingly Strongly Linked

Interaction with the universities is normally a strong characteristic of RTOs, and is realised through co-publications, joint PhD supervision or PhD placement, and part-time employment of RTO staff as university teachers. NIFUSTEP found that 57% of the scientific publications of the Norwegian RTOs in 1999-2002 were co-published with university authors[18]. The Danish case shows a high level of cooperation between the GTS institutes and the Danish universities (Figure 14). In 2008, the Swedish institutes collectively spent 21% of their core funding on joint projects with universities, aiming to increase their capabilities and develop technology platforms. SINTEF, the largest Norwegian RTO, was founded by the Technical University of Norway, with which it still shares a campus. Professors are active in the work of the RTO, equipment is shared and well over 100 university registered PhDs do their doctoral training within SINTEF. Fraunhofer is so tightly linked to the university sector that the directors of its institutes have at the same time to practice as professors at a nearby university, similarly bringing a flow of PhD workers and recruits to the Fraunhofer institutes, who typically spend some years there before moving to industry.

[17] Oxford Research, 2008

[18] Aris Kaloudis and Per Koch, De næringsrettede instituttenes rolle i det fremtidige innovasjonssystemet, Rapport 4/2004, Oslo: NIFUSTEP, 2004

Figure 15 Interactions with Danish Universities



Source: DAMVAD: Analysed from data from the GTS Association, 2008
Note: Based on individual staff member responses

Together with universities, TNO has established some 30 knowledge centres to develop knowledge in selected fields. These knowledge centres function as innovation centres, where companies also participate. One example is the collaboration established in 2007 with three universities to form a Climate Centre (Vrije University, Amsterdam, Wageningen University and Research Centre as well as the meteorological institute KNMI and University of Utrecht). Other examples are the Utrecht Centre for Geosciences and the Integrated Basin Tectonics Knowledge Centre (Amsterdam), where TNO collaborates with universities.

CRP Henri Tudor - SITec

CRP Henri Tudor's SITec training centre for innovation was established in 1988, soon after the foundation of the research centre in 1987. The main aim of the training centre is to promote innovation and technological development through disseminating information, organising vocational training and qualifications. SITec's main missions include knowledge transfer to SMEs and individuals; valorisation of the research centre's research results; exchange of knowledge and best practice and acting as catalyst for innovation. SITec operates as an innovation service department within CRP Henri Tudor with a total staff of 15,6 people in full time equivalent.

The training centre is active over a broad range of fields with a core competence in the conception and process management of various training and dissemination activities. SITec applies a sectoral approach in its activities, which reflects the technology areas covered by CRP Henri Tudor. In terms of sectoral coverage, information and communication technologies account for almost 2/3 of the CRP Henri Tudor's activities, a further 10% is devoted to material and surface technologies, 10% to enterprise management, 15% to environmental technologies and 5% to health technologies, although this area is partially covered by the ICT field. SITec's sector based and also integrated approach, stemming from its embedded position into the research centre, enable a quick response to emerging needs.

SITec covers a whole chain of activities from the conception of an idea through to its implementation and execution. Its heterogeneous activity portfolio includes organisation of training (e.g. vocational and professional training), e-learning courses; university trainings ('Master Studies in Innovative Dimensions'); professional and scientific conferences at both national and international level; valorisation of research results and developing sector partnerships through managing networks and working groups. The portfolio is diversified by the target audience and varies from general training to bespoke courses and sessions. SITec organised a total of 120 qualifying training courses in 2009 out of which 40 were customised (company in-house) [19].

To ensure the quality of their education and training activities SITec puts emphasis on training the trainers and systematically carries out participant satisfaction surveys and benchmark exercises to serve the changing needs of its clients and to improve its services. Training content is developed based on SITec's client needs and delivered in a flexible way that most suits the participants. Examples include the delivery of

[19] CRP Henri Tudor: Annual Report 2009

a vocational training course Friday afternoons, in a time slot that enables broad participation; or the integration of an additional module on renewable energy sources into the vocational training courses in the building and construction sector in line with the growing importance of the subject field.

In addition to its education and training activities, SITec also provides advice to the other CRP Henri Tudor research departments on strategic questions concerning their training and dissemination activities. It carries out market analysis, mapping and feasibility studies and marketing activities on request in growing and emerging sectors and fields. The training centre also aims to adopt and implement European best practices to maximise the quality of the knowledge transfer activities.

The main clients of the training centre are the Luxembourg businesses, particularly SMEs. In a broader sense SITec provides services to anyone with the potential for innovation in his work. In reaching businesses SITec applies proactive methods. CRP Henri Tudor's internal research departments are SITec's internal clients. This results in a situation where SITec is both a partner and also a service provider for the other CRP Henri Tudor departments. The training centre has considerable autonomy regarding the way it provides its services.

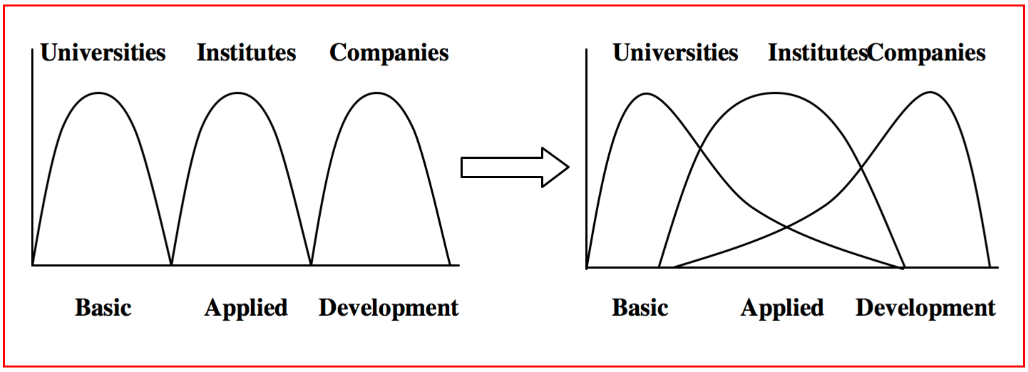
SITec uses European expertise extensively and it aims to provide businesses in Luxembourg with the knowledge gained. Therefore the training centre is very active in networking and partnering. SITec's main partners include authorities, regulators, universities, other professional training providers on national and European level, lead actors in lifelong learning activities in other countries and various national associations such as the chamber of architects and engineers, L'Ordre des Architectes et des Ingénieurs-Conseils – OAI. Together they can refine and modify the content of SITec's training portfolio to provide the most up to date and suitable information. Furthermore, these partnerships help SITec to deliver a large number of educational and training activities and to provide access to broader expertise.

While the training centre has the expertise to carry out all non-scientific activities including strategic and operational processes, the scientific part is accomplished by in-house researchers and external speakers invited. CRP Henri Tudor has strong partnerships with universities and together, through its SITec department, they deliver the 'Tudor Masters'. These degrees focus on multidisciplinary education with a strong professional orientation and an innovative real-life project about six months. These six months projects are financed by the participating companies and therefore have a special focus on the needs of the company. The programme is designed to provide advantages both to the participating businesses and students. The students gain professional experience and receive practical oriented education, while the businesses benefit from a refreshed know-how within their organisation. Different Master's degrees are delivered with various university partners from Luxembourg, Belgium, France and Canada with a continuously broadening portfolio. From early 2011 a new Master's will be offered in partnership with various universities that enables of pooling together knowledge from across different disciplines. The new Master's, the EMISS (Executive Master in Innovative Service Science) will be implemented in cooperation with the University of Geneva, the Faculty of Engineering of the University of Porto, the Faculty of Informatics of the Masaryk University, Universitat Politècnica de Catalunya and Vrije Universiteit Amsterdam.

SITec offers more than 240 professional training courses and four international Master's degree courses and every year organises around 50 professional and scientific conferences with national and international partners. Their training provision for the year 2010 includes 233 days of vocational training engaging approximately 1870 attendees, 4 'Tudor Masters' with 120 attendees, organisation of 42 events with more than 2000 participants and 12 innovation networks. The training centre's activities result in significant impact on Luxembourg SMEs through stimulating discussion; by the training provided; through transferring European best practices to the country; and through the application of the knowledge generated by each individual businesses.

While, therefore, universities and RTOs have quite distinct roles in the innovation system, the overlap is increasing. This is healthy. It is increasingly recognised that if the old 'three-hump model' – Figure 16 – ever worked, it has now broken down. The 'three hump' model is the idea that universities do basic research, institutes do applied research to translate basic ideas into applicable knowledge and industry gratefully accepts and uses the knowledge handed down to it by the knowledge infrastructure. The model does not work in relation to the institutes in part because of the growth of Mode 2 (i.e. problem-orientated) R&D, in part because institutes do not have the passive 'translation' function described but rather are active problem-solvers who from time to time need to do research as a way to solve problems and in part because institutes have to do more fundamental work in order to underpin the development of the capabilities or knowledge 'platforms' they need to solve problems.

Figure 16 The Breakdown of the 'three-hump model'



Improved boiler performance in energy plants

The Swedish Waste Refinery Excellence Centre is coordinated by the SP Technical Research Institute of Sweden. Research activities are carried out by the Centre in close collaboration with industry, research organisations and society. The Centre is partially funded by its members including industrial partners and the SP Research Institute of Sweden; further funding is received from the Swedish Energy Agency and from regional public bodies. SP's Waste Refinery Centre focuses its activities on three main areas: systems analysis, biological and thermal treatment. It also carries out interdisciplinary research. Projects at the Centre are often based on long-term partnerships. The research institute's involvement in collaborative projects mitigates the risks of project implementation through its expertise in the technology areas and the coordination provided. The researchers at the Centre are aware of their industrial partners' needs. This enables them to act fast and to provide businesses with tailor-made services.

The 'Improved boiler performance in energy plant' is a joint project that was carried out by SP's Waste Refinery Centre on behalf of an energy utility, Borås Energi och Miljö, an operating contractor, Dalkia, a boiler manufacturer, Metso Power, and a fuel supplier Stena Metall and with the involvement of a science-based university, University of Borås as collaborative partner. The researchers at the Centre applied a proactive approach when they learnt a new method and they recognised that with modification it might also be applied to a partner's problem.

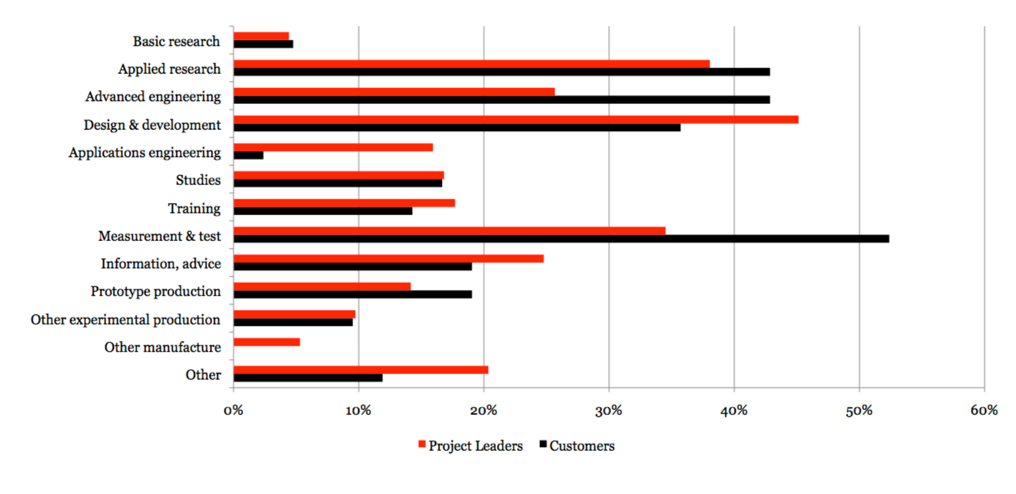
During the project, trials were carried out in a commercial refuse incineration plant to demonstrate solutions for improving the performance of fluidised bed boilers by reducing the temperature in the bed. As the first stage of the joint project, a preliminary study was carried out to identify how the new approach can be applied in boilers. The successful preliminary project was followed by a full-scale demonstration study. The project lasted about a year in total from the idea till the design and it resulted in the design of a new operation strategy, including new operation parameters. The results of the project include a reduced risk of operating problems caused by the build-up of slag or abrasion of heat transfer surfaces. In addition, the plant in which the trials were conducted is now operated at a lower bed temperature, and the same benefits can now be relatively easily applied to other incineration plants as the new refuse incineration method does not require any additional investment.

Economic benefits were realised both by the owner and the operator of the energy plant due to the new method designed. The savings are expected to amount to about SEK 2 million per year, which is equivalent to about 4-5 % of the entire operating and maintenance cost of the energy plant.

3.3 RTOs Do a Wide Range of Activities

Earlier, we saw the range of activities that Swedish RTOs pursued with their **core funding.** Figure 17 looks at the main body of routine projects done together with or for industry and compares the perceptions of the RTO project leaders with those of the industrial customers. There appears to be a small but tantalising difference of view, with the customers seeing R&D projects as just a little more fundamental in nature than the project leaders do. This is consistent with the 'one step beyond' idea discussed earlier, that the institutes help companies into areas that are just beyond their capabilities. The other difference of view relates to measurement and testing, where the project leaders seem to see their role as more advisory and analytical than the customers seem to think.

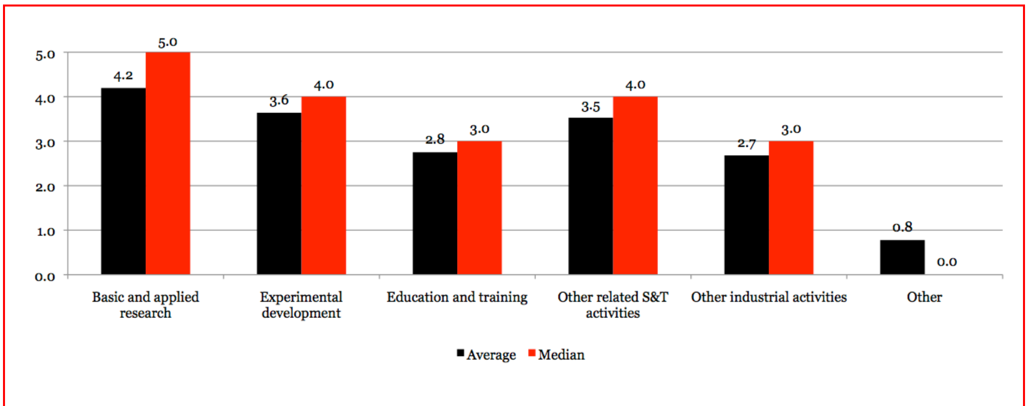
Figure 17 Swedish RTO Customer and Project Leader Views of Project Activities



N = 113 project leaders, 43 customers

Our survey of EARTO members asked them about the **importance** of these activities to their mission (on a scale of 1-5, where 5 is high – Figure 18). They place a very high priority on basic and applied research, as requirements for delivering their mission.

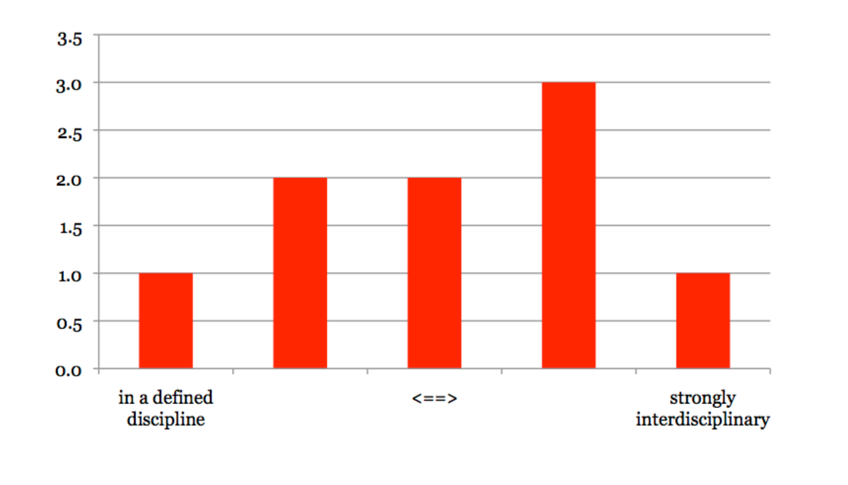
Figure 18 EARTO Member Views on the Importance of Key Activities



n=38

Because it is problem-orientated, a lot of the work of the RTOs is interdisciplinary. Figure 20 shows the responses to a 2007 survey of EARTO members, showing their views of the degree of interdisciplinarity in their work.

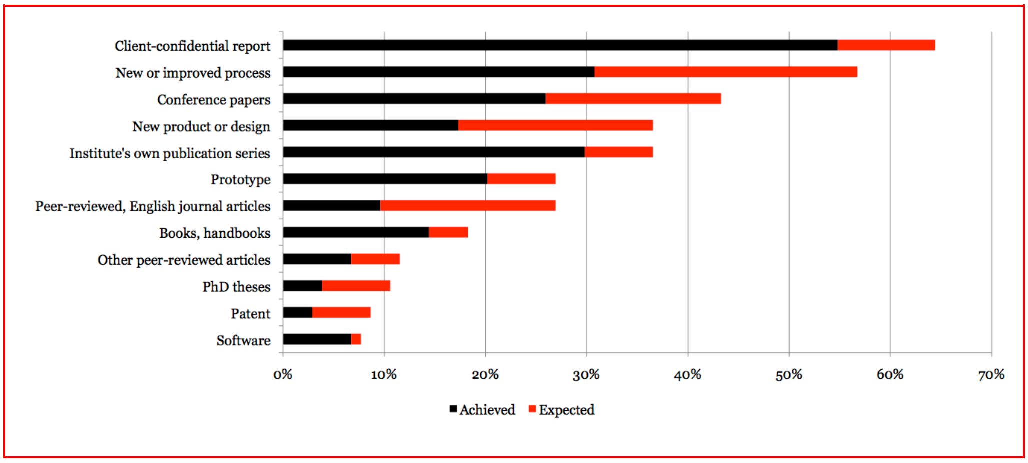
Figure 19 Degree of Interdisciplinarity in RTO Work



Source: Reinhold Hofer et al, 2007. N=9

We would expect the results of RTOs' work for industry to be rather firm specific and to be kept private. Figure 21 reports the proportion of Swedish RTO projects producing outputs in various categories. The biggest category is indeed private reports. Product and process designs are important results, in line with customers' reasons for going to the institutes. However, it is noteworthy how many projects have published or plan to publish in the scientific literature as well as the larger number which publish results at conferences or in the institutes' own publications series. This is a significant public good outcome. Better than 10% of projects are likely to contribute to PhD theses, underscoring both the robustness of much of the research in scientific and technological terms and the importance of the links to universities. So not only core-funded RTO projects but also their more routine work creates a lot of knowledge spillover. Below, we build this spillover into our economic model of RTO impacts.

Figure 20Project Outputs Achieved and Expected



N = 113

Knowledge based construction details

The Norwegian Building Research Institute was established in 1949 to promote building research in Norway and to transfer the research results to the public. The Institute was merged with SINTEF's building and construction research groups to form SINTEF Building Research AS in 2006. Building Research Design Guides have been published since 1958 with the main aim to disseminate the results and experience generated by building research to the construction industry. The design guides are fully compliant with the performance-based requirements of the Norwegian building codes and standards. The guides are translations of the building rules into practical solutions and they consist of detailed information with illustrations and descriptions of 'pre-accepted' solutions. The guides provide concrete solutions and recommendations on a wide range of specialist building issues from the planning and design phase to the construction of the buildings.

The most influential government regulatory measure to ensure adherence to building codes and standards is the Technical Regulations under the Norwegian Planning and Building Act (PBA), which since 1997 have been performance-based. The principal motive for a transition from a prescriptive-based code to a performance-based code in Norway has been to stimulate to an increase in the quality of buildings and a reduction of the amount of building defects. The transition has been a gradual process, and the performance-based way of thinking was introduced in Norwegian building regulations as early as 1969. The transition from a prescriptive to a performance-based code has strengthened the demand for supporting standards and design guidelines.

There were 35 design guides published during the first year of the series. Nowadays, there are approximately 750 design guides in use. The guides are continuously updated to comply with the building codes, changing regulations and experience-based knowledge. The series is the most commonly used planning and design tool amongst Norwegian architects and engineers, and it is found on nearly all construction sites in Norway. Recognition of the series is also reflected in the fast and steady increase in the number of its subscribers. During the first year of publication, the number of subscribers reached 600 and today it exceeds 6000. The series forms a national knowledge system which is accessible via the Internet. The publication of the design guides is an essential and planned part of the research work carried out by SINTEF. Contract research customers also accept or even encourage the application of the generated knowledge in updating and publishing the design guides.

The design guides solve challenges linked to the entire construction process, and offers guidelines in technical fields ranging from architecture and construction physics to the management, operation and maintenance of buildings and other forms of infrastructure.

About 240 people from SINTEF are involved in building and construction sector related research of whom 40 researchers are working on updating the design guides. SINTEF Building Research publishes new or revised recommendations eight times a year. The estimated costs of keeping the guides up to date are about NOK 30million. The resources devoted to this and its long history make the design series one of the biggest projects in SINTEF's activity portfolio.

SINTEF's design guides present a quality standard in the building and construction sector in Norway. They are present and referred to at different construction sites from building houses to large infrastructures and are also well-regarded as information sources for construction detail. In addition to the practical benefits provided to the construction industry, the design guides also contribute to a reduction in building damage and to safer buildings. The design guides adapt experience and results from research and practice in order to be of practical benefit to the construction industry.

The main purpose is to provide guidelines, solutions and recommendations that encourage high quality in the planning, design and construction of buildings. The concise guidance on the principles and practicalities of construction is in conformity with the regulations to the building act, and has become a standard of quality and the most authoritative and important tool to secure that buildings in Norway achieve good quality.

3.4 Customers

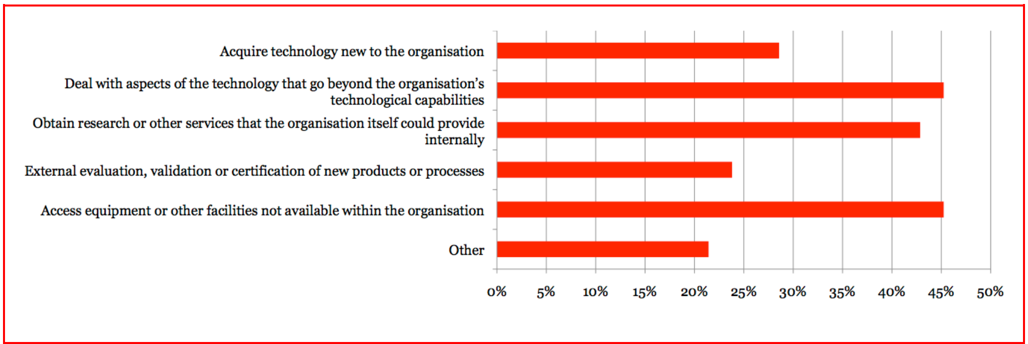
The Fraunhofer Society's recent survey of 309 companies sheds some light into the nature of the RTO customer base. Three-quarters of those surveyed regarded themselves as research-intensive. Forty-three percent of all the customers (and 53% of the research-intensive ones) planned to increase their R&D investments in the next few years – increasingly using external partners. Surveys of GTS users confirm that they are more innovative than a control group of non-users[20]. Customer satisfaction is very high: 93% are either completely or partly satisfied with the service they obtained. They also tend to come back for more – almost 85% of GTS' clients are repeat customers. Overall, it is clear that GTS captures a large proportion of the more dynamic and progressive firms in the economy.

[20] Oxford `Research, Brigerundersøgelse af GTS-institutterne, 2008, Copenhagen, 2008

Figure 22 confirms that RTO customers aim to move 'one step beyond' their existing capabilities via the institute projects, seeking new technologies, tackling aspects of technology that they do not currently master and accessing resources not normally available to them. Projects with these aims are especially likely to be supported by Swedish R&D funders. However, customers say that they could have done part or all of the project themselves in just over 40% of the cases, using existing resources. Much of the work of the institutes therefore is additional to, rather than displaces, company R&D. Where this is not the case, we assume that companies are likely to be peak lopping so that they do not need to expand their permanent development capabilities.

For all the first three categories in Figure 22, projects were more likely than most to involve advanced engineering. Projects acquiring technology and dealing with aspects of technology going beyond the customer's existing capabilities were particularly likely to involve design and development and are especially unlikely to result in publications.

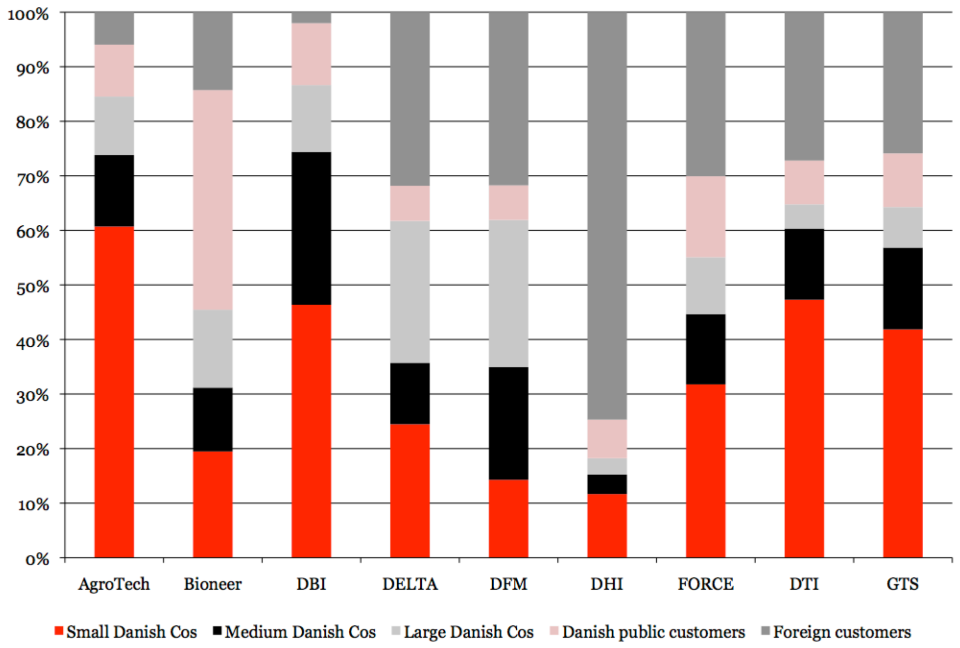
Figure 21 Aims of the Customers of Swedish RTOs (% of projects)



N = 42

GTS is unusual among RTOs in having an internationally diversified customer base – largely because it has adopted a strategy of selling technical services outside Denmark and using the profits from these to fund some of its internal R&D and capability development. Figure 9 shows that about 25% of GTS' customers are outside Denmark, with DHI primarily serving international customers. Numerically, small Danish companies (under 50 employees) are the biggest customer group. However, small customers usually have small requirements. Figure 22 shows how the company customers divide among small, medium (50-200 employees) and larger companies. Overall, the 'large' firms provide half the company income (though it should be recalled that these are not necessarily 'large' in international terms). However, the diversity within the GTS group is also important because it reflects the kind of diversity seen among RTOs more generally. Some are heavily orientated towards SMEs; others focus on large companies; yet others have a mixed customer base. This varies with industry structure, companies' levels of technological capability and with technology.

Figure 22 Company Groups Served by GTS Institutes, 2007



Basis: Number of customers per category
Note: AgroTech data for the first half of the financial year only

Multiphase flow transport

Much of the oil that is still to be exploited is located in harsh environments (longer, colder, deeper) and smaller fields; therefore multiphase flow research provides the basis for the future development of Norwegian oil supply. Multiphase technology enables transport of unprocessed oil and gas to shore or to a nearby platform for processing instead of building platforms over every oil field. Research in the field of multiphase transport began with ESSO initiating the finance of a laboratory that was to be operated by SINTEF in 1979, and continued with Statoil in investing NOK500million in multiphase flow research in the 1990s. Oil companies had to invest 50% of their research investments in Norway to get access to the oil on the continental shelf. As a result, a large-scale multiphase flow laboratory was opened in Trondheim in 1983 and SINTEF took over the laboratory from ESSO after a year of operation.

The main aim of the laboratory was to generate knowledge and data and develop prediction tools, as well as verifying the concept that it is possible to transport oil and gas in the same pipeline on the seabed. Furthermore, the large-scale experiments are essential for understanding the physics of multiphase flow and in building models. At that time, research in multiphase flow was pioneer work, and the large-scale laboratory with a kilometre long loop which is 8 inches in diameter, was and still is a unique installation in the world. It provides the opportunity to carry out validation before installation. Companies have performed large projects for more than 25 years at the facility. Nine oil companies financed a joint project of about NOK 40million (€5million)[21] between 1984 and 1986. The total investment including the construction costs of NOK 80million amounted to NOK 140million (€7.5million) by the end of 1986 which shows an extraordinary interest of the oil industry in multiphase flow research.

Research activities in multiphase technologies have been carried out by SINTEF in collaboration with the Norwegian Institute for Energy Technology (IFE). IFE had already developed a preliminary version of a software package, named OLGA, in the early '80s. OLGA was designed to simulate the two-phase flow in a single pipeline. A reliable simulator results in large cost savings, safer operation of oil and gas fields and enables the better understating of multiphase flow. SINTEF's collaboration with IFE was at its most intensive in the 1980s and through the mid 1990s. While IFE was developing the models, SINTEF's role was to provide experimental data that could verify the models. Although the peak period is over, the two organisations are still working closely together in several projects.

The first multiphase transportation system of 63 kilometres was installed in February 1996. The system carried gas and condensate from the North Sea to the shore.

[21] IFE, SINTEF: Flow, 25 years of multiphase subsea transport of oil and gas

"At a press conference in 1989, Norske Shell, the operator, said that splitting the Troll project between offshore and onshore plants would reduce development costs by NOK 4.5 billion (570 million euro), and cut annual operating costs by NOK 330 million (40 million euro). "[22]

According to Statoil, their initial investment was returned during two years. They invested NOK 500 million in the early '90s and the payback they estimated is around NOK30billion.

There was less demand from the industry for research activities in the large-scale laboratory between the mid '90s and the millennium. As new research challenges arose, such as oil fields being located at a greater sea depth and colder environments (meaning that multiphase transportation has to cover longer distances and steeper slopes), renewed effort has been made in the multiphase transport research since 2000. The research aims to understand the details of multiphase flow transportation and to expand the physical modelling as well as verify the subsea technology. Around the millennium SINTEF initiated the development of new simulation software entitled LEDA in collaboration with the two major oil companies ConocoPhillips and TOTAL. The main difference between OLGA and LEDA is that the new platform is based on physical modelling in contradiction to OLGA who is based on correlations.

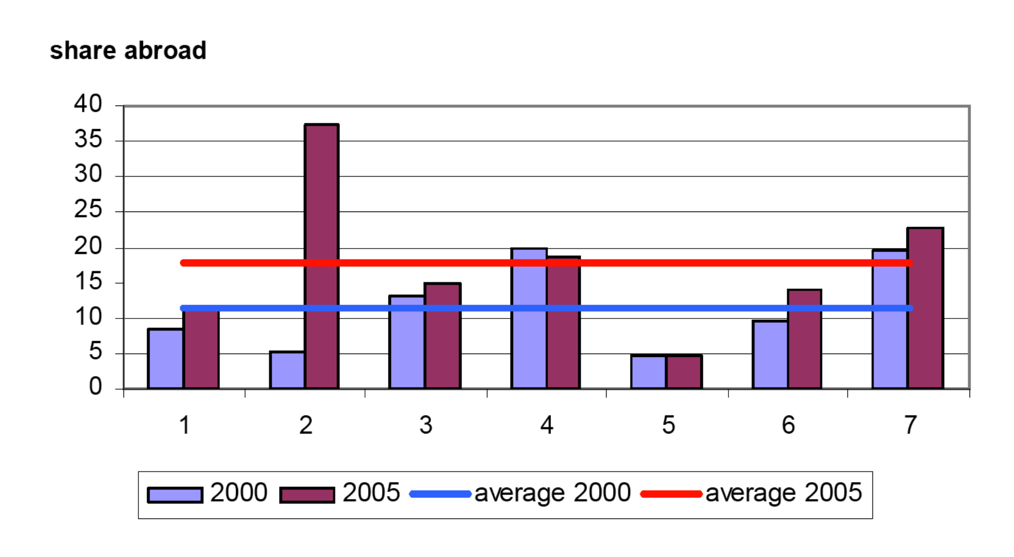
Nowadays there are 24 people working at SINTEF Multiphase flow laboratory while as much as 6-700 people out of a total 2200 are working with oil and gas related projects across the various departments. To meet the future challenges, SINTEF spent about NOK 85 million of its own funds during the last couple of years to upgrade its multiphase flow facilities. These investments resulted in the establishment of three new laboratories. A medium-scale multiphase flow laboratory was created with a new flow loop which enables research on the flow phenomenon with a more complex structure such as viscous or 'heavy oil'. A new High pressure, High Temperature (HPHT) laboratory was also established which consists of six explosion proof cells. It is a well-known fact that the chemistry of the oil plays a crucial role in multiphase flow. The HPHT lab is specialized for doing experiments with real crude oil to unveil the complex chemistry of the oil. The third facility is a CO_2 laboratory that was designed to carry out research on energy efficient procedures for capturing CO_2 with the aim of reducing the energy consumption by 50%. These investments aim to prepare the oil and petroleum research for the future challenges such as an increased amount of water coming in the pipes from the reservoirs, prevention of hydrate formation, increased oil viscosity and altered flow patterns all in an energy effective approach.

RTOs in most other cases have a more national customer base, even if leading organisations like TNO, Fraunhofer and SINTEF are making an effort to internationalise. Thirty-one of the EARTO members we surveyed for this study provided us with information about the share of their income that came from abroad. Aggregate exports as a proportion of their aggregate turnover was 8% (including Framework Programme income) in this sample. Five RTOs earned 40% or more of their income from abroad. Of these, two were private for-profit organisations and three were small-medium, specialised non-profits.

There is a trend towards international income forming a growing (if so far rather modest) proportion of turnover as RTOs begin to serve industrial customers abroad, in addition to winning increasing proportions of their income from the Framework Programme. Joanneum Research conducted a survey of 20 RTOs in 2007, which confirms this modestly rising trend in international income (Figure 23).

[22] IFE, SINTEF: Flow, 25 years of multiphase subsea transport of oil and gas

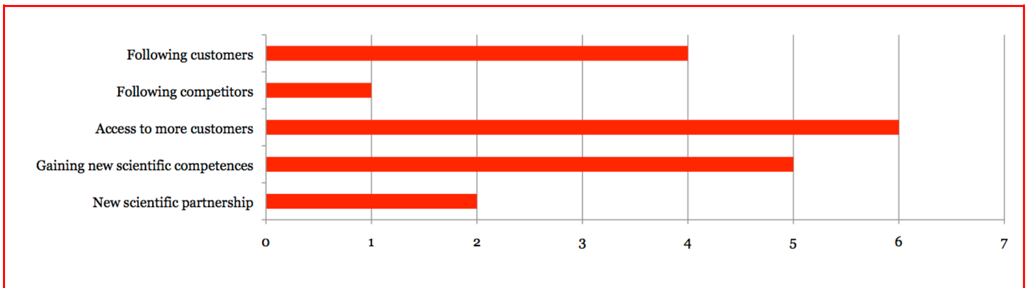
Figure 23 Share of Income from Abroad, 2000-2005 (n=7)



Source: Reinhold Hofer, Brigitte Nones, Elke Jantscher, Wolfgang Polt and Helmut Wiedenhofer, Europäischer Benchmark der EntwicklungstrendsAußeruniversitärer Forschungsinstitutionen, Vienna: Joanneum Research, 2007

Figure 24 shows the responses of the 7 that answered the question about **why** they were internationalising or wanted to internationalise by setting up operations outside their home countries. Of the 20 respondents to the questionnaire overall, only 4 indicated that setting up abroad was relevant or very relevant to their strategies (4 or 5 on a 5-point scale). Clearly, the **incentives** for going abroad are not all that strong – an important problem in relation to creating the common market in knowledge services that is a key component of the European Research Area vision.

Figure 24 RTO Motivations for Internationalisation



Source: Reinhold Hofer, Brigitte Nones, Elke Jantscher, Wolfgang Polt and Helmut Wiedenhofer, Europäischer Benchmark der EntwicklungstrendsAußeruniversitärer Forschungsinstitutionen, Vienna: Joanneum Research, 2007

3.5 The Framework Programme

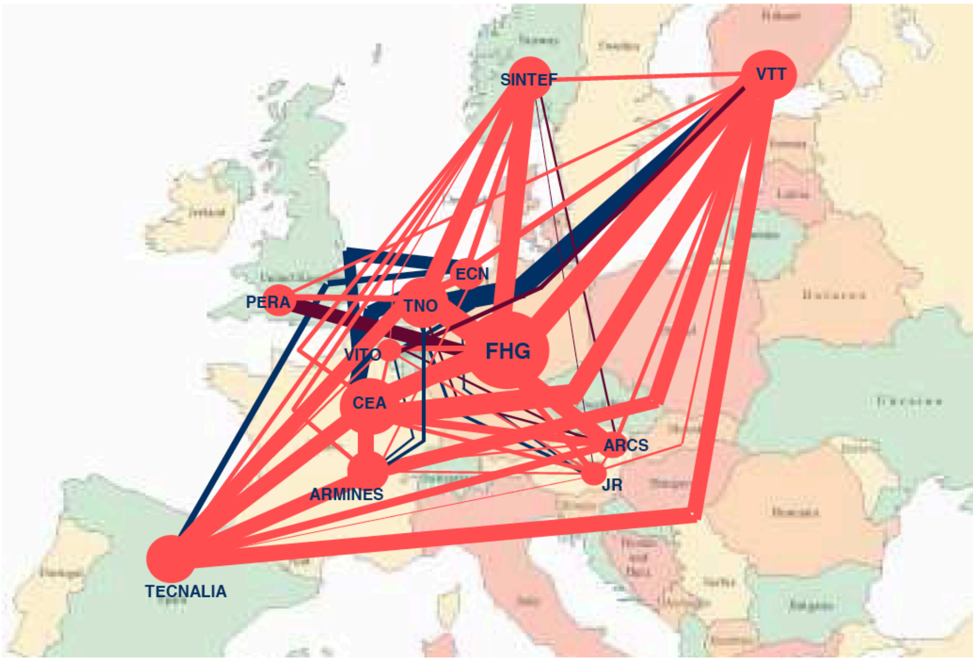
In an important sense, the RTOs hold much of the Framework Programme together. They play a very significant role as project coordinators – their professionalism equipping them well to handle the management as well as the technological aspects of this task.

Figure 25 illustrates the pivotal role of the RTOs. It shows the more important network linkages among the major European RTOs in the Sixth Framework programme. Including the additional links makes the true picture hard to make out, but each of the projects shown brings a network of other participants, so the RTOs serve as key nodes interconnecting the different parts of the European research and innovation system.

The engagement of the RTOs is intense, as Figure 26 indicates. Another way to see this is through the number of FP6 projects per 1000 RTO employees, shown in Figure 27 for a sample of major RTOs.

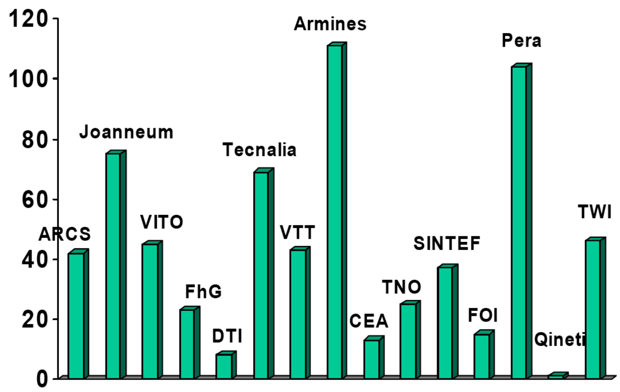
RTOs accounted for 28% of FP6 participations and received 32% of FP6 funding. They provided about 35% of FP6 coordinators. While they represented just 4.5% of all FP6 participations, they were involved in 22% of all FP6 projects and those projects obtained 44% of all FP6 funding[23].

Figure 25 Network Role of the RTOs in the Sixth Framework Programme



Source Fraunhofer Gesellschaft

Figure 26 Number of Projects in the Framework Programme per 1000 Employees



[23] EARTO, Research and Technology Organisations in the Evolving European Research Area: A Status Report with Policy Recommendations, Brussels: EARTO, 2010

4. Economic Impacts of the RTOs

In this Chapter, we bring together others' studies of the economic impacts of RTOs with our own analysis, which takes the form of a spreadsheet model of economic effects based on the RTOs' inputs, outputs and spillovers.

Most attempts to quantify economic impacts of RTOs focus on a sub-set of their activities that directly supports innovation projects in firms. Typically, the rewards from such innovation activities are highly skewed: some projects make a lot of money; many make little or nothing. Where it is possible to identify impacts, however, these can be quite high.

The second, more macroeconomic approach to understanding the economic impact of RTOs tackle all of their activities but suffer from inability to account in detail for the mechanisms of impact. Both approaches are therefore problematic. Rather than placing faith in a particular set of numbers, we note that whatever approach is used the impacts appear to be **significant** in size. This is also consistent with the survey and case-based evidence.

4.1 Evidence from Other Studies

A number of the RTOs have themselves tried to assess their economic impacts using a range of techniques, most often by asking customers to estimate the effects of particular projects or interactions with the RTO on their turnover. This is relatively easy to do with SMEs, which are small enough to make a direct connection between specific activities. The technique is very hard to apply to large, multi-product firms whose technical resources are used in many part of the enterprise. These 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.

TNO periodically tries to estimate the effects of its 'Co-financing programme', which shares costs of innovation with companies. The most recent analysis[24] was based on 77 responses. Two thirds to three quarters of firms of different types said they had used the knowledge gained from TNO or expected to do so within three years. Twenty-five of the companies were able to estimate the effects of the projects. The Ministry of Industry had invested €12.86m in their projects, which the companies said led to an increase in turnover of €150.262m, a direct contribution to profits of €18.012m and cost savings of €11.797m. Illustrating the highly skewed nature of innovation, three participants were alone responsible for two thirds of these direct economic effects.

The Swedish ICT Institute (SWICT) monitors the impacts of its work on the turnover of the 15-20 SMEs with which it works each year[25]. Details of the method are not published but the figures suggest that a kronor invested through the SME programme with SWICT produces 15 or more kronor in increased sales. SWICT argues that about 40% of the turnover increase returns to the state in the form of taxes and other charges, giving the taxpayer a return of about 6 times the subsidy provided.

A study of company innovation projects funded by the Austrian Research Promotion Agency (FFG) found – based on a sample of 332 companies – that these led to very large increases in turnover among beneficiaries. One Euro of subsidy from the main funding programme to a company triggered €19 in additional turnover. Where Austrian Cooperative Research was involved as an RTO partner, subsidies were

[24] TNO, Effectmeeting TNO Cofinancieringsprogramma, 2006; internal document

[25] SWICT Annual Report, 2009

smaller (on average €94.6k, compared with €318k for the remaining projects) and the return was higher, at €25.3 per Euro invested. The effect appeared to be caused by the smaller size of the companies that used ACR rather than their own internal R&D capacity[26].

A more sophisticated study[27] of the impacts of FEDIT projects in Spain, based on 309 responses, found

- Technical impacts: collaboration with RTOs has had a positive influence primarily on new and improved products but also on new and improved processes
- Economic impacts: Collaboration with RTOs resulted in increased turnover (on average by 4% on an annualised 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
- Impact on investments: Overall, collaboration contributed to increased investments by individual companies in internal and external R&D as well as in outsourcing innovation and IT infrastructure
- Impacts on intangible assets: These types of impacts are important as firms' competitiveness increasingly depends on intangibles – which are difficult to measure
- Impact on human resources: collaboration had a positive impact on learning and staff training and also enhanced intra-firm collaboration, knowledge sharing and problem-solving
- Impact on firms' strategy: Collaboration improved firms' understanding of the market as well as their capacity to define and plan innovative activities
- Impact on information management: Collaboration improved the selection of information systems and software by firms and the relations between the R&D and other departments
- Impact on relations with the environment: Collaboration enhanced considerably the use of both knowledge from external sources (e.g., universities, research organisations, R&D companies and consultant) by firms and information on public funding schemes available for innovative activities
- Satisfaction from & Value added of collaboration: The overwhelming majority of firms are sufficiently or very satisfied with collaboration. Collaboration, in their opinion expedited the completion of projects and permitted business to carry out successfully more ambitious projects

[26] Austrian Cooperative Research, Press release, Wirksamkeit der Forschungsförderung: Kleine Projekte mit besserer Wirkung, (undated) 2010

[27] Aurelia Modrego et al., 'Hacia una medida de la contribución de los Centros Tecnológicos (CTs) españoles a la mejora de la competitividad de las empresas.' FEDIT – DOSSIER, 14.04.09

VTT Customer Satisfaction Surveys

VTT started systematic work in the late 1990s to develop a concept that enables the organisation to carry out impact assessments. After a pilot survey in 2000 VTT launched their first impact assessment survey in 2004. VTT then launched these surveys every second year up to 2008, when the survey became annual. A consultancy company is used to carry out telephone surveys. The questionnaire has been developed in parallel with VTT's impact model and with the aim of showcasing the positive impacts of the organisation. VTT's motives to carry out its surveys include:

– That the results help them in understanding how to improve their services towards their customers. Therefore the surveys are communicated to the personnel at VTT and the results are analysed and taken into account by the management of VTT

– The need to show the benefits and impact generated by VTT to the Ministry of Employment and Economy. The results are used in discussions for steering VTT activities and resources

– The need to showcase their results to their customers and the Finnish economy

The survey comprises questions that assess the extent, nature and additionality of the benefits and impact generated by VTT' for its customers; measure customer satisfaction with VTT personnel, marketing and communication; and help to understand the barriers and obstacles that need to be overcome in the future to improve the quality and results of the collaborative projects. Questions regarding customer expectations assist them in developing tailor made services and in improving their customer care.

The customer survey is carried out on a sample of VTT's projects that were finished during the previous two years. At the beginning the survey population comprised 200 customers. Nowadays the sample consists of 120 customers in Finland and 30 international customers. The inclusion of customers from abroad reflects the shift in VTT's strategy and the move towards the internationalisation of its income. The survey is representative of and covers all of VTT's technology areas, but the selection of the customers included in the survey is chosen randomly from a 'long list' of customers. The customers in the sample represent all the different types of VTT client including businesses, universities and also public bodies. However vast majority of the customers in the sample are private businesses which reflect the actual customer base of VTT. In the 2010 of the customers surveyed 53% have an annual turnover of more than €25 million, while 42% have a turnover of less than €25million (5% of the customers could not give out this information), but there is no distinction made between the different sized companies in the survey.

VTT has approximately 5-6000 customers with about 4000 projects and the survey covers only 150 customers. Taking into account that a customer might have multiple projects during a year, the sample covers approximately 5% of VTT's project activities including both co-financed projects (national and international public bodies) and contract research activities. Although the survey is relatively small, it provides VTT with reliable information on the trends concerning how the organisation's impacts have developed. In addition responses of 150 customers on the open-ended questions of the survey can highlight some specific and topical issues which can lead to new measures within the organisation (related e.g. to IPR management, project management or communications development).

There seems to be a tendency that VTT's role in generating impacts has increased over time, but meanwhile the impacts in total have decreased. VTT tries to explore the reasons behind this trend by analysing the open-ended responses of the survey. Furthermore VTT follows up those customers who reported especially good or bad experiences or results. This provides them with a valuable learning tool and opportunity to improve their services and to overcome the barriers of exploiting the project results.

One of the main results include a very high proportion of customers, 67% in 2009 and 58% in 2010, reporting that that they have commercialised the research results or intend to do so in the next three years. Taking into account the large proportion of projects that are not aimed at commercialising the results, 18% and 28% retrospectively, the ratio seems to be very high. Further results include that 92% of the respondents reported improved knowledge base and expertise due to the collaboration; 60% believed that a VTT project had speeded up or otherwise improved R&D work; more than half of the respondents thought that a VTT project had promoted networking; and 57% confirmed that new products, services or processes were created. Furthermore, 54% reported improved competitiveness; almost half of the customers believed that the VTT project had contributed positively towards the opening up of new business opportunities; and 30% reported that a whole new technology was adopted.

The 2010 survey included questions on how its customers see VTT's future role in promoting public affairs. Based on a ranking one to five, where five represents very important, survey respondents gave an overall ranking of 4.1 to VTT as a supplier and developer of research and testing infrastructures. Other potential roles in a descending order of importance include: promoter of sustainable development (3.85), promoter of efficient use of energy and raw materials (3.62), technology developer and facilitator of technology utilisation (3.53), promoter of human health, security and welfare (3.52) and supporter of public policy-making (in the given technology field – 3.45).

4.2 A Simple Economic Model

In a project[28] for AIRTO, the UK association of RTOs, Oxford Economics estimated the economic impacts of the RTO sector (on a wider definition that the ones we use here) as being £3.1 billion per year. In the Oxford Economics study, UK RTOs are identified as comprising AIRTO (the UK Association of Independent Research and Technology Organisations) members, plus a selection of other organisations (compiled in consultation with AIRTO members) that report full accounts at UK Companies House and classify their activities as 'R&D on natural sciences and engineering' or 'Technical Testing and Analysis'. They considered four categories of 'impact': the value the RTOs add internally; the value they create by buying inputs from their suppliers; the value they add downstream through the economic activity they stimulate (the Keynesian multiplier, in other words); and the value generated through R&D by the private returns to the companies involves plus the spillovers from these customers to the rest of society.

EARTO asked us to do a similar exercise at the European level. We have done so by considering the same four components of economic impact

- A 'direct' component, representing the contribution of RTOs to GDP, i.e. their contribution to value added (equals output minus input values, or wages plus salaries plus profits)[29]
- An 'indirect' component which incorporates the dependence on the RTOs of their (upstream) suppliers and (downstream) users of their outputs, normally calculated from estimated flows of inputs and outputs
- A component representing Keynesian-type 'multiplier' effects, whereby expenditures by RTOs and their employees stimulate activity in other sectors ('induced' impact)
- Returns to R&D investments, including 'spillovers' to other sectors of the economy

We discuss how we did this in the following sub-sections. The approach is simple and can be criticised, but we believe it is useful in so far as it adds another way to understand impacts to our armoury.

4.2.1 Direct Component – Contribution to GDP

In assessing the contribution to GDP (value added) of the European RTO sector, we make use of our earlier estimates of size in terms of turnover, combined with estimates of ratios of value added to turnover derived from input-output tables.

The OECD has recently (January 2010) produced a set of input-output tables covering 43 countries with data for years around 2005.[30] Of particular interest to us is the 'Research and Development' sector (sector C73), which is a very imperfect representation of the RTO sector but provides useful information for our purposes – in particular we are interested in ratios of, for example, inputs to the sector compared with outputs from it, rather than absolute numbers. Such ratios for the R&D sector should be indicative of values appropriate to RTOs in particular.

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[28] Oxford Economics, 'Study of the Impact of the Intermediate Research and Technology Sector on the UK Economy', May 2008

[29] An indication of the uncertainties involved can be gleaned from an earlier study by Public and Corporate Economic Consultants (PACEC),'The Contribution of Research and Technology Organisations to Innovation and Knowledge Transfer', July 2004. They estimate the size of the UK RTO sector (total turnover) at £1.2 bn (2002), compared with Oxford Economics' £2.2bn (2006), both figures including the for-profit company Qinetiq, by far the largest player among UK RTOs. The PACEC study also cites an even earlier study with an estimate of a £2bn turnover, with the comment that 'it is not clear why this figure is so much higher'.

[30] These tables can be accessed from the OECD's website, through the sequence of themes 'industry and services', structural analysis (STAN) databases', 'input output database'.

We have estimated the total turnover of European RTOs at €23bn (wide definition) and €18.5bn (narrow definition); data from input-output tables for European economies suggest that, on average, value added (outputs minus inputs, the contribution of the sector to GDP) is approximately 53% of output. Adopting this figure yields estimates of about **€12.2bn/€9.8bn** as the value added contributed by European RTOs under our definitions.

4.2.2 Indirect Component – Inputs to Research and Development

Items of relevance to the indirect component from the OECD input-output tables are:

- Research and Development value added = 'gross operating surplus' + 'compensation of employment' (wages and salaries) + 'net taxes on production'
- Inputs to the R&D sector = 'intermediate consumption', the sum of inputs from to the sector from all sectors
- Output of the R&D sector = value added + inputs + net taxes on products

Input-output data are available on this consistent basis for 19 of the countries covered in this report. On average, across these countries, the ratio of inputs supplied to the Research and Development sector to output produced by that sector is 47%. We assume that this figure provides a reasonable estimate for the RTO sector. Thus we assume that each €1 of output produced by that sector effectively stimulates around €0.47 of output from the supply chain.

Applying this estimate to RTOs' estimated output (turnover) gives an indirect contribution of **€10.8/8.7bn** under our two RTO definitions.

4.2.3 Induced Component – the Keynesian Multiplier

As is well known, Keynesian economists have long argued for substantial 'multiplier' effects arising, in particular, from increased Government expenditure not only stimulating growth directly but also leading to further growth as those benefitting from increased disposal income spend it on other goods and services, thus stimulating output and employment in various sectors.

The multiplier is traditionally considered in relation to Government 'shocks' to the economy in terms of higher expenditure or lower taxes. Our assumption here is that such a multiplier can be applied to income, which, by implication would be fully foregone if the RTO sector ceased to exist. Estimates of the value of the multiplier vary hugely. Values of up to 5 or more were current in the 1930s, while more recently estimates have tended to range between 1 and 2, with some (based on monetary theory) suggesting a value of less than one, implying that a monetary stimulus to the economy contributes less than its own value to GDP.

The Oxford Economics study of the impact of RTOs in the UK takes a value of 1.25 for the multiplier, based on their econometric model of the UK economy[31]. Evidence at the European level, however, suggests values considerably lower even than this. A recent study by Kirchner, Cimadomo and Hauptmeier[32] suggests that the Keynesian multiplier was above unity in the late 1980s, but has since declined to values of less than unity. The consensus certainly seems to be that multipliers of this type have declined substantially in recent decades.

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[31] 'Estimates based on Oxford Economics' detailed econometric model of the UK economy suggest that the induced multiplier is 1.25 – ie for every £1m of output generated by the intermediate sector, and its supply chain, a further £0.25m of output is generated in the economy as workers spend their earnings on other goods and services' (Oxford Economics, op. cit., p. 26)

[32] Kirchner, M., Cimadomo, J., and Hauptmeier, S: (2010): 'Transmission of Government Spending Shocks in the Euro Area – Time Variation and Driving Forces', European Central Bank Working Paper Series no. 1219, July.

The value of the multiplier is reduced by three factors

- The extent to which individuals intend to save their earnings – or, conversely, the marginal propensity to consume
- Taxation on the earnings
- Expenditure on imported rather than domestically-produced products

Recent financial uncertainties seem likely to have adversely affected propensities to consume, while import penetration of manufactured goods (especially from China) has increased substantially.

In the current study, reflecting uncertainties, we assume that the multiplier to be applied to RTOs and their suppliers is in the range **0.8-1.2**. suggesting that the direct output effects could be enhanced or constrained by up to **€4.6bn** (wide definition) and €**3.7bn** (narrow definition).

4.2.4 Private Returns to R&D and Spillovers

An additional economic benefit of the RTO sector identified in the Oxford Economics study is that of spillovers – the benefits conveyed to other organisations and sectors as a result of R&D by RTOs[33]. The presence of spillovers implies that social rates of return will exceed private rates[34]. Thus, estimates of the extent of the 'gap', and evidence on those economic areas where the gap appears to be relatively large or small, should provide clues on the extent and nature of spillovers.

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. Total *social* rates of return, including spillovers *outside* the industry, are normally estimated to be much greater still.[35]

Be that as it may, there has been a consistent story for decades, notably through the pioneering work of Griliches[36] and followers, that spillovers are very significant. In comparing results however, it is important to recognise that *definitions* of rates of return can vary considerably, both conceptually and (in the case of social rates) in the *range* of externalities covered. Despite this, there seems to be a remarkable degree of consensus in the ranges of values obtained.[37]

Mansfield et al. (1997) have carried out case studies of 17 specific industrial innovations, estimating the social and private rates of return from investments in each

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[33] Jaffe (1998) identifies three categories of spillover – 'knowledge' spillovers (appropriation of knowledge/expertise by third parties), 'market' spillovers (whereby the market for a new product or process causes benefits to flow to market participants other than the innovatoro) and 'network' spillovers (where the value of a technology depends on the existence of a set of related technologies).

[34] The private rate of return is the annualised income (by implication, in perpetuity) deriving from R&D investment accruing to the investing organisation itself, as a proportion of that investment. The social rate of return comprises both benefits to the innovator and those to the wider community, potentially including, for example, benefits to the consumer and environmental benefits. The latter can be identified as the overall contribution to GDP from the R&D.

[35] For example, work by Jones and Williams (1997), using modern growth theory, suggests that, from a societal viewpoint, optimal R&D investment may be four times larger than actual investment.

[36] Griliches, Z. (1958) 'Research Costs and Social Returns: Hybrid Corn and Related Innovations', *Journal of Political Economy,* 66, pp. 419-431. Griliches, Z. (1992), 'The Search for R&D Spillovers' *NBER Working paper 3768,* specifies a simple model which suggests that R&D accounts for up to 3/4 of growth in total factor productivity, most of which comes from the spillover component.

[37] Commenting on the 'surprisingly uniform' estimates of social rates of return, Griliches (1992) observes that 'While one must worry whether this is not just the result of self-imposed publication filters, my own involvement in this work and my acquaintance with many of the other researchers in this area leads me to believe in the overall reality of such findings.'

case. Three kinds of innovations are distinguished – product innovations used by firms, product innovations used by households, and process innovations – however the methodology is broadly similar in all cases.

The median estimated social rate of return found for all these innovations is 56%, regarded for various reasons by the authors as a conservative lower bound. The median private rate of return comes out at 25%. These are the figures we adopt for this study, which are in line with other estimates, including Oxford Economics' own estimate of a social rate of return of 50%. From this, our estimate of the annual impact on GDP from the total social return (private return plus spillovers) is **€12.9bn** (wide definition) and **€10.4bn** (narrow definition).

Following Oxford Economics, we have not attempted to carry these benefits beyond year 1, although in principle the benefits of R&D activity carry forward to future years, declining according to an assumed discount rate. In the UK, the current discount rate assumed by HM Treasury is 3.5%, which represents a slow rate of attrition of benefits, suggesting that returns could be many times those given in the above estimates. However, to err on the side of caution, and to be consistent with the Oxford Economics study, we include first-year effects only.

Were we to take account of the returns to R&D over time, the effect on the impact figures would be dramatic. Using the UK Treasury's working assumption of a discount rate of 3.5% yields a total social return of the order of €100m with a 10-year time horizon, on the basis of the above figures.

Studies prior to Mansfield et al. were concerned primarily with returns to agricultural R&D, apparently because the data were of better quality than those for other sectors. Estimates of social rates of return by Griliches (1958) – 37% for hybrid corn, Peterson (1967) 18% for poultry and Schmitz and Seckler (1970), tomato harvester, were of the same order as those of Mansfield at el., - but slightly lower, perhaps because the analyses were less comprehensive in terms of the social benefits incorporated. There have been relatively few case studies on rates of return since Mansfield et al, and not a great deal has been added either to knowledge or to methodological approach.

4.2.5 Summary of Economic Impact of RTOs

Figure 27 summarises the estimates of the economic impact of European RTOs using the above methodology

Figure 27 Estimated Short-Term Economic Impact of European RTOs – Central Estimates

Component	Wide definition (€bn)	Narrow definition (€bn)
Direct	**12.2**	**9.8**
Indirect	**10.8**	**8.7**
Induced	**+/- 4.6**	**+/- 3.7**
Social returns	**12.9**	**10.4**
TOTAL	**31.3-40.5**	**25.2-32.6**

Some issues regarding this estimate are the following

- The estimated short-term impact is thus considerable, of the order of €30-40bn under the wider definition. Under the narrow definition, it would be about €10bn less
- This is an initial estimate based on rough data, and uncertainties surrounding the above figures are high. It is recommended that statistical authorities consider giving more attention to what is clearly a major economic sector in Europe
- In the longer term, cumulative social returns exceeding €100m from each years' expenditure on R&D activity could be expected

- An alternative approach to estimating the impact of R&D-based institutions is provided by econometric studies of relationships between levels of R&D and GDP (or total factor productivity). These are highly suggestive of a very strong, positive relationship (e.g. Guellec and van Pottelsberge, 2001[38])
- The 'mechanical' procedure used clearly takes no account of individual activities of the RTOs. Impacts from individual R&D activities , for example, may greatly exceed the contribution as measured in the above, for example by generating significant consumer surplus, over and above the measured financial contribution

It is important to note that quantification of 'economic impact' of the RTO sector based on the above analysis cannot be applied to all other economic sectors to give figures which can be aggregated to give estimates of overall impacts on GDP. Inclusion of upstream 'dependent' sectors, for example, would include a large degree of double counting, yielding an implied GDP perhaps 2-3 times its actual value.

[38] Guellec, D. and van Pottelsberge de la Potterie, B. (2001): 'R&D and productivity growth: Panel data analysis of 16 OECD countries', *OECD Economic Studies*, 33, 2001/11

5. Futures

5.1 Trends

Recent work on the history and future of RTOs[39] has pointed to a number of important trends affecting the sector.

Convergence. There is widespread agreement that many technologies are becoming increasingly scientific, with research making an important contribution to technological progress. A second convergence trend is towards 'hyphen technologies' (micro-electronics, bio-technology, etc) that cross traditional disciplinary boundaries. More generally, it is believed that growing technological complexity means that research has an increasingly systemic character. These trends clearly have implications for institutes' thematic specialisation, driving them towards a wider range of disciplines.

University links. One way RTOs are responding to this is by increasing their overlap with universities. This is partly done by involving PhD students in the work of the institutes, helping the institutes develop and renew capabilities and is part of a wider pattern of RTO up-skilling and improving further the quality of RTO research. At the same time, the universities are under growing economic and policy pressure to adopt a 'third mission' of supporting society and the economy. As a result, some are trying to compete not only with the scientific institutes but also with the RTOs, in delivering services to industry[40].

Globalisation is widely discussed as a change driver in the institute world, as elsewhere. RTOs have reasons to diversify geographically, keeping in touch with their customers, while institutes focused on fundamental research may do better by building scale at one location. There are important opportunities, for example, for the RTOs and their host countries in the BRIC countries and in developing new, internationally collaborative innovation models.

Commercialisation and long run increase in the importance of markets. Almost all institutes are in some way engaged in the '3rd task' of commercialisation, but often in ways that are rather unreflective. Over a very long period, research institutes have tended to derive a growing proportion of their income from R&D markets (competing for public as well as private work). While this has been particularly important in the RTOs, the trend has also affected scientific research institutes and government labs.

Organisation and Scale. As a result of the growing need to be 'businesslike' in accessing markets many institutes are trying to improve their business processes and their staff's awareness and understanding of business as well as research. This included attempts to make people 'IPR-aware' in a way they have not previously been by improving and documenting laboratory practice and more deliberately looking for commercialisation opportunities. Some institutes seek increased scale. RTOs increasingly need to be polytechnic in order to service wide-ranging customer needs, and to be big enough in each specialisation to be attractive to customers and be visible internationally.

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[39] Erik Arnold, Kate Barker and Stig Sliperseter, *Research Institutes in the ERS*, S 106-12999 FORESIGHT-200702 Lot 2, Brussels: European Commission, 2010. This Chapter leans heavily on the findings of that study

[40] Erik Arnold, Neil Brown, Annelie Eriksson, Tommy Jansson, Alessandro Muscio, Johannah Nählinder and Rapela Zaman, *The Role of Industrial Research Institutes in the National Innovation System*, Vinnova Analysis VA 2007:12

Policy. The effort to generate an ERA provides an important set of change drivers. If the idea of a European Research Area is to become a reality, then research resources will need to be much more concentrated. Now that EU research policy has shifted to make increasing use of 'variable geometry' and the Commission is taking its mandate to 'structure' the ERA more seriously, EU-level incentives for cross-border restructuring may well appear. At present, national boundaries and national funding represent major sources of geographical lock-in.

5.2 Policy Needs

A recent Foresight exercise involving representatives of major European RTOs concluded that the driving forces shown in Figure 28 are among the most important operating on the sector.

Figure 28 Large RTOs: Historical and Future Drivers

Historical Drivers	Future Drivers
Convergence University links, up-skilling Globalisation Reorganisation Increasing scale of institutes ERA Policy Climate change research agenda Food production and safety research agenda Duplication of effort Rationalisation opportunities	Political desire for clear return on state investments in R&D Industry R&D is becoming more short term in nature Pressures on state budget available for funding RTOs Need to satisfy both local and global demands ERA policies University 'third mission' generating competition The 'knowledge explosion'

The foresight study concluded that the **RTOs'** mission of supporting innovation among their industrial customers induces them to behave much more like businesses than institutes in the other sectors. Successful privatised RTOs (e.g. Pera, QinetiQ) and those with very low core funding (GTS, SINTEF) can be driven to internationalise by setting up offices abroad, exporting or both. Large European RTOs with higher levels of core funding are increasingly exporting but tend not to establish offices abroad beyond a minimal level.

The large RTOs have to a degree become trapped in their national markets, unable to follow the globalisation patterns of their major customers or to compete effectively with each other because of their nationally-based incentive (funding) systems. They make extensive use of the Framework Programme in order to extend their geographic reach and they also increasingly export contract research and other services; but they are not able to exercise their developmental role across borders within the EU owing to the national nature of their funding. Increasing European strength (scale, critical mass, quality) among the RTOs and enabling them to take on the rest of the world depends upon loosening these ties to the national level. In doing so, they will provide leverage to, and exploit the knowledge of, the European universities with which they increasingly partner. (This should entail not only helping exploit new knowledge from the universities but also providing signals about global research needs and developments of interest, especially in the applied sciences.)

RTOs are generally subsidised to support national industrial development and increase the rate of industrial innovation. There is an element of competition with other EU RTOs and – especially – other EU countries' industry built into their role. But they are trapped by the national subsidy logic so that they struggle to serve their globalising customers – who instead build links with other knowledge organisations outside Europe – and they are constrained from building the scale that would help them operate more effectively at a global level. The way to escape this logic is to attract new funding at European or trans-national level, for example by taking on the RTO role in more than one country, thereby changing the RTOs' incentives better to match their customers' needs and RTOs' opportunities.

Moving beyond Europe would let the RTOs serve their customers better – both through physical presence outside their home countries and by accessing more of the world's technology. Increased scale coupled with competition-based specialisation would also improve their competitiveness and their ability to serve their customers. This would depend upon – and reinforce – the opening of knowledge markets within Europe.

5.3 Policy Implications

In the light of the ERA objectives, which are ultimately to build a healthy 'research ecology' at European level, objectives for EU-level policy for the research institute sector should be to optimise the research institute sector towards European needs by

- Integrating European knowledge markets to create a common market for knowledge and knowledge services
- Removing barriers to RTOs building globally competitive and naturally viable scale[41] through competition and specialisation
- Exploiting the capabilities of the RTOs to tackle the grand challenges, once these are defined and integrated into EU research and innovation policy
- Ensuring that Community provision of research infrastructure addresses not only the needs of basic research (ESFRI) but also of the RTO sector
- Supporting the self-organisation of the RTO sector at the European level via organisations such as EARTO and their connection to areas of developing policy need at European level
- Supporting developments in the institute sector that are **disequilibrating**, i.e. that combat existing lock-ins and enable new and existing institutes or groups of institutes to build positions in competition with others that overall strengthen the 'offer' of the European institute sector and its global competitiveness

An urgent need is proper statistics about the institute sector. The Commission should ask Eurostat to establish definitions and collect statistics about the RTOs and other research institutes, as is done for the university sector, and should encourage the OECD to act in a similar way.

The Commission should adopt a tiered approach to supporting integration and structural change, in order to address the different stages of development at which individual institute sectors find themselves. In some sectors it will be important for these actions to be inclusive; in others, it may be preferable for institutes themselves to select those whom they see as key to building and delivering an 'offer' to the European level.

One level is to offer support through planning or exploratory actions, enabling groups of RTOs to develop common research agendas and strategies addressing needs at the European level. Key to this action is the development of a strategy and the creation of a connection to a European-level, transnational customer. Planning grants could encourage rationalisation as well as wider improvements in strategy: small projects to undertake feasibility and impact analyses of institute mergers or expansions[42]. Examples are powerful. Once one or two cross-border mergers or alliances are in place – probably between small neighbouring countries – the idea will no longer be so unthinkable.

[41] Comparisons with the USA are often made in defining the aims of EU research and innovation policies. However, it is not self-evident that the scale or monolithic structure of key US government laboratories would be optima for Europe. Rather, an evolutionary approach is needed to discover the scale and degree of competition that is appropriate in each European sector

[42] There is a precedent in UK funding for RTOs in the 1990s, when the Department of Trade and Industry offered strategy support to RTOs aiming to improve their services to SMEs

A second level is to invite groups of RTOs collectively to develop new intellectual capital (technology platforms or capabilities) at the European level that they subsequently can exploit in their wider operations. In effect, this means injecting European funding into the first stage of the innovation process depicted in Figure 1, creating shared public goods that can then be exploited in the institutes' wider operations.

A third level is to provide competitive funding for shared infrastructure, enabling specialisation and division of labour while reducing unnecessary duplication in the sector. Some such infrastructures may be shareable with universities. Others may be provided only to a sub-set of RTOs

As EURAMET has demonstrated, Article 169 provides a good opportunity to begin to implement a reorganisation of an institute sector, based not only on a common strategic plan but also competition. This instrument could also be a useful vehicle for the RTO sector

Perhaps most fundamentally, however, the Commission should tackle the fact that there is not really a functioning cross-border market for institute research and services in the EU. In particular, there is no cross-border competition for 'competitive' government projects, so that the degree of competition is nationally limited and the institutes do not receive adequate market signals or incentives to encourage specialisation or improved performance. At the detailed level, it is not clear what all the obstacles are to opening up such markets. The Commission should ensure that these obstacles are studied and then aim to institute a reform to overcome them.

Appendix A EARTO RTO Turnovers - 'Correction' factors

Country	Turnover per employee (€k)	No-info turnover (€m)	Comments
Austria	125.2	11.3	Top 3 (>€50m) omitted from ave.
Belgium	87.1	14.6	Top 5 (>€80m) excluded from ave.
Bulgaria		1.3	Based on FTE figure (21) and Czech € per emp.
Czech Republic	60.6	9.8	Ave. of all but largest
Denmark	148.1	-	
Estonia	60.6	-	Same as Czech
EU (JRC)	138.2	-	
Finland	88.3	-	
France	96.7	51.3	Same as smallest
Germany	96.7	12.5	Ave. of lowest 11 (<€50m) out of 20
Greece	87.2	10.9	Ave. of lowest 3
Hungary	30	-	
Iceland		?	
Italy	89.9	12.9	Top 3 (>€30k) excluded
Latvia		?	
Luxembourg	96.3	-	
Malta		?	
Netherlands	127.8	29.3	Ave. of lowest 2 (<€70m)
Norway	126.1	29	Same as smallest
Poland	62.5	13.1	Same as smallest
Portugal	83.2	30.4	Average of all
Romania	24.6	5.1	Average of all
Slovakia	71.4	50	Same as only other
Slovenia	53.5	8.65	Ave. of all but largest
Spain	77.7	18.3	Ave. all but two largest
Sweden	105.3	15.1	Ave. of 4 smallest
Switzerland	128.6	8.4	Ave. of 2 smallest
UK	111.8	-	

Appendix B Summary statistics – 'Wide' definition

Country	Database entries (RTOs)- Wide definition	Corresp. no. institutes	Turnover on database	Number RTOs with turnover data	Corresp. no. institutes	Turnover grossed-up - RTOs	Turnover grossed-up - Institutes	Turnover - best estimate
Austria	35	72	964	17	44	1984.7	1577.5	1133.3
Belgium	14	14	562.5	9	9	875.0	875.0	649.8
Croatia	7	7	80	7	7	80.0	80.0	80
Czech Republic	8	8	70.4	2	2	281.6	281.6	130.0
Denmark	3	11	471.3	3	11	471.3	471.3	471.3
EU (JRC)	1		380	1		380		380.0
Finland	9	9	575.1	6	6	862.7	862.7	649.5
France	7	100	7700	4	97	13475	7938.1	7854.0
Germany	29	186	3453	12	99	8344.7	6487.5	3769.3
Greece	10	15	91.3	3	8	304.3	171.2	159.2
Hungary	3	8	0.6	1	1	1.8	4.8	7.2
Italy	37	135	251.8	10	36	931.7	944.3	687.2
Luxembourg	2	2	112.7	2	2	112.7	112.7	112.7
Netherlands	8	8	938.2	5	5	1501.1	1501.1	1022.4
Norway	3	49	929	2	48	1393.5	948.4	958.0
Poland	9	18	83.5	2	11	375.8	136.6	175.0
Portugal	12	12	76	3	3	304	304	365.0
Slovakia	2	2	50	1	1	100	100	100.0
Slovenia	6	6	64	3	3	128	128	88.9
Spain	25	98	865	11	84	1965.9	1009.2	1165.7
Sweden	14	58	400.8	10	33	561.1	704.4	446.1
Switzerland	6	6	321.2	5	5	385.4	385.4	329.6
UK	25	25	2147.4	18	6917	2982.5	7.8	2356.5
Total	**275**	**849**	**20587.8**	**137**	**7432**	**37802.8**	**25031.4**	**23090.7**

Appendix C Summary statistics – 'Narrow' definition

	Database entries (RTOs)-Tech definition	Corresp. no. institutes	Turnover on database	Number RTOs with turnover data	Corresp. no. institutes	Turnover grossed-up - RTOs	Turnover grossed-up - Institutes	Turnover – best estimate
Austria	31	68	473.5	14	40	1048.5	805.0	526
Belgium	10	10	500	7	7	714.3	714.3	569
Croatia	7	7	80	7	7	80.0	80.0	80
Czech Republic	4	4	0	0	0			45
Denmark	3	11	471.3	3	11	471.3	471.3	471
Finland	6	6	432.2	3	3	864.4	864.4	507
France	5	98	7700	4	97	9625.0	7779.4	7751
Germany	16	102	3189	8	94	6378.0	3460.4	3395
Greece	10	15	91.3	3	8	304.3	171.2	146
Hungary	3		0.6	1		1.8		6
Italy	33	131	105.6	7	34	497.8	406.9	584
Luxembourg	2	2	112.7	2	2	112.7	112.7	113
Netherlands	8	8	938.2	5	5	1501.1	1501.1	1022
Norway	2	48	929	2	48	929.0	929.0	929
Poland	9	18	83.5	2	11	375.8	136.6	175
Portugal	8	8	76	3	3	202.7	202.7	248
Slovakia	0							0
Slovenia	5	5	60	2	2	150.0	150.0	85
Spain	25	98	865	11	84	1965.9	1009.2	1166
Sweden	12	52	395	9	52	526.7	395.0	440
Switzerland	6	6	321.2	5	5	385.4	385.4	330
UK	0							0
Total	**205**	**697**	**16824.1**	**98**	**513**	**26134.6**	**19574.5**	**18587.4**

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