A Step Beyond:
International Evaluation of the GTS Institute System in Denmark

Forsknings- og Innovationsstyrelsen
Ministeriet for Videnskab Teknologi og Udvikling

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Analyse af små og mellemstore virksomheders internationale FoU-samarbejde

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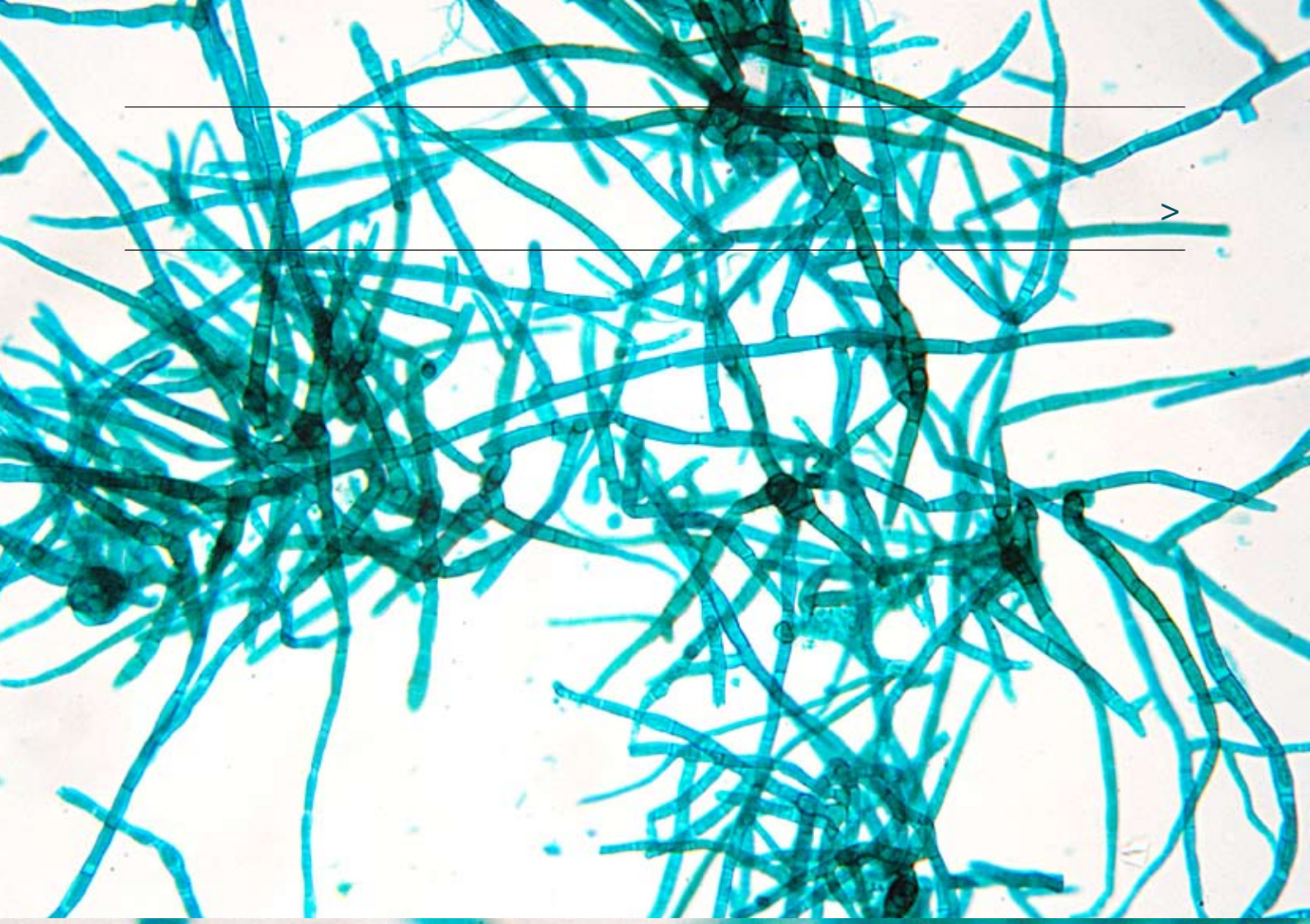

Chairman's Foreword >

This is the report of an international panel appointed by the Danish Ministry of Science, Technology and Innovation (VTU) to evaluate the GTS institutes – Godkendte Teknologiske Serviceinstitutter or Authorised Technological Service Institutes. These make up a key part of Denmark's knowledge system, aiming to support industrial innovation and economic growth.

Internationally, the job of such institutes is to reduce the risks of innovation by helping companies and other producers go beyond what their capabilities would let them do unaided. This may involve something as apparently simple as providing a testing or calibration service or as complex as doing new research in order to help solve an industrial problem.

Our central message is that, just as the GTS institutes help companies go a step beyond what their own capabilities let them do, so the growing knowledge-intensity of production means that it is time for the institutes themselves to increase their capabilities by doing more R&D, so as to be able to support increasingly sophisticated companies in their innovation efforts. This implies greater engagement with national needs through closer integration of the GTS system complemented by the greater core funding required to devote more effort to R&D in addition to service delivery.

We are grateful to the GTS secretariat and the directors and staff of all the GTS institutes, who have patiently tried to answer all our questions, provided us with a considerable body of documentary evidence in advance of our work and acted as generous hosts during the course of the work. We thank VTU both for the opportunity to carry out a very interesting mission and for all the help it has provided to us. In particular, Joakim Quistorff-Refn has supported us meeting by meeting and been a constant source of help and advice between those occasions.

Sverker Sörlin
Stockholm 23 February, 2009

Summary of the Report >

This is the report of the international panel, commissioned to evaluate the GTS institutes. Our work takes point of departure in the globalisation strategy issued by the Danish government 2006. It is intended to be an input to the coming new strategy for GTS developed by the Council fore Technology end Innovation (RTI) and the implementation of the Innovation Denmark 2007-2010 plan, which proposes a new and potentially wider role for the institutes in the Danish innovation system.

The GTS institutes in their policy context

The Danish innovation system has performed well in recent years but nonetheless faces challenges, including the lack of an adequate supply of skilled and highly-trained labour to support Danish growth. In the context of the national globalisation and innovation initiatives, there is scope to take action to strengthen the role of the GTS institutes.

The GTS institutes are a group of independent not-for profit and mainly self-owning institutions. Their role is "to deliver on a market basis solutions to tackle capability failures that may arise in companies in connection with innovation." [1] According to Christensen et al, their closest 'relatives' in the innovation system are consultants, consulting engineers, advertising bureaux, etc, and their role has to be understood as part of a Danish policy focus on technology diffusion, as opposed to technology push through the creation of new technology platforms. [2]

[1] Erhvervsfremme Styrelsen, Teknologisk service Redegørelse 1995, Copenhagen: Erhvervsfremme Styrelsen, Erhvervsministeriet, 26 January 1996

[2] Jens Frøslev Christensen, Pauline Tue Christensen, Kirsten Foss and Peter Lotz, Teknologisk service: Tendenser og udfordringer. En diskussion af GTS-institutternes værdi for Danmark, Hørsholm: Institutrådet, 1996

The GTS institutes collectively have a long history, with roots both in industry branch associations and in 'technology push' by the research and education system. Three major institutes dominate the network in terms of size but other parts of the system include new institutes whose share of the whole is expected to grow. Institutes vary in their proportion of R&D to services and in the proportion of core funding they receive. Overall R&D-related activities (namely R&D and 'services with high knowledge content') comprise about one third of GTS' work – a low proportion by international standards. As in some other countries, the overall share of core funding is lower than it has been in the past.

Role and performance of the institutes

The GTS institutes have co-evolved with the economy around them, changing their roles as needs have changed. Some important broad trends of increased knowledge intensity of production, globalisation and growing needs for synergy with the higher education system have affected the institutes in recent years, too.

Like most applied research institutes, GTS serves many SMEs. Unlike others, GTS has very many customers abroad. Small companies, however, mean small projects so larger organisations are also important in GTS' turnover. More capable firms make greater use of institutes and universities for research and related services, so GTS has different roles to play with less and more technologically capable companies.

The division of labour between institutes and universities is becoming less clear and the need for them to work together is growing. GTS' declining R&D-intensity and falling production of research outputs like scientific publications is therefore a problem. This does not mean that the universities and the institutes are substitutes – most of what they do is distinct. Nor, despite intermittent protests from some consultants, does GTS substantially compete with the private sector in practice, and this is enforced by the objectives and contract terms, or rules of the game, underpinning the GTS institutions.

GTS conforms to the three-stage innovation model used by most institutes, using core funding to generate knowledge and capabilities, developing these further in cooperation with industry and then exploiting them via more routine services as technology matures. GTS' customers are very positive about the services they receive.

The GTS institutes in international comparison

The GTS network shares a common mission and set of values with applied research institutes in other countries. However, its comparatively low R&D-intensity and unusually strong focus on services means that Danish industry tends to get a lower amount of R&D-related, knowledge-intensive support from its institutes than does industry in other countries. This is reflected in the comparatively low proportion of PhD-holders among the GTS staff and the comparatively low rate of scientific publication and linkage with universities among GTS staff.

GTS is unusually internationalised but most of its international activities are services rather than R&D-related. However, this is not alone enough to justify GTS' comparatively low rate of core funding, compared with others. The use of a performance-contract funding model has in the past made sense because it related to the performance of customer-delivered services. However, the 'performance' now required of the GTS institutes by RTI (Rådet for Teknologi og Innovation – the Council for Technology and Innovation)/ VTU is not of services but primarily of capability development, raising the question whether a more open form of core funding that provides both support to institutes' strategic development and some societal influence over their agendas would be appropriate, in line with international practice. The lack of strong coordination across the institute system also marks GTS out from the others.

Future needs and opportunities

Two foresight-related studies were performed in conjunction with this evaluation. The GTS network produced a list of fifteen candidate technology/business areas, which it could consider entering or in which an expansion of existing business would appear to make sense. A business case was made for each. The second study essentially confirms that the areas suggested by GTS are broadly consistent with the technological trends and opportunities discussed in the international foresight literature. To the extent that the areas identified may form bases for future action, they need to be considered by the individual institutes, the GTS network and VTU/RTI using technological and market criteria, as well as considering the potential uniqueness of Danish resources in addressing these opportunities.

Conclusions and recommendations

In our view, the GTS system has done well in meeting its small and large customers' national and even international needs for technological services. However, the world is changing around it, so GTS must adapt as needs evolve.

The GTS network's primary role is 'de-risking' innovation by providing a range of R&D and technical services that enable its customers to go beyond what their internal technological capabilities allow. GTS should not abandon its services work but needs to increase the R&D content in order to match the growing knowledge intensity of production. This requires a more active and united strategy across the institutes.

GTS is already more internationalised than other institutes but needs to strengthen its international R&D activities through both industrial and EU Framework Programme contracts. Increased specialisation will be needed to compete internationally and GTS could usefully partner with foreign institutes, especially in the Nordic area, to offer Danish and other customers capabilities that are both broad and deep. The example of IMEC in Flanders shows that small countries can gain considerable benefit from hosting internationally capable research institutes.

In Denmark, most government funding for research goes to the university system – a focus that has been increased by the recent merger of the government research institutes into that system. This leaves GTS as the institutional mechanism through which government supports innovation in industry and among other producers. It is crucial therefore that the GTS system is adequately funded and capable of providing the highest quality of relevant knowledge inputs into the productive economy.

The context of industry in Denmark and abroad demands an increasingly research-based offer from GTS. It follows that GTS needs more core funding, in order to build the needed knowledge platforms. This should come as a mixture of funds that can be used strategically by the management and funds

channelled through 'focusing devices' such as innovation consortia or other more societally orientated mechanisms. Close interaction with Danish and foreign universities (and research institutes) is also necessary, in order to strengthen the knowledge content of GTS.

Acting only on core funding is not sufficient to tackle GTS' increasing knowledge needs. Research and industry are becoming increasingly PhD-based, and so must the GTS institutes. The GTS offers a good way to draw universities' attention to societally relevant research themes and to provide a source of research-trained manpower able to work in areas of national and industrial need defined by the strategy of GTS. GTS institutes already (in varying degrees) have links with the universities but these need to be deepened.

Organisation and governance

A new strategy must be accompanied by the organisational ability to deliver coherent action across the existing institute network and by constant renewal and optimisation of the portfolio of capabilities GTS offers to industry. In the Danish context, reinforcing the existing network is the most acceptable way to do this, but unless it is achieved within a handful of years there may be a strong case for merger to create something that looks more like VTT, TNO or SINTEF. Creating common awareness and help to new users in finding their way in the GTS network are also required. We see little need to change the performance indicators used for GTS – but more attention needs to be paid to overall turnover and research output indicators as the two key signs of health in R&D contracting organisations. Other key signs would be more soft esteem indicators reflecting the societal impact of their R&D, such as improving the quality of life. The institutes may benefit from international sparring-partners and quality control at the level both of the individual institutes and of the GTS networks as a whole.

On basis of its observations, the panel recommends that

- Government and RTI should continue to make sure the rules of the game allow GTS institutes to provide the wide range of technological services needed to share the risks of innovation with industry in Denmark and to test the adequacy of GTS' strategy and performance in this task
- The institutes themselves should establish a strategic mechanism that allows both the individual institutes and GTS as a collective to set and implement a strategy in support of evolving Danish societal needs, as well as the needs of the individual institutes' current customer groups. Elements of the strategy should include
  - What capabilities the institutes should develop or abandon
  - The services they should provide
  - The customer groups they should address (and by implication, which ones they should not)
  - The organisational structures needed to deliver the GTS mission
- GTS should be encouraged to continue its internationalisation trajectory
- Continuing to build scale and international customer bases in self-funding, routine technical services
- But complementing this with increased international activity in R&D and R&D-related services
- GTS core funding should be strengthened by specific resources that support greater participation in the EU Framework Programme and eventually other European and global collaborations that have a similar knowledge-developing and knowledge-sharing character
- VTU and GTS should explore opportunities for partnerships with other non-Danish institutes. These should include initiating action at the Nordic level and exploring the opportunities to use new or existing EU actions to support the emergence of regional institute partnerships that promote increased specialisation with the purpose of sharing knowledge and improving the fit with customer needs
- VTU should increase the average proportion of total funding subsidy to the GTS institutes towards the 20% level emerging as the new Scandinavian desideratum. The higher level of services in GTS turnover means that the proportion of core funding should remain lower than that in the more R&D-focused continental institutes (Fraunhofer, TNO)
- The higher level of core funding should have two components: an institute-specific part, equivalent to today's core funding and therefore accounting for perhaps 50% of the core funding, which should be negotiated between the institutes and VTU or the RTI; and another similarly-sized component, aiming to tackle national needs and challenges, that should be based on a collective strategy of the GTS institutes. This will be informed by foresight, road mapping and other forms of strategic intelligence that go beyond the institutes' existing, market-focused planning processes. Both types of core funding should be usable as co-finance for Framework Programme projects

- The core funding should continue to be complemented by the successful Innovation Consortia programme, which uses industrial problems as focusing devices, building reusable knowledge resources within the GTS institutes, and potentially other instruments yet to be invented. The funding for these should be additional to the 20% core funding
- The GTS institutes forge tighter links with the universities, such as increased teaching by GTS staff at the universities and increased placement of PhD students within the institutes in applied fields of research
- GTS institutes raise the proportion of their staff with PhDs by exploiting the industrial doctorand scheme and EU mobility schemes such as Marie Curie
- VTU programming of research and innovation be adjusted to provide incentives for increased cooperation between the GTS institutes and the universities
- A proportion of the increased core funding for GTS should be allocated to PhD training for GTS staff, funding GTS staff to take up Adjunct Professorships in universities and eventually funding joint positions shared by universities and institutes
- Where possible, these measures should apply to universities outside as well as inside Denmark
- VTU/RTI should periodically manage a foresight, road mapping or other similar strategic exercise to strengthen the role of the GTS system and for planning future demands of the GTS system
- The GTS Board (which comprises the directors of the institutes) should be responsible for developing the common strategy of the GTS insttitutes and for collectively negotiating and allocating the new 10% of core funding. Doing this will also involve a strategic process of foresight, road mapping etc
- The GTS Board should investigate and implement the means to increase the effectiveness of GTS as a strategic arena among the institutes and to improve visibility to customers as well as referral
- The GTS Board should consider whether to appoint a scientific advisory committee for the system as a whole. This could be a mixture of Danish and foreign experts and could meet annually to discuss the strategy and progress of the GTS system as a whole in national and international context, acting as a scientific and managerial sparring-partner for the GTS Board
- Core funding should be allocated in 4- not 3-year periods in future
- VTU/RTI should place greater weight on total turnover and on the indicators of R&D output already collected in deciding the allocation of core funding
- VTU/RTI and GTS should consider reinstating the practice of periodically peer reviewing the institutes, in order to obtain independent scientific advice on the quality and relevance of the institutes' work to both VTU/RTI and to the institutes themselves. This is especially important as the knowledge-intensity of the institutes' work increases

1. Introduction >

This is the report of the international panel, commissioned to evaluate the GTS institutes. Individual institutes have been evaluated before, in connection with their role as approved providers of 'authorised technological services' – namely, research, measurement, certification and other technical support services – to a degree subsidised by the Ministry of Science, Technology and Innovation (VTU). This is the first time the whole system has been evaluated.

Our work is intended to be an input to the coming new strategy for GTS developed by the Council fore Technology end Innovation (RTI) and the implementation of the Innovation Denmark 2007-2010 plan, which proposes a new and potentially wider role for the institutes in the Danish innovation system. While we must necessarily deal with some of the characteristics of individual institutes, our remit is to evaluate and make recommendations about the GTS system as a whole.

The terms of reference for the evaluation (shown in full at the Appendix) say that it should make recommendations about

- How the Danish GTS institutes' capabilities and resources can best be used for the benefit of industry[3] and society; and the division of labour with other actors in the knowledge infrastructure
- What the GTS institutes and RTI more widely can do to ensure that the institute's offerings of development and services always reflect the latest technology and future patterns of demand
- The future directions of technological service

[3] The Scandinavian languages generally use 'industri' to refer to manufacturing industry or even to engineering. The reader should note that we use 'industry' in the English sense of 'industry and commerce', covering all privately owned economic activity. Recognising that important parts of economic production also take place within the state, we might also add the public production of goods and services, which in many cases could also benefit from support by organisations like GTS.

The basis for these recommendations should be provided via interactions between the panel and relevant stakeholders and through four background reports, published in parallel with this evaluation, and respectively concerning

- The role of the institutes in the Danish innovation system
- Two foresight studies, focusing on the demands that will be made of the institutes in future
- An international comparison of the GTS system with relevant foreign industrial research institute systems

In addition, GTS supplied a significant volume of background documentation on both the GTS system and on individual institutes.

The panel met a total of five times between October 2008 and February 2009. It received presentations of the GTS system from its secretariat and of the wider policy context from VTU. Each of the institutes presented itself and its work and the panel was able to make brief site visits to four of the institutes. The authors of the three of the background studies presented and discussed their work with the panel. GTS' own foresight was not presented but was available for the panel to read.

All governments fund research and innovation. This is justified in economic theory by the idea of 'market failure' [4]. Private companies cannot fully capture the economic benefits of research, some of which spill over to others in society, therefore entrepreneurs 'under-invest' in research. In compensation, state invests on behalf of society, which is rewarded via the creation of public goods and spillovers.

While the old 'linear model' of innovation – the idea that fundamental research somehow 'causes' innovation – remains influential, it was shown 30 years ago[5] to be incorrect. We bring a contemporary perspective on the way research and innovation systems function to this evaluation. Research and innovation play roles in complex 'innovation systems' [6], where actors make imperfect decisions and depend to a significant degree upon interaction with other actors and the broader context. Current research and innovation policies therefore tackle not only market failures but also various kinds of systems failures, such as lock-ins to old or inappropriate trajectories, failures of information, networking and coordination.

The linear model implied that the role of institutes was somehow to translate the work of basic scientists into applied knowledge that could be transferred to a waiting and grateful industry. Seeing research and innovation systems as essentially non-linear also implies viewing applied or industrial research institutes as having their own dynamics as institutions, seeking out problems and finding solutions internally or externally rather than simply acting as brokers for science.

In our report, we begin by explaining the nature of the GTS institutes and their relationship to Danish innovation and research policy. We go on to describe the way they perform their roles and their impact in Denmark. Comparing them with a handful of international examples of industrial research institutes provides a basis for reflecting about opportunities to improve the way the GTS institutes are governed, funded and run in Denmark in the light of the experience of other countries. We go on to consider what future needs the GTS institutes could address and what kind of process they collectively need to undertake in order to adapt to changing circumstances and requirements. Finally, we draw conclusions and make recommendations.

[4] Ken Arrow, 'Economic Welfare and the Allocation of Resources for Invention,' in Richard Nelson (Ed.), The Rate and Direction of Inventive Activity, Princeton University Press, 1962; see also Richard Nelson, 'The simple economics of basic scientific research,' Journal of Political Economy, 1959, vol 67, pp 297-306

[5] Mowery, D.C. and Rosenberg, N., 'The Influence of Market Demand upon Innovation: A Critical Review of Some Recent Empirical Studies', Research Policy, April 1978

[6] Christopher Freeman, Technology Policy and Economic Performance: Lessons from Japan, London: Frances Pinter, 1987; Bengt-Åke Lundvall, National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning, London: Pinter, 1992; RR Nelson, National Innovation Systems, New York: Oxford University Press, 1993

2. The GTS Institutes in their policy context >

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The GTS institutes are a group of independent not-for profit and mainly self-owning institutions. Their role is "to deliver on a market basis solutions to tackle capability failures that may arise in companies in connection with innovation." [7] According to Christensen et al, their closest 'relatives' in the innovation system are consultants, consulting engineers, advertising bureaux, etc, and their role has to be understood as part of a Danish policy focus on technology diffusion, as opposed to technology push through the creation of new technology platforms.[8]

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[8] Jens Frøslev Christensen, Pauline Tue Christensen, Kirsten Foss and Peter Lotz, Teknologisk service: Tendenser og udfordringer. En diskussion af GTS-institutternes værdi for Danmark, Hørsholm: Institutrådet, 1996

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2.1 The Danish innovation system

The Danish innovation system has performed well in recent years, generating a GDP per head of population almost 25% above the EU average and labour productivity 8% above the average. Gross Expenditure of R&D (GERD) was 2.43% of GDP in 2006, compared with the EU-27 average of 1.74% and the OECD mean of 2.25 (2005)[9]. Both government and industry's expenditures on R&D are a little above the EU and OECD averages. The government budget is in surplus and national debt is limited compared to normal EU levels.

[9] OECD, Main Science and Technology Indicators, 2007, Paris: OECD, 2007

The main constraint on the system in recent years has been a shortage of labour – both skilled and unskilled – which appears to have caused growth to slow even before the onset of the current recession. The main innovation challenges are seen[10] as tackling this labour shortage, increasing human capital formation and promoting innovation by SMEs, which have tended to receive only limited policy attention until recently.

[10] Karen Siune, INNO-Policy TrendChart – Policty Trends and Appraisal Report: Denmark 2008, Brussels: European Commission (published at www.proinno-europe.eu)

The government published a Globalisation Strategy in 2006, aiming to establish a world-class education system, strong and innovative research, more entrepreneurship and more innovation. In February 2007, the Danish Council for Technology and Innovation published an 'Innovation Action Plan' bringing together 70 innovation initiatives. The main objectives are to make all Danish enterprises, including SMEs, permanently more innovative. The action plan intends to turn 5 000 SMEs into innovative enterprises and to encourage an additional 2 000 SMEs to employ workers with higher educational

qualifications. Knowledge transfer and collaboration between research and private enterprises has to be strengthened. Key targets are to double the number of industrial PhDs to 500 a year and to establish 500 new knowledge transfer projects between private enterprises and knowledge institutions.

Denmark, then, was an economy in robust good health at the start of the recession, with solid rather than spectacular innovation performance and where the government has considerable fiscal freedom. This evaluation of the GTS system takes place against a background of policy focus on innovation, a government with a plan and the resources to carry it through.

2.2 Some history

Looking at the origins of research institutes internationally, there are at least three archetypes. Some institutes 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 (eg 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, sometimes set up in the more recent past, in order to promote industrial development more widely. 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 abandoned
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 institute development. In some cases (eg TNO), a defence mission was partly integrated. Sometimes, providing a home for nuclear energy research was an important factor. GTS is firmly in Category 3, showing the beginnings of a trend towards more research-intensity through the addition of new institutes.

The current set of GTS Institutes has its origins in three former institute groups

- DTI (Dansk Teknologisk Institut) and its predecessors
- The ATV (Akademiet for de Tekniske Videnskaber – Academy of Technical Sciences) institutes
- Other institutes

Teknologisk Institut (TI) was set up in 1906, primarily as a teaching organisation providing training and further education in technological subjects as well as various technical services, and a competing school (Jysk Teknologisk Institut - JTI) was founded in Jutland in 1943. The two organisations merged in 1990 to form Dansk Teknologisk Institut (DTI), which has more recently reverted to the old name of Teknologisk Institut.

Trade and research associations financed TI wholly, and while the state played an increasing role in financing TI (and JTI) in the post-War period, in 1995 about a quarter of DTI's income still came from 90 member organisations. This history helps explain the continuing importance of education and training at DTI. Partly as a result of reducing state subvention but also because of changes in the social role of the institutes, DTI experienced severe financial difficulties in its early years. Its staff numbered 1242 at the beginning of 1994. This was cut by 14% during the year, and the institute was restructured into a smaller number of thematic divisions, largely abandoning the previously branch-oriented structure. Several activities were transferred to other organisations.

While DTI has its roots in the collective needs of certain Danish branches, the ATV institutes reflect the desire of the independent Academy of Technical Sciences (ATV) to build technology push institutions and to establish industry-relevant research at Denmark's School of Technical Science (DTH – now DTU), which originally was purely a teaching institution. Rector P.O Pedersen of DTH, who was a founding father of ATV in 1937, explicitly aimed to kill two birds with one stone. Industry and foundations should pay for equipment and researchers at DTH, which would satisfy the college's need to do research and at the same time generate results for transfer to industry. The resulting institutes in areas like welding, electronics, hydrology and corrosion were more technology- than branch-oriented, reflecting their 'technology push' character, and were co-located with DTH.

The third group of institutes has mixed origins – though in some cases ATV helped establish them. They are more oriented to social needs such as, fire, metrology, testing and standardisation. The metrology institute was set up in 1985 and is the only GTS institute set up by government initiative. There have been discussions about whether to establish an institute in the 'new economy' but these have not led to anything new being set up although a small GTS institute of Design did exist for some years around 1990. In 2006, the Danish Government initiated a semi-open call for parties interested in assuming GTS status. This resulted in AgroTech and the Alexandra Institute joining the network in 2007.

The GTS system itself was established under the 1973 Law on technological service. A Council for Technological Service formerly oversaw the GTS institutes. More recently, GTS has been supervised by Rådet for Teknologi og Innovation, which supervises a range of innovation-related programmes and activities to promote knowledge transfer. Evaluation has been introduced, and a system of performance contracts has been established between the responsible Ministry and the institutes, at the same time as the state's contribution to their

financing has been falling. Since 1995, all GTS institutes have collaborated within their umbrella organisation, GTS – Advanced Technology Group (GTS). This is a small secretariat with a staff of 4, acting primarily as a common interface between the institutes on the one hand and the RTI and ministry on the other. Its Board comprises the directors of the GTS institutes.

2.3 GTS Today

GTS today comprises a network of nine institutes (organised as not for profit companies) with two primary functions: to provide knowledge and problem-solving services; and to maintain and provide access to the national 'technological infrastructure' of advanced measurement, test and certification facilities. Forsknings- og Innovationsstyrelsen currently says that

> The aim of the GTS institutes' activities is to strengthen technological services in Denmark as a basis for the development and exploitation of technological, management and market knowledge and to increase companies' own innovation efforts. The institutes establish and develop technological capabilities and make these available to industry. They also build bridges to knowledge organisations in Denmark and abroad.[11]

[11] www.fi.dk

In 2007, the GTS network employed some 3,000 people and turned over DKK 2.46bn (€330m, or about €110k per person). Less Than 10% (DKK 234m or €31.4m) of this is core funding from the Danish government. A correspondingly low proportion – 17% – of turnover represents R&D activities. This is a reduction compared with five years ago, when the proportion of R&D typically lay in the range 20-25%.

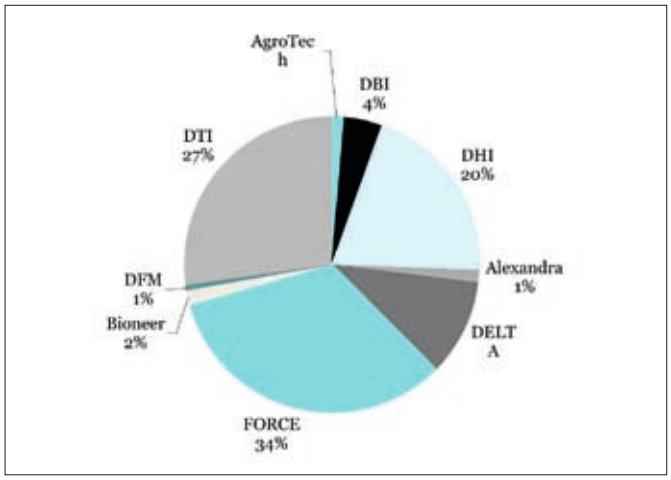
The GTS institutes are (numbers of employees in 2007 in brackets)

- The **AgroTech** (48) institute for agriculture and food. The AgroTech (48) Institute for agriculture and food. AgroTech is one of the newest members of the GTS network and specialises in tasks covering the entire value chain from primary production to final consumption
- **DBI** (119) is the fire, safety and security research institute, foocused on protection of life and property. It is heavily involved in services and practical work in inspection, fire prevention, safety and security of people and properties
- **DHI** (750) works within the fields of water technology, environment and health and is the most internationally engaged of the GTS-institutes (including establishment of international research and development centres)
- The **Alexandra** Institute (37) is a recent addition to the GTS network, researching in new parts of Information Technology such as pervasive computing, with focus on IT security, software infrastructure, pervasive healthcare, interactive spaces, advanced visualization and interaction, pervasive positioning, new ways of working, and business understanding for pervasive computing.
- **DELTA** (230) has a strong history in testing and electrical safety, focusing on electrical and electronic technologies, optics, acoustics, noise and vibration

- **FORCE** Technology (960) provides technical and R&D services to a wide range of largely traditional industries, especially energy, oil and gas and transportation
- **Bioneer** (36) is one of the newer GTS members, focusing on R&D and to a lesser degree services in biotechnology
- Danish Fundamental Metrology **DFM** (18) is, despite its measurement focus, the most PhD- and R&D-intensive of all the institutes and probably the only part of the GTS system that can be said to do basic research
- Teknologisk Institut, **DTI** (795), is a polytechnic institute providing services and R&D to manufacturing, construction and to an increasing degree the service industries

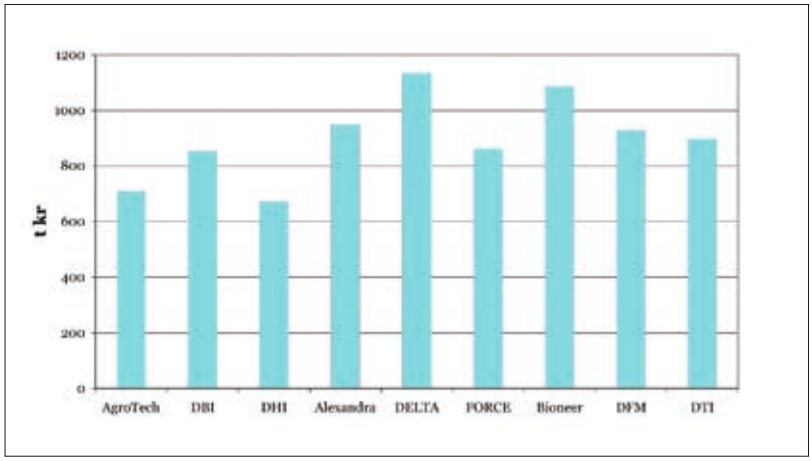
As Figure 1 illustrates, the GTS network comprises institutes of widely differing sizes. The largest is FORCE Technology, which has a heavy emphasis on technical services. The two other large institutes are DTI, which is a large polytechnic applied research institute with a high ratio of services to research, and DHI, which has a somewhat higher research content. Together the big three account for 83% of GTS turnover and 86% of employment.

Figure 1 GTS turnover split by institute, 2007



Those institutes with a historically strong basis in testing and similar services have to varying degrees managed to move into more knowledge-intensive, research-related areas. FORCE and DBI are still operating very strongly in service delivery mode, while DTI and DHI have succeeded to a greater extent in moving into more knowledge-intensive areas. Figure 2 shows that there is a range of productivity (in terms of turnover per employee) among the institutes. (This indicator must, of course, be treated with some caution, as the institutes 'business mix' varies a great deal. DHI also has comparatively high proportion of staff outside Denmark, who are paid lower rates than Danish staff, in line with local labour market conditions.) Both DELTA's service- and Bioneer's research-focused strategies allow high productivity.

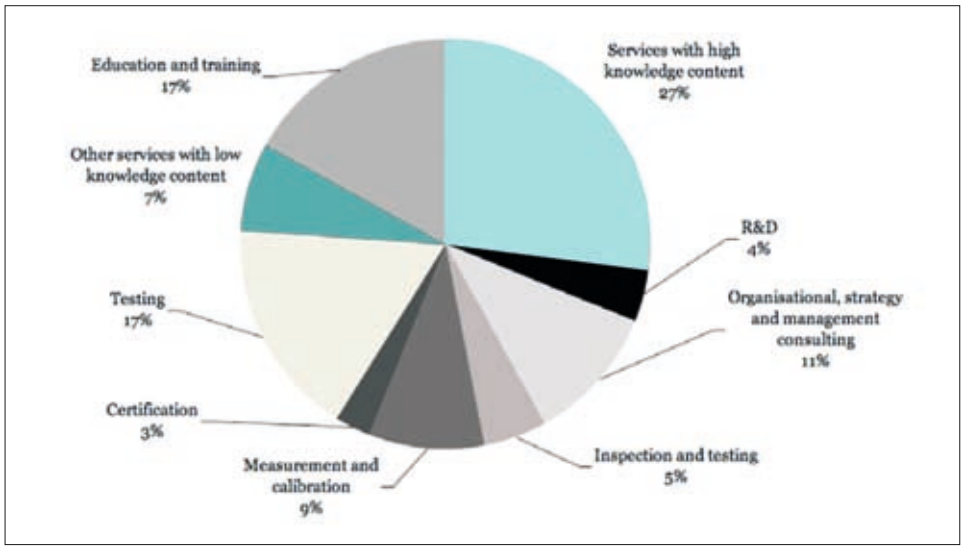
Figure 2 GTS institutes' turnover per employee, 2007



The GTS institutes obtain core funding through 3-yearly performance contracts with the Ministry. In principle, the core funding pays for the acquisition and development of knowledge and other capabilities needed to provide technological service but some of the performance contracts also specify the delivery of specific services. The contracts are very specific about how the money is to be spent: unlike in some other institute groupings, the core funding cannot be spent at the whim of the director or be used as blanket subsidy for all activities. The Ministry's intention is that core funding should not be used to subsidise service delivery, which should be cost based, and that the institutes should not develop services available in either the private or the university sector.

Figure 3 shows how the institutes' commercial turnover in Denmark divides among different kinds of services in 2006. The Figure excludes both the self- and core-financed R&D activities in Denmark and the international income, which is predominantly obtained from more routine services. About a third ('high knowledge content services' and R&D) are research-related while the remainder are more routine. Other institutes do not publish equivalent data, but in we would generally expect to be the ratio to be the other way around, with the knowledge-intensive component being the larger.

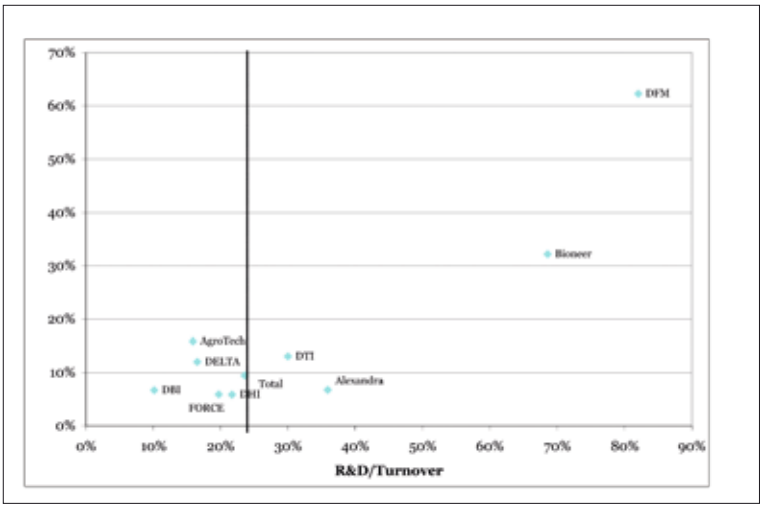
Figure 3 Share of GTS' Danish commercial revenues from different activities, 2006



Source: GTS Performanceregnskab, 2006

Broadly, the share of core funding among research institutes internationally tends to be higher among those that do a greater proportion of more fundamental research, compensating for the market failure involved that makes it unattractive for industry to do research that leads to spillovers. Perhaps surprisingly, there is only an extremely coarse relationship between core funding and the R&D-intensity of individual GTS institutes. Bioneer and the Danish Fundamental Metrology laboratory (DFM) stand out from the other GTS institutes in being R&D-intensive and highly core-funded, but there is not a uniform relationship between R&D and core funding among the other institutes as a group (Figure 4).

Figure 4 Core funding and R&D intensity of GTS institutes, 2007



Note: The ratio between performance contracts and turnover for Alexandra in this figure is somewhat misleading since the institute was established late in 2007.

Unlike other institute systems, GTS is extremely international. While R&D activities are focused in Denmark, foreign sales were 43% of total GTS revenues in 2007, compared with 36% in 2002. GTS institutes have offices in the Nordic countries and other parts of Europe but now also in North America, Russia and the Far East. The international activities provide access to technical and market knowledge. However, individual institutes argue that they work abroad primarily in order to make profits needed to sustain their operations overall. Financial profits are recycled into capability-building R&D. The main channel for acquiring knowledge from abroad is via internationally (primarily EU) funded R&D programmes. However, as with the proportion of R&D in total activity, the proportion of international R&D activity has also fallen since 2000.

Figure 5 underlines that four of the institutes – FORCE, DHI, DELTA and Bioneer are heavily dependent upon international commercial markets.

Figure 5 Components of GTS institutes' turnover, 2007

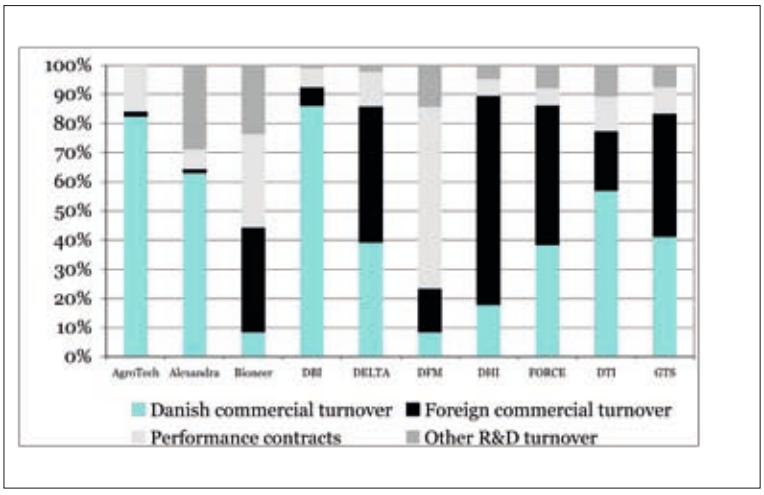


Table 1 GTS Institutes' Turnover (MDKK), 2007

	AgroTech	Alexandra	Bioneer	DBI	DELTA	DFM	DHI	FORCE	DTI	GTS
Danish commercial turnover	28.0	23.0	3.3	87.5	102.3	1.4	89.1	316.6	427.7	1,027.9
Foreign commercial turnover	0.6	0.5	14.0	6.3	121.6	2.5	361.6	396.7	152.8	1,055.5
Performance contracts	5.4	2.5	12.6	6.8	31.4	10.4	29.7	49.4	88.9	229.2
Other R&D turnover	0.0	10.5	9.2	1.0	5.8	2.4	23.6	65.1	81.1	188.2

PhDs make up just less than 10% of the GTS staff (up from 7.5% five years ago), which is a rather small proportion compared with some other systems. For example, SINTEF and Fraunhofer have about one third PhDs in their staffs. Correspondingly, 45% of the GTS staff do not have a Masters degree or above, reflecting the importance of comparatively routine services in GTS' activities. Figure 6 shows how staff qualification levels vary considerably among institutes. FORCE and DBI have lower levels of qualification than the other institutes.

Figure 6 Composition of GTS institutes' staff, 2007

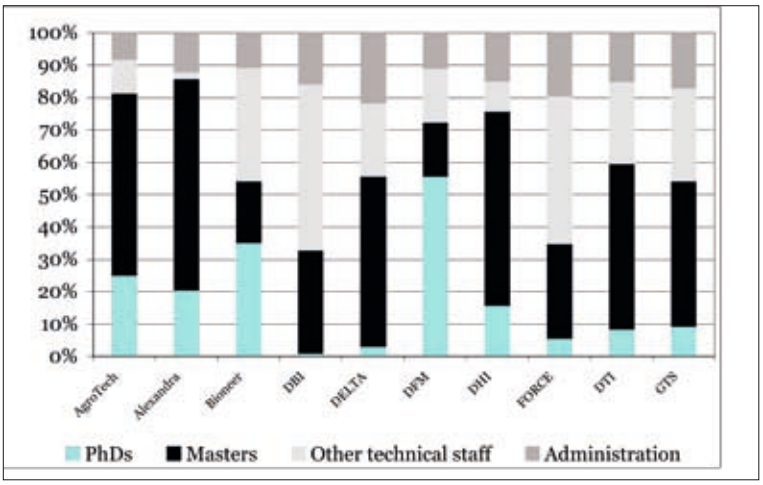


Figure 7 Three sorts of institutes?

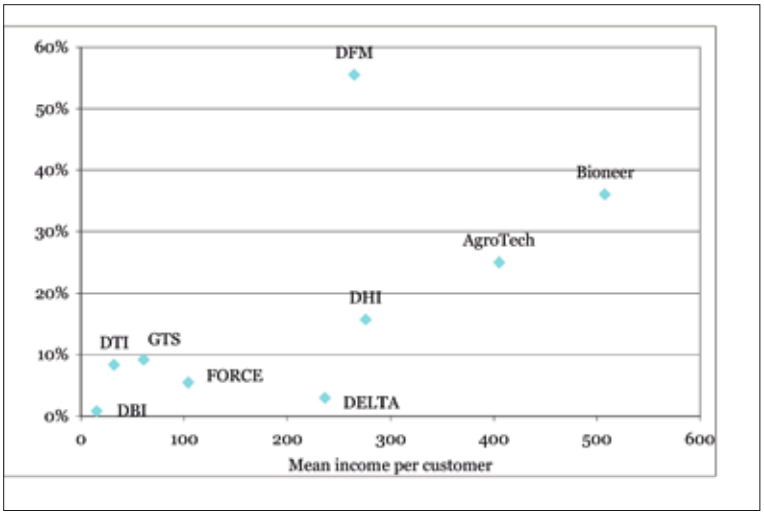


Figure 7 shows that the average size of project at GTS is rather low (DKK61) and suggests we may think of GTS as comprising three sorts of institutes. DBI and DELTA are almost wholly given over to services, with DBI doing high volumes of small jobs while DELTA undertakes larger projects. DFM, Bioneer, AgroTech and the Alexandra Institute (which does not appear in Figure 7 because we have no customer data for it) are all rather research focused and work with larger projects. They are the newer members of GTS and represent a new direction. On the middle ground are the big three institutes, with a mixture of services and research (though one could also argue for classing DHI with the research-intensive institutes). This is the centre of gravity of GTS.

Like industrial research institute systems in most countries, GTS operates today with a much lower level of subsidy than in the distant past. The system does not contain government laboratory functions orientated towards policy and regulation. These have been integrated into the universities in Denmark. The high proportion of traditional technical services (test, measurement, training etc) in GTS activities means that its overall profile is not especially knowledge-intensive. Hence, it has low proportions of PhDs and of R&D in overall turnover. In many countries, the state has retreated from involvement in routine technical services – and in fact some of GTS' foreign offices, for example in Sweden, were formerly parts of other countries' national technical service systems. We need to consider, therefore, the GTS activities in two parts: first, this wide-ranging technical services business; second the R&D-related functions that elsewhere have increasingly become the focus of research institutes' activities.

3. Role and performance of the GTS institutes >

As we showed earlier, the GTS institutes have a long history, during which they have co-evolved with the economy around them, changing their roles as needs have changed. Some important broad trends of increased knowledge intensity of production, globalisation and growing needs for synergy with the higher education system affect the institutes in recent years, too.

Like most applied research institutes, GTS serves many SMEs. Unlike others, GTS has very many customers abroad. Small companies, however, mean small projects so larger organisations are also important in GTS' turnover. More capable firms make greater use of institutes and universities for research and related services, so GTS has different roles to play with less and more technologically capable companies.

The division of labour between institutes and universities is becoming less clear and the need for them to work together is growing. GTS' declining R&D-intensity and falling production of research outputs like scientific publications is therefore a problem. This does not mean that the universities and the institutes are substitutes – most of what they do is distinct. Nor, despite intermittent protests from some consultants, does GTS substantially compete with the private sector in practice.

GTS conforms to the three-stage innovation model used by most institutes, using core funding to generate knowledge and capabilities, developing these further in cooperation with industry and then exploiting them via more routine services as technology matures. GTS' customers are very positive about the services they receive.

3.1 The changing context

Leijten argues[12] that a key factor in the current stage of development of RTOs (Research and Technology Organisations) like GTS is 'fading boundaries' – especially in the form of technology convergence, convergence between fundamental and applied research, between users and producers, between science, technology and socio-economic analysis and among institutions.

Certainly, the knowledge-intensity of production and consumption has increased overall. Gibbons et al[13] say this is the result of the 'massification' of higher education that has vastly increased the ability of people across society to work in knowledge-intensive ways and especially to do research. If there ever was a university monopoly of knowledge production (which is doubtful), then it has decisively been broken by this trend. A result is that much more knowledge is produced in the context of application, in an interdisciplinary manner by networks of people whose composition constantly shifts. Gibbons et al call this 'Mode 2' knowledge production, in distinction to the 'Mode 1', disciplinary tradition favoured by the universities. Mode 2 starts with problems; mode 1 starts with theories and discrepancies between theory and observation.

The statistical manifestation of this change is the great growth in Business Expenditure on R&D (BERD in the OECD language) of recent decades. Whether or not 3% of GDP is the right amount to spend on R&D (no-one knows

[12] Jos Leijten, The future of RTOs in the European Research Area, Contribution to the DG Research Group on the future of key actors in the European Research Area, Delft: TNO, 2005

[13] Michael Gibbons, Camille Limoges, Helga Nowotny, Schwartzman, S., Scott P. and Trow, M., The New Production of Knowledge, London: Sage, 1994

the answer to that question), the Barcelona Goal nicely captures the idea that developed economies should have a high ratio of BERD to state expenditure on R&D, aiming for business to spend 2% of GDP on R&D while the state invests 1% through universities, institutes and other R&D-performing organisations.

As mode 2 spreads and BERD increases, so producers in the economy have increasing absorptive capacity: "the ability of a firm to recognise the value of new, external information, assimilate it, and apply it to commercial ends." [14] Cohen and Levinthal, who coined the term absorptive capacity, tend to treat R&D capacity as a proxy for absorptive capacity (because there are statistics about R&D), but the real meaning of absorptive capacity is wider and relates to the ability of producers not just to do R&D but to use knowledge in innovation – both technical and non-technical.

[14] Wesley M Cohen and Daniel A Levinthal, 'Absorptive capacity: a new perspective on learning and innovation,' Administrative Science Quarterly, Vol 35 (1), March 1990, pp 128-152

Another key trend is globalisation. With continued globalisation of production, the 'Triad' (Europe, USA, Japan) has lost its quasi-monopoly of R&D. China, India and other large developing countries such as Brazil have become major actors with huge R&D investments and are becoming increasingly integrated into the world system of knowledge production. Most institute systems have completely failed to move beyond their national boundaries and to deal with this new reality. At the European level, globalisation is reflected in the increasing integration of EU markets for goods, services and knowledge – an integration that may be accelerated by the EU's drive to establish a European Research Area, but which is quickly developing under its own steam.

The role of the universities has also been changing in the past coupe of decades – at different rates in different countries. A 'third task' or mission has generally been added to their responsibilities: namely, to contribute directly to social and economic development, especially through innovation. Increasing autonomy and steering through incentives and performance assessments or performance contracts means that universities have additional incentives to increase their focus and their external incomes, not least from industry. There are therefore growing numbers of strategic partnerships between universities and industry – both bilateral and in the form of increasingly long term consortium arrangements, as in competence centre programmes. Hence, the universities increasingly provide a supplement to the institutes in dealing with the technological problems and challenges of industry, potentially altering the division of labour within the 'knowledge infrastructure' of universities and institutes.

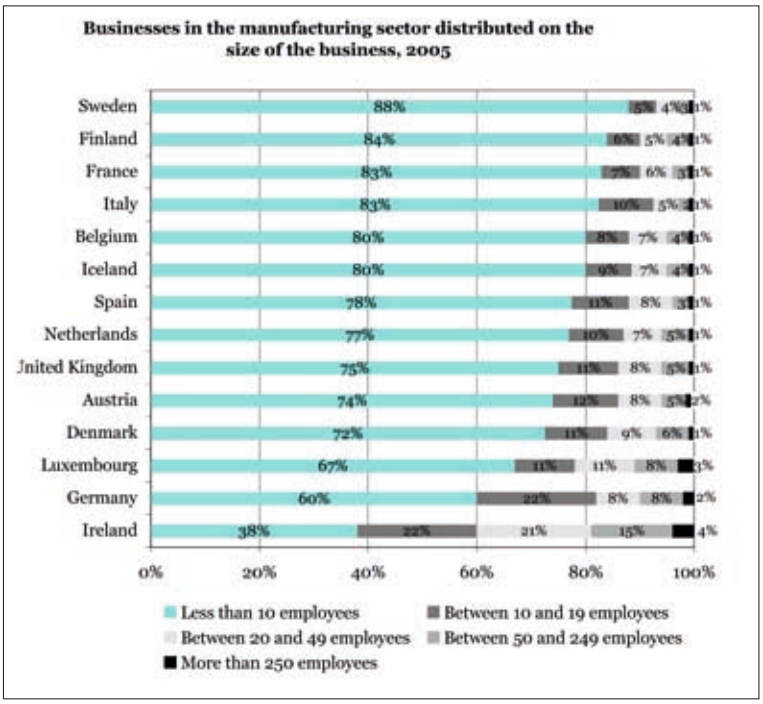
The Danish higher education system underwent a reform in 2002 where the Universities become "independent institutions under the public sector administration and supervised by the Ministry of Science, Technology and Innovation". The reform set out to ensure greater openness, increased academic self-determination and the freedom for the university to decide on its own internal organisation within the legislative framework. A new University Act in 2003 established a Board as the supreme authority at the universities. It was at that point decreed that the majority of the members of the Board must

come from outside the universities, and the Board has to be chaired by one of the external members. In addition the Board comprised representatives elected among the students, the academic staff and the administrative staff. Furthermore, the law stipulated that university leaders and managers shall be appointed on the basis of both their scientific and their managerial skills.

3.2 Industry in Denmark

Denmark is famous for having an 'SME economy'. In terms of numbers of companies, almost all economies are SME economies (Figure 8) in the sense that SMEs are vastly in the majority. The more important issue may be the proportion of economic activity for which SMEs are responsible and their potential to grow into large firms. Applied research institutes are normally funded in part because they support the development of small firms and sometimes provide services that compensate for the deficiencies of these companies.

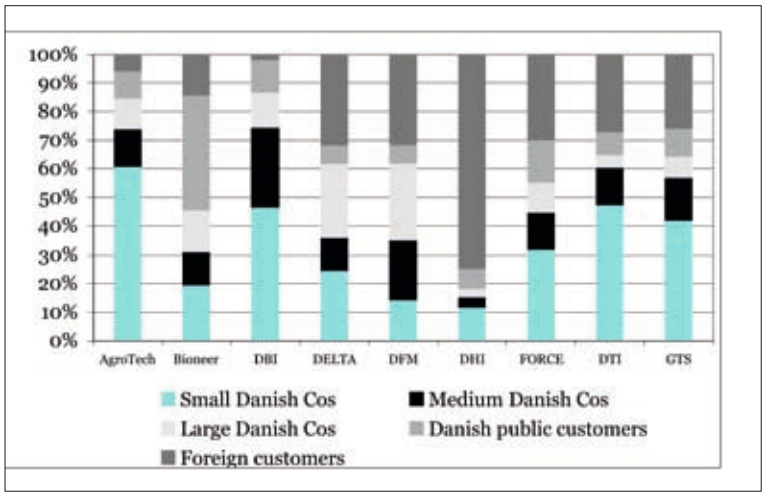
Figure 8 Manufacturing company size by country



Source: OECD, Factbook, 2008

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 10 shows how the company income divides 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).

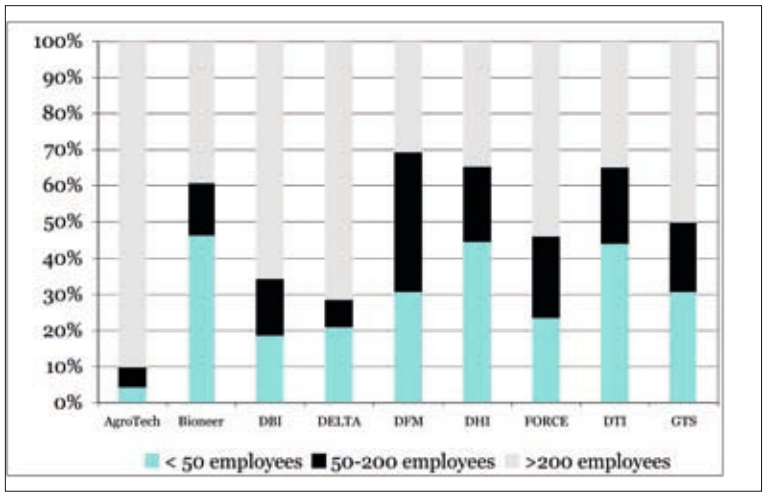
Figure 9 Company groups served by GTS institutes, 2007



Basis: Number of customers per category

Note: AgroTech data for the first half of the financial year only

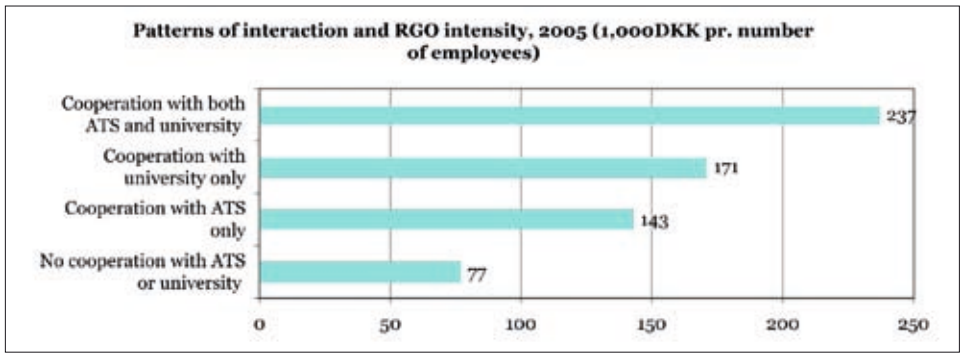
Figure 10 GTS institute income from Danish company groups, 2007



Note: AgroTech data for the first half of the financial year only

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 11 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 11 R&D intensity and cooperation behaviour of Danish firms



Source: Customised data, CFA, Forskningsstatistikken, 2008

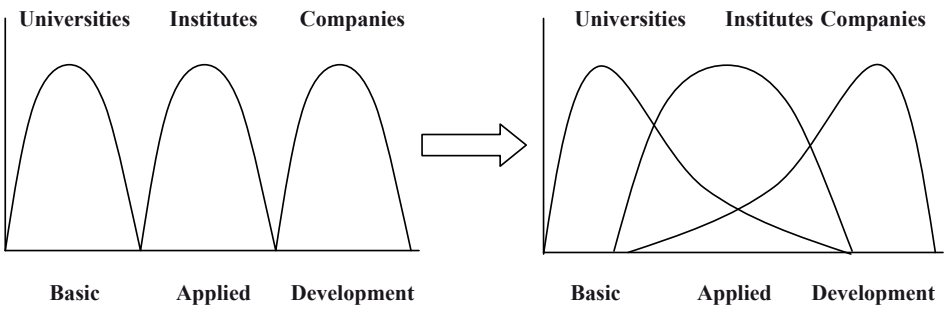
It follows that there are roles for the GTS institutes to play both with small and larger firms as well as with firms with a range of absorptive capacity. The trajectory towards greater knowledge intensity among its customers suggests that GTS should itself be moving in the same direction.

3.3 Division of labour among knowledge institutions

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.

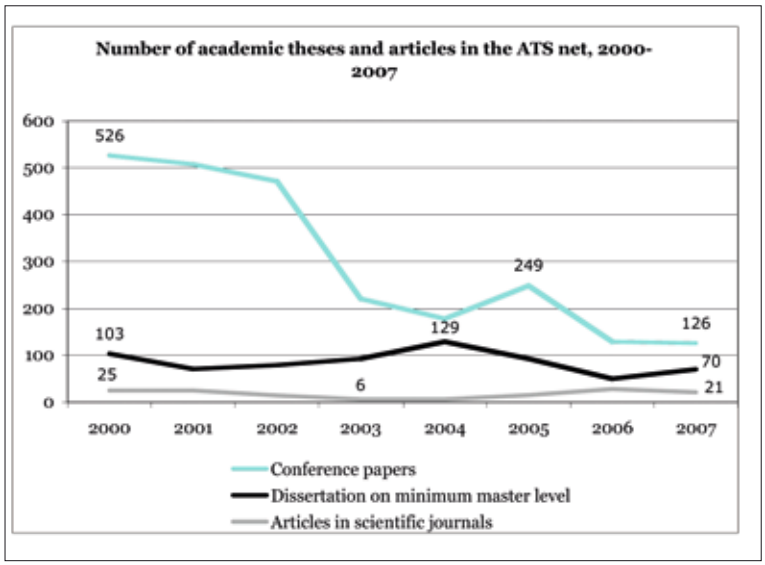
It is increasingly recognised that if the old 'three-hump model' – Figure 12 – ever worked, it has now broken down. The 'three hump' model is the idea that universities do basic research, institutes do applied research to translate basic ideas into applicable knowledge and industry gratefully accepts 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 (ie 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 12 The breakdown of the 'three-hump model'



Conferences are very important means of communication in the traditional 'heartland' of GTS, especially for organisations like the GTS institutes, which need to make contacts and sell work. To this extent, the rapid decline in conference participations shown in Figure 13 is worrying. Given the size of the staff, the numbers of papers and theses produced are low by academic standards. This is normal for institutes, but against the background of increasing knowledge-intensity in their work it is disappointing not to see an upward trend in these curves.

Figure 13 Research outputs from the GTS system

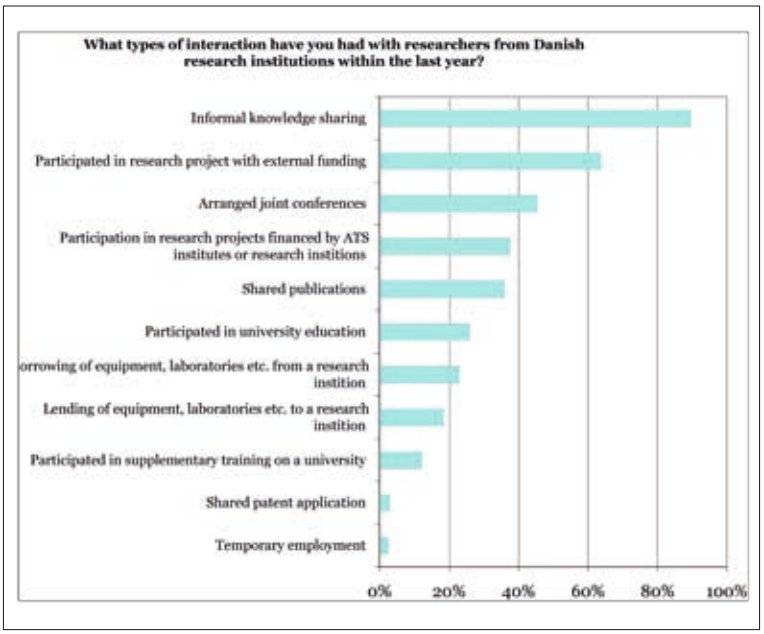


Source: The GTS Association, 2008

There clearly is a level of cooperation between the GTS institutes and the Danish universities (Figure 14) but this needs to be increased. Alarmingly, as Damvad show, the number of international research cooperations in which GTS engages is falling[15]. Such cooperations tend to be R&D-focused and to be key sources of new knowledge for RTOs.

[15] Damvad, Mapping the Danish knowledge system with focus on the role and function of the ATS net, Report to the Danish Agency for Science, Technology and Innovation, Copenhagen: Damvad, 2008

Figure 14 Interactions with Danish universities



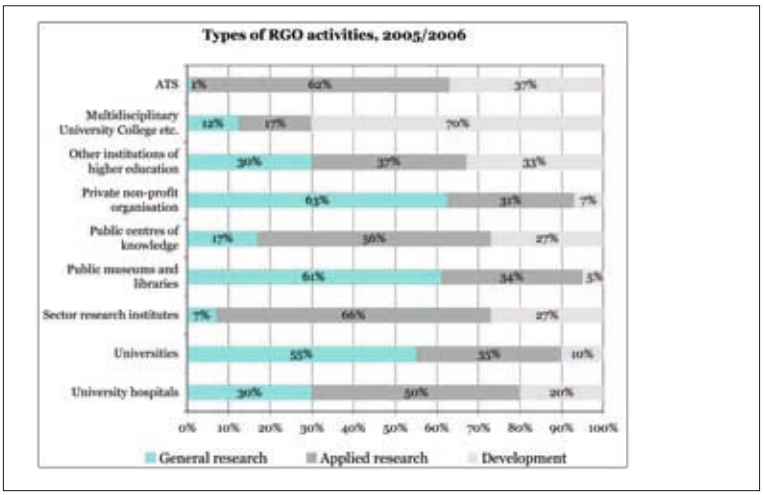
Source: DAMVAD: Analysed from data from the GTS Association, 2008

Note: Based on individual staff member responses

There are nonetheless clear differences between the applied institute and university systems in the overall pattern of R&D effort. Figure 15 shows this for Denmark[16], with the GTS institutes (in their R&D activities, ie excluding technological services) being strongly focused on applied research and development while the universities focus on basic and applied research.

[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

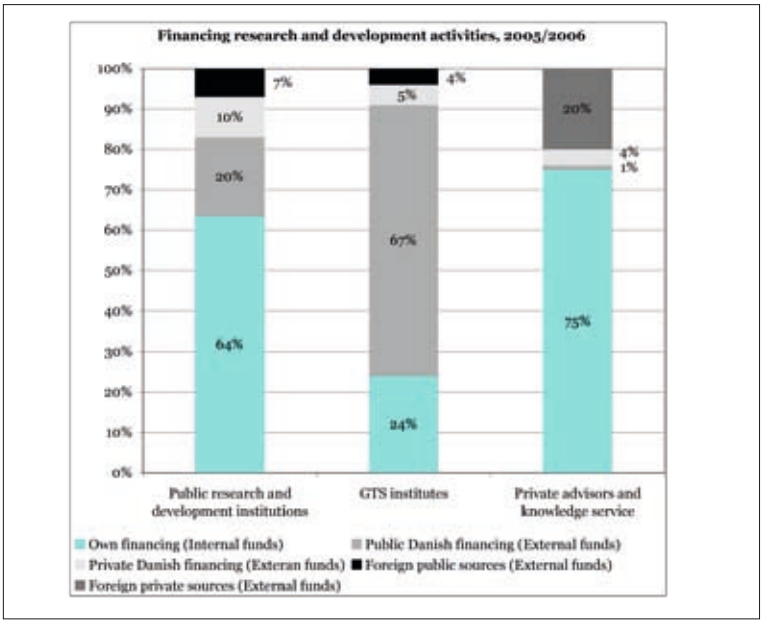
Figure 15 How R&D activities differ among actors



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

Both universities and GTS institutes use internal 'core' funds – provided by the state – to pay for research. The institutes, however, are much more dependent upon competitively won external money to build capacity. In contrast, the private organisations' predominant source of funds for research is internally generated profit. This means that they typically are unable to tackle the more fundamental or generic research questions addressed by the state-funded institutions.

Figure 16 Funding of university, GTS and private organisations' R&D



Source: CFA, Forskningsstatistikken for offentlig (2006) og privat sector (2005)

Damvad note however that the GTS institutes spend more than twice as much (DKK343 per employee) on R&D as private knowledge service providers (DKK149 per employee) and that the R&D done by the GTS institutes is dominated by applied research (62%), while the consultants' work is heavily dominated (76%) by development.

Damvad's survey of people in the knowledge system is problematic[17] but they report 53% of respondents saying that GTS institutes do tasks that in some cases can be done by other actors while 24% said GTS do things that in many cases can be done by other actors. As long as the discussion stays at this abstract level, or is conducted in terms of wide categories like 'research', an impression of overlap remains. When, as in the preceding Figures, these categories are broken down to a more specific level, it becomes clear that the overlaps are small. 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.

[17] The sample of people consulted is an arbitrary mixture of people from different kinds of knowledge organisations. What it represents is unclear. Given that on some of the issues covered in the questionnaire the opinions of people in different parts of the knowledge system tend to be systematically different, the lack of representativity undermines the meaning of the survey.

Table 2 Ideas Interviewees Associated with Institutes and Universities

Research Institutes	**Universities**
Resources	Developing human resources, especially PhDs
Competence	Developing human resources, especially PhDs
IPR handled professionally	Basic and precompetitive research
Confidentiality	No timetable
Used to working with industry	Difficult to steer or predict outcomes
Project management routines in place	Poorly equipped, compared to the institutes
Timeliness (mostly)	May be opportunities to get additional state funding to carry on the project
Can address focused research questions	
Close to applications and products	
Understand real industrial processes	
Understand industrial customer needs	
Less focus on publications than universities	Note: In the special case of competence centres, access to academic and industrial networks were also mentioned
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	

Note: In the special case of 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 other consideration in the division of labour between GTS 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 GTS 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.

3.4 The institute innovation model

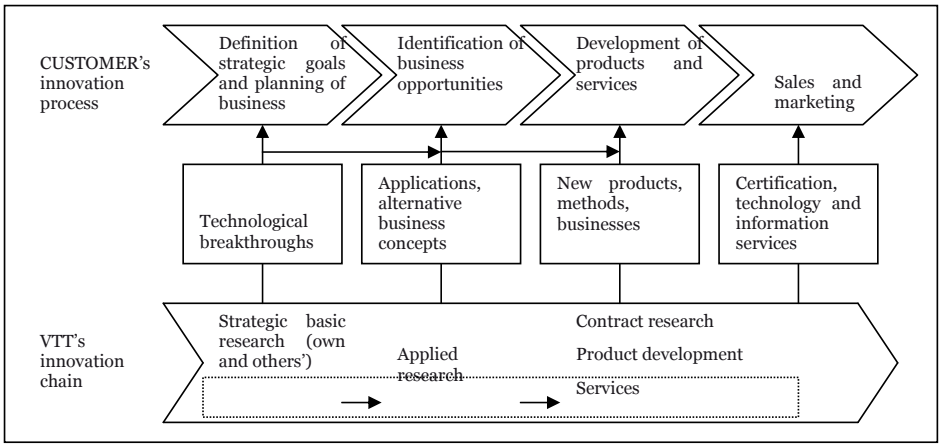
Applied research institute systems tend to operate with an explicit or implicit innovation model that involves

1 Exploratory research and development to develop an area of capability or a technology platform

2 Further work to refine and exploit that knowledge in relatively unstandardised ways, often in collaborative projects with industry
3 More routinised exploitation of the knowledge, including via consulting

Figure 17 shows VTT's version of this model. (VTT is the main Finnish applied industrial research institute.)

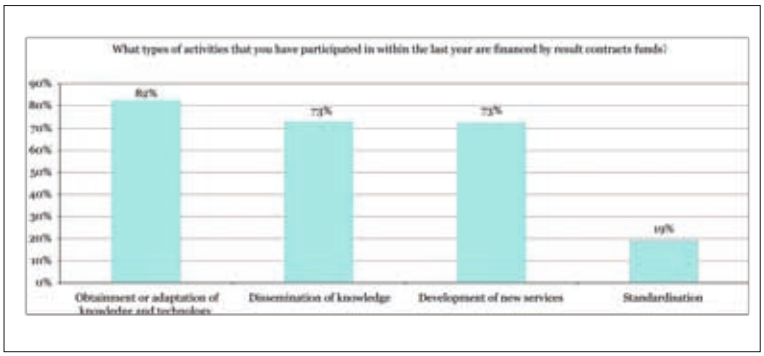
Figure 17 VTT's Innovation Model



Source: VTT

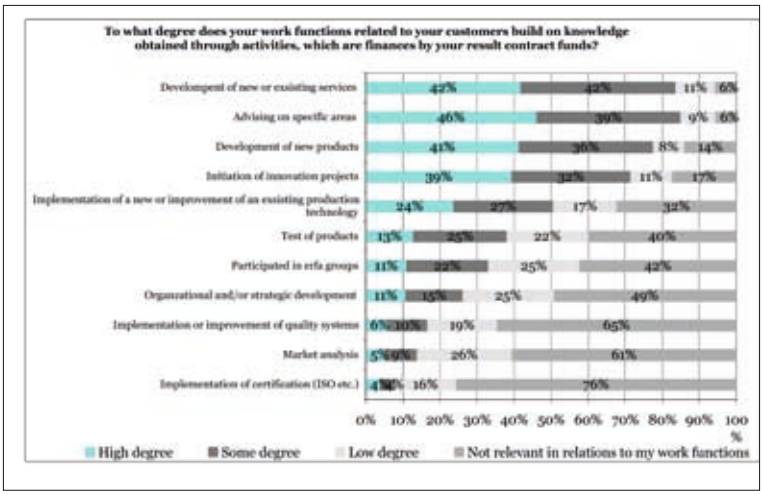
The GTS system shares this approach, using core funding or Innovation Consortium funding to build up new capabilities that it then develops and makes available to Danish (and foreign) industry. GTS tends to do less at the second stage of further developing knowledge in cooperation with industry. This would become a more significant activity if the R&D-intensity of GTS were increased by raising the amount of core funding provided. Damvad's survey of GTS staff showed that they felt the GTS core funding (via performance contracts) played its most important roles in relation to establishing new or significantly changed knowledge platforms or services (Figure 18). The performance contract money is of little importance in delivering established services (Figure 19). This use of core funding is consistent with international practice.

Figure 18 What the performance contract pays for



Source: DAMVAD, Mapping of the Danish knowledge system, 2008
Note: Based on individual staff member responses

Figure 19 Importance of performance contract funding in customer services



Source: DAMVAD, Mapping of the Danish knowledge system, 2008

Note: Based on individual staff member responses

An internationally unusual feature of the GTS system is that it has two sources of capability-building funds. One is the performance contracts, where the institute directors effectively negotiate their own development goals with the RTI. The second is the Innovation Consortia (formerly, Centre Contracts) programme. Centre contracts were designed as a mechanism for bringing together R&D needs of a group of companies with the research capabilities of a university in order to generate both usable R&D results and re-usable intellectual capital for the GTS institutes. These institutes would then exploit this intellectual capital in order to provide Technological Service to other, often non-R&D-performing companies, thereby generating social returns (externalities). Innovation consortia represented a minor adaptation of the centre contract formula to tackle larger networks of companies, institutes and universities. In these projects, company needs tend to provide a 'focusing device' [18] that draws the attention of the knowledge infrastructure on societal needs. The combination of core funding and user-steered money on the one hand gives the institute directors the strategic freedom they need to develop their 'businesses' and the other hand tends to keep the institutes focused on new as well as existing societal needs.

[18] Nathan Rosenberg, Perspectives on Technology, Cambridge University Press, 1976

3.5 Performance

User surveys produce a very positive picture of GTS performance, seen from the perspective of their Danish company customers. Oxford Research carried out user surveys in both 2006 and 2008 [19]. The latest one suggests a slight change in the customer base, with a growing proportion of the customers being in the size range 5-50 employees – itself already the largest size grouping (47%). GTS customers are markedly more innovative than a control group and are more engaged in international markets. Industry in general is increasing its use of

[19] Oxford Research, Brugerundersøgelse av GTS-institutterne, Kvantitativ undersøgelse blandt private brugere og ikke-brugere af GTS-institutterne, Copenhagen: 2008

outsourced innovation services, but GTS' customers are much more frequent outsourcers of knowledge services than non-users. Overall, it is clear that GTS captures a large proportion of the more dynamic and progressive firms in the economy.

The main activities are given as 'transferring knowledge' and 'solving specific technical problems'. The high proportion of testing in GTS' work is clear from Table 3. The other main activity is support in product development. The survey suggests little of the more knowledge-intensive or speculative activity we associate with research institutes elsewhere, though by their nature such activities tend to be somewhat invisible to the bulk of the industrial customers.

Table 3 Percentage of customers using GTS for development activities

1. Activity	2. Proportion Using GTS Institute
3. Product testing	4. 39.7%
5. Product development	6. 24.5%
7. ERFA experience exchange groups	8. 8.6%
9. Production technologies	10. 7.0%
11. Certification	12. 6.3%
13. Large innovation projects	14. 5.3%
15. Quality systems	16. 4.8%
17. New service development	18. 4.6%
19. Organisational and strategy development	20. 1.4%
21. Market analyses	22. 0.0%

Source: Oxford Research, 2008

Customer satisfaction is very high: 93% are either completely or partly satisfied with the service they obtained. Some 84% of customers are repeat customers, indicating that this level of satisfaction is real.

The main negative note in the survey in fact comes from the non-users, 63% of whom say that GTS does not cover the areas of technology in which they are interested. About a similar proportion also say that it is hard to find the right person within the GTS system when they do need help. The user feedback, then, is very positive but reinforces the idea that there is a need for further development of the range of knowledge GTS can provide.

4. The GTS institutes in international comparison >

GTS shares a common mission and set of values with applied research institutes in other countries. However, its comparatively low R&D-intensity and unusually strong focus on services means that Danish industry tends to get a lower amount of R&D-related, knowledge-intensive support from its institutes than does industry in other countries. This is reflected in the comparatively low proportion of PhD-holders among the GTS staff and the comparatively low rate of scientific publication and linkage with universities among GTS staff.

GTS is unusually internationalised but most of its international activities are services rather than R&D-related. However, this is not alone enough to justify GTS' comparatively low rate of core funding, compared with others. The use of a performance contract funding model, which has its roots in the history we discussed in Section 2.1, has in the past made sense because it related to the performance of customer-delivered services. However, the 'performance' required of the GTS institutes in the future is not only of services but to a greater extent of capability development, raising the question whether a more open form of core funding would be appropriate in line with international practice. The lack of strong coordination across the institute system also marks GTS out from the others.

The background work [20] for this study included a comparison of five institute systems

- The GTS System (Denmark)
- The SINTEF Group (Norway)
- The IRECO Group (Sweden)
- TNO (Netherlands)
- The Fraunhofer Gesellschaft (Germany)

[20] Tomas Åström, Marie-Louise Eriksson, Lars Niklasson and Erik Arnold, International Comparison of Five Institute Systems, Stockholm: Faugert & Co, 2008

We also provide a vignette of IMEC, the world-leading microelectronics research institute in Flanders. This offers a radically different vision of a research institute bringing national value not by predominantly being national but by being international in its focus.

The RTO systems studied essentially have in common the business concept to provide knowledge-based support for the development of the activities of private and public customers and society as a whole. They aim to achieve this by disseminating research-based applied knowledge to their customers and helping them implement this knowledge in their own operations. The knowledge may be developed by the RTOs themselves or by other R&D providers. From an innovation-systems perspective, the institute systems all place themselves 'between' the university sector and industry and they tend to market themselves as intermediaries, interpreters or 'bridge builders' between the two 'sides'. Although the RTOs' strategies vary in wording, emphasis and structure, they all boil down to a number of common focus areas, including

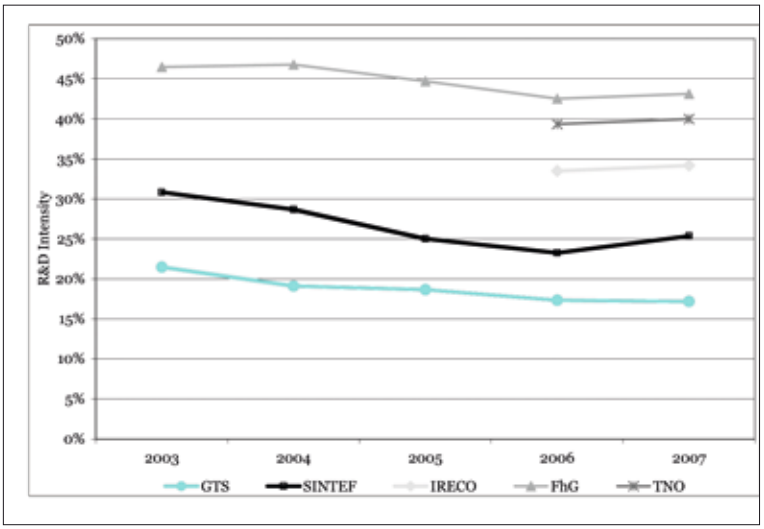
- Customers: Close and lasting relations with customers, including public ones, are sought, in some cases through membership programmes; SMEs are said to be the main focus and often are in terms of number of customers, but large enterprises dominate private turnover

- Science: Services are based on research, development and innovation activities; strategic partnerships with other knowledge providers and in particular with universities are sought
- Globalisation: Ever-fiercer competition among the RTOs' customers and between the increasingly globalised RTOs themselves require continuously enhanced international competitiveness
- Sustainability: The society as a whole is to benefit, meaning that environmental concerns receive high attention from both the RTOs' customers and by RTOs themselves
- Employees: The human capital is an RTO's most important asset and therefore needs to be carefully nurtured, both to keep the personnel content and to ensure that its competence is continuously developed so that it stays abreast with international developments and the RTO thus maintains its technical and scientific competitiveness
- Independence and impartiality: Two important, often crucial, qualities for many customers, particularly when it comes to testing and certification

There are significant differences in ownership, legal form and governance among the systems studied. Despite these, the state exerts a strong influence over the strategy and mission of the institutes via the provision of core funding, while at the same time leaving institute management with a high degree of autonomy in executing its strategy.

R&D intensity, defined as the proportion of non-commissioned R&D in total turnover, varies significantly, as demonstrated by Figure 20. There may also be significant elements of R&D in commissioned work. In 2007, the Fraunhofer Society had an R&D intensity of as much as 43%, followed by TNO with 40%, IRECO with 34%, SINTEF with 25% and GTS with 17%. R&D intensity shows a downward trend for the Fraunhofer Society, SINTEF, and GTS, mainly due to increasing turnover.

Figure 20 R&D intensity of case study RTOs



Source: GTS; OECD Main Science Indicators

As Figure 21 indicates, GTS' importance in Denmark's overall investment in R&D (Gross Expenditure on R&D – GERD) is about the middle of the range, compared with other institutes. While TNO, GTS and IRECO each comprise the bulk of the industrial research institute system in their respective countries, there are other significant industrial applied research institutes in both Norway and Germany, which, if included, would tend to drive their data points upwards. The trend in the Figure suggests, as one would expect, that the more knowledge-intensive the economy the smaller becomes the relative role of the institutes. Since the driving component of GERD is Business Expenditure on R&D, this is implicit in the arithmetic. But a much greater part of GTS' turnover (two thirds) is technical services than is the case for the other economies considered. There is therefore scope to move GTS' position upwards in order to provide an input of R&D-related, knowledge-intensive services equivalent to that in the other countries.

Figure 21 Share of Institutes' national turnover in GERD vs GERD/GDP, 2006

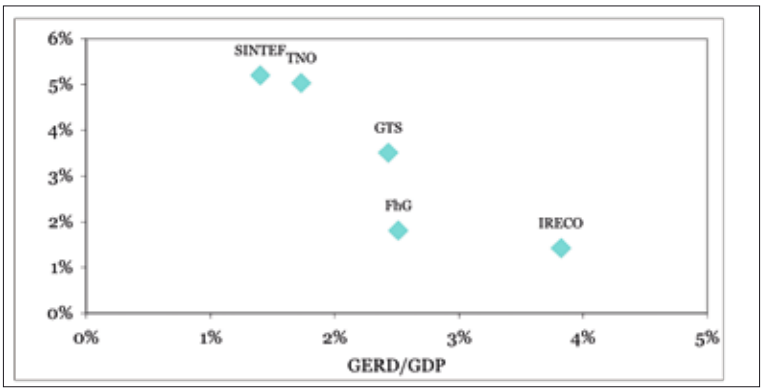
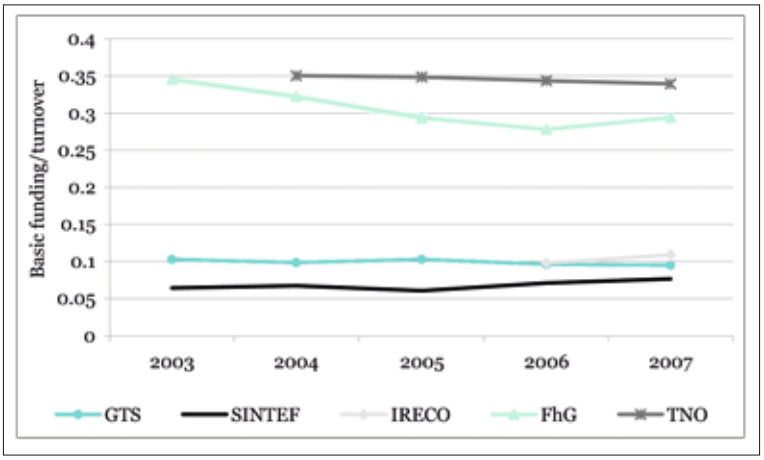


Figure 22 reveals that at 34% in 2007, TNO had the highest level of basic funding, followed by the Fraunhofer Society at 29%; both with overall negative gradients. The Scandinavian RTOs have only about a third as high basic funding; in 2007, IRECO had 11%, GTS 10% and SINTEF 8%.

Figure 22 Share of core funding in RTO turnover



The international proportion of the RTOs' sales includes both commercial turnover and project grants. At 43% (2007) and still rising, the GTS institutes are in a class of their own. In 2007, TNO's international sales were 22%, IRECO's 19%, SINTEF 14% and the Fraunhofer Society 9%.

The PhD-intensity of the institute systems is rising. GTS is at the low end with about 8%, compared with VTT at 18%, SINTEF at 28% and IRECO at 27%. (Fraunhofer's is said to be about one third, but it has not been possible to find official data on this.) We note, that Denmark is among the countries that only recently adopted the US/UK style of start-of-career PhD and that this explains why many of the older researchers may not have doctorates. However, most if not all of the comparator countries are in a similar position.

In 2007, there were 312 informal and 248 formal cooperations between the GTS institutes and the Danish universities. There are several forms of cooperation

- Cooperation through ownership
- Formalised cooperation contracts, including exchange of employees, use of laboratory facilities and supervision of students
- Innovation networks, which aim to enhance collaboration with industry and universities and colleges. GTS institutes participate in 18 such networks and coordinate five
- Innovation consortia, wherein GTS institutes are knowledge mediators to strengthen and increase the innovation rate in Danish industry

While the other systems also have essentially project-based university cooperations, , they place greater emphasis on faculty and PhD relationships, with institute staff teaching university courses, faculty occasionally working for periods in the institutes and – especially – the placement of doctoral students in the institutes. The low R&D-intensity of GTS is probably an important impediment to this in Denmark.

There appear to be six different types of RTO funding

1 Unconditional basic funding
2 Performance-related basic funding, either based on turnover, or fulfilment of criteria, or a combination
3 Strategically targeted basic funding for RTOs, applied for in competition with other RTOs
4 Strategically targeted basic funding for RTOs, allocated by funding agency
5 Expansion/restructuring basic funding
6 Other public R&D funding, applied for in competition with other R&D providers

Table 4 shows the types of funding used at the case study institutes. The dominant types of basic funding are performance-related and strategically targeted funding, both competitive and allocated. There seems to be a trend towards increased focus on performance-related funding, which is probably

related to an increased belief in the value of competition. Concurrently, there is among the funding agencies a desire to retain some influence over how funding is used, which is evidenced by the use of strategically targeted funding. In this respect, the Dutch system is at the extreme end of the control scale, while the Scandinavian systems allow for more bottom-up influence.

Table 4 Funding types use by case study RTOs

Type of funding	GTS	IRECO	SINTEF	FhG	TNO
1. Unconditional basic funding			X		X
2. Performance-related basic funding	X	X		X	
3. Strategically targeted basic funding for RTOs, competitive	X	X	X		
4. Strategically targeted basic funding for RTOs, allocated					X
5. Expansion/restructuring basic funding		X			
6. Other public R&D funding	X	X	X	X	X

All five RTOs claim to focus on SMEs. While there is a lack of consistent, quantitative information, it is nevertheless clear that SMEs dominate the customer portfolios of the GTS System (88%), SINTEF (50–70%) and the Fraunhofer Society (>50%), and it is probably safe to assume that similar customer patterns apply also to the IRECO Group and TNO, considering that they explicitly target SMEs as customers. Around 9% of all Danish enterprises are customers of a GTS institute. While Denmark does not have a significantly greater proportion of SMEs than the other countries in this study, it seems as if the GTS System has a greater proportion SMEs as customers than the other four RTOs.

The GTS institutes are different to the others considered here, in part owing to the lack of common ownership or strong central management. While central management does not solve everything – the Fraunhofer Society, for example, has a central management function but has struggled to generate a strategy coordinated across many tens of institutes – it does provide opportunities to make shifts in direction that are harder to take in a more networked environment.

All the RTO systems are also increasing their cooperation with universities

- To gain access to their R&D results, so as to be able to exploit them commercially
- To be able to retain and develop its own personnel by providing more challenging work, by securing the possibility to have in-house graduate students, by allowing staff to be adjunct professors etc.
- To achieve or increase critical mass
- To 'borrow' some of the research 'quality seal' of universities
- To be able to recruit qualified researchers

In the case of SINTEF and some parts of the Swedish system (such as YKI), this also results in considerable hidden subsidy, by making PhD labour available to support the knowledge generation work of the institute. The GS system's comparatively low educational level and R&D intensity are important factors limiting such university cooperation, as well as probably failing to match the growing knowledge-intensity requirements of its customers. It appears that the GTS institutes are using export markets in order to cross-subsidise their efforts in Demark – notably in the area of capacity and knowledge building.

Comparable data are hard to obtain, but most of the institute groups maintain a spin-out activity. TNO and SINTEF maintain subsidiaries to look after spin-outs while Fraunhofer Venture Group provides potential spin-outs with links to external capital sources. GTS does not have a common function for dealing with spin-outs but apparently the network as a whole have produced abut 3 spin-outs per year in recent years while strongly supporting 3-4 external start-ups per year.

4.1 IMEC [21]

Traditionally, there is a worry that encouraging national research institutes to operate internationally or with international companies can result in 'leakage' of knowledge. Especially in the case of small countries (whose total contribution to global knowledge production is after all small), this argument is simply not tenable and IMEC – the Interuniversity Microelectronics Centre – provides a good illustration of the value of extreme internationalisation.

The Flanders government decided in 1982 to set up a wide-ranging programme of activities to ensure that the region would benefit from the production and use of Information Technology. In 1984, IMEC was set up to link the developing microelectronics capabilities in Flemish universities and to do more application-oriented research than was possible within the universities themselves, given the high cost of the research infrastructure needed.

Flemish industry at that time included not only a number of microelectronics-using companies but also a strong presence by Philips. IMEC nonetheless recognised the need to operate at an international level to build enough critical mass and resources to be world leading. It developed a business model that involved bringing multiple industrial partners together on a one-to-one bilateral contract basis, to explore and develop the knowledge and capabilities needed to tackle next generations of design methods and microelectronics process technologies.

IMEC's major research focus has been mainstream silicon microelectronics process technology. A key to its recent success is the fact that in 2004-2005 it was able to persuade its industrial partners and the regional government together to finance a state-of-the-art pilot line able to process 300mm diameter silicon wafers – an investment of some €400M, which was ready for use in 2006. This provides IMEC with a unique advantage, since it is one of the few independent microelectronics research laboratories worldwide to possess such a facility.

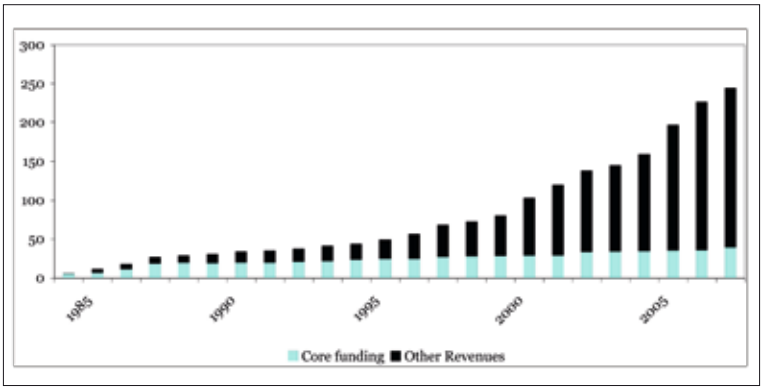
[21] This vignette is based upon Erik Arnold, Neil Brown, Anne-lie Ericsson, Tommy Jansson, Alessandro Muscio, Johanna Nählinder and Rapela Zaman, The Role of Research Institutes in the National Innovation System, VA 2007:12, Stockholm: VINNOVA, 2007

IMEC serves six groups of customers: top-ranking global microelectronic chip manufacturers; major international companies involved in other microelectronics technology areas; suppliers of equipment and specialised semiconductor materials; its own spin-off firms, in which it may hold a minority stake; other local companies, which IMEC supports with a range of innovation oriented activities; a number of Flemish higher education institutions and companies, to which IMEC provides education, training and prototyping services. In many cases, it cooperates with these customers not only through bilateral contracts but also via the EU Framework Programme or Eureka projects.

Until 2002, some 10% of IMEC's core funding was to be spent on joint projects with local universities to fund longer-term research projects in areas of strategic interest to the institute. A key component of continuing relations with the universities is based on having PhD-students and post-docs performing their research at IMEC's facilities. Over 200 PhD students, most of which are registered at the partner universities, actually work at IMEC's premises and a certain number of IMEC's own staff (about 30) teach part-time at these universities.

Figure 23 shows how IMEC's total revenues have developed since 1984, when it began operations. The red portion is largely foreign revenue.

Figure 23 IMEC 'Grant from the Flanders Government' and Other Revenues, 1984-2007



Source: IMEC Annual Report, 2007

IMEC's structural funding comes in the form of a yearly 'grant', against which a number of key performance indicators have been put by the Flanders Government. In return for this grant, the institute is expected to be an international centre of excellence, to provide benefits to the Flemish economy and to the universities in several ways, including spillovers from its normal research (e.g. spin-off companies), specific services to Flemish industry (both inside and outside the electronics industry), training, prototyping services and research alliances with regional universities. A series of (unpublished) evaluations shows that IMEC's contribution to the regional economy far exceeds the cost of its subsidy – and that one of the most important 'soft' benefits it brings is access for the region to world-class ICT technology. The IMEC example illustrates that

- Internationalisation of the customer base brings learning advantages and can help an institute build world-class capabilities, despite having a small geographic home market
- It is possible to build to very high levels of foreign income, bringing a high 'leverage' effect for taxpayers
- As a result, a small country can benefit from knowledge services of a size and quality well beyond what it could finance domestically

5. Future needs and opportunities >

[22] GTS – Advanced Technology Group,GTS 2015 – Catalogue of technological focus areas, Copenhagen: GTS, December 2008

[23] Birgitte Rasmussen, Per Dannemand Andersen, Review of science and technology foresights, Copenhagen: DTU Management Engineering, January 2009

Two foresight-related studies were performed in conjuction with this evaluation. The GTS network produced a list [22] of fifteen candidate technology/business areas, which it could consider entering or in which an expansion of existing business would appear to make sense. A business case was made for each. The second study [23] essentially confirms that the areas suggested by GTS are broadly consistent with The technological trends and opportunities discussed in the international foresight literature.

The list of potential areas is

1 Energy systems of the future
2 Future climate change and climate adaptation
3 Competitive environmental technologies
4 Bio-resources, food and other biological products
5 ICT-support for efficiency, productivity and innovation
6 The production systems of the future and Denmark's competitiveness
7 Strategic growth technologies
8 Future health and [disease] prevention
9 Innovation – accelerated development of new products
10 The public sector of the future – the need for labour-saving technology
11 Service innovation
12 Sustainable infrastructure (utilities, transport, communications and planning)
13 Education, training and lifelong learning – sustainable innovation
14 Health and safety and their interaction with environmental factors
15 Better lifespace – space for life and growth

These appear to the panel to be a good fit with national and international conventional wisdom but they are at this stage not prioritised. To the extent that they may form bases for future action, they need to be considered by the individual institutes, the GTS network and VTU/RTI using criteria that include

- Technological opportunity
- Market opportunity
- Present and foreseeable Danish capabilities in industry, institutes and universities
- Basis for Danish comparative advantage
- Degree of Danish industrial commitment to the area
- Societal and policy priority of the area
- The need for complementary policies and the likelihood of the needed policy changes being realised

The GTS network forms the obvious arena for such a prioritisation process,

which should consider not only priorities but also implementation. In particular, GTS and RTI/VTU have to decide whether to open or include additional institutes, whether to tackle all the areas chosen within existing institutes and the degree to which it would be necessary to matrix new 'competence centres' across the institutes (potentially involving also universities and firms).

Tackling this task in effect implies an increased coordination role of the GTS network in the process of developing group strategy.

6. Conclusions and recommendations >

In our view, the GTS system has done well in meeting its target groups', national and even international needs for technological services. However, the world is changing around it, so GTS must adapt as needs evolve. These changes especially involve

- The role and activities of GTS
- Internationalisation
- Increasing knowledge intensity
- GTS' position in the knowledge system
- Organisation and governance

In this chapter we consider each of these in turn, drawing conclusions and making recommendations, before discussing how and when to deploy our recommendations.

6.1 The current role and activities of GTS

Overall, the GTS system is doing a good job in its national context, serving the needs of industry in Denmark and eliciting great satisfaction from its customers. It plays an especially important part in supporting SMEs, which tend to acquire technological services a little at a time in small projects, to be reluctant to pay what they often see as high prices and to need a lot of introductory help and after-care. These hard-to-serve customers are very unattractive to the private sector but looking after their needs is vital to the health of the substantial SME sector in Demark.

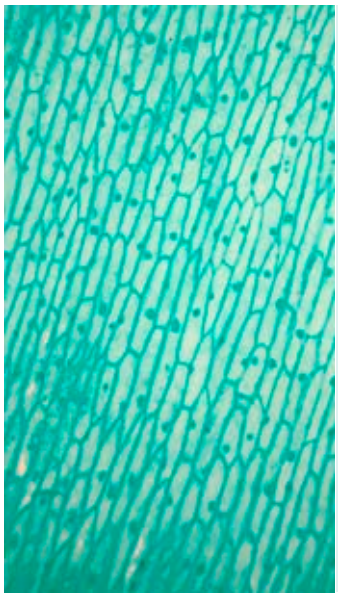
Irrespective of the size of firm involved, however, the GTS network's primary role is 'de-risking' innovation by providing a range of R&D and technical services that enable its customers to go beyond what their internal technological capabilities allow. The fact that capabilities vary among firms and branches of industry means that – like equivalent organisations – GTS must offer a wide and differentiated range of services. For some firms, a test, advice on what material to use, applying a well-known piece of software or providing a certificate of quality is enough to enable them to innovate more and faster. For others, the need is for new engineering applications, development or even research results. Small firms and large firms often have different kinds of technology services needs and since both kinds of company are important to national prosperity, both need to be served. The variety of needs met by the GTS institutes means that no single short-term performance measure could be applied to the GTS system.

The wider economic impact of such services in Denmark is inadequately studied, but they are internationally recognised as increasing the rate of innovation and therefore promoting economic development and growth. The GTS institutes can largely make this contribution because of the capabilities society funds through their performance contracts. Society gets a return on its investment through re-usable knowledge that translates into growth.

To a greater extent than other European institute systems, GTS' centre of gravity is in testing and other services. There is no evident reason to abandon this activity, for which there is demand and which has significant societal value, though it needs to be complemented by activities that are increasingly knowledge-intensive.

However, internationally the character of needs for research institute services is changing and, as the recent interest in foresight illustrates, GTS' strategy cannot remain static. Major institute systems such as Fraunhofer, VTT, TNO and the IRECO system have already reorganised in order to provide customers with more holistic services spanning many technologies. It is hard to see why Denmark should be immune to the need both for more holistic services and for the increased strategic flexibility at which these reorganisations have aimed. A key aspect of the needed holism is the ability to be interdisciplinary, reflecting the interdisciplinary nature of most industrial problems

While we recognise that the GTS cooperation already goes beyond common branding and reporting to RTI, meeting current and future challenges requires the institutes to step up to the national challenge. Developing an holistic approach requires the GTS network to develop a common strategy, not just a collection of nine strategies, as at present. This requirement is reflected in the following and subsequent recommendations.



We recommend that

- Government and RTI should continue to make sure the rules of the game allow GTS institutes to provide the wide range of technological services needed to share the risks of innovation with industry in Denmark and to test the adequacy of GTS' strategy and performance in this task
- The institutes themselves should establish a strategic mechanism that allows both the individual institutes and GTS as a collective to set and implement a strategy in support of evolving Danish societal needs, as well as the needs of the individual institutes' current customer groups. Elements of the strategy should include
- What capabilities the institutes should develop or abandon
- The services they should provide
- The customer groups they should address (and by implication, which ones they should not)
- The organisational structures needed to deliver the GTS mission

6.2 Internationalisation

Compared with other European institute systems, GTS is highly internationalised, in part through acquiring and establishing organisations abroad that provide technical services, for example in Sweden. These activities add scale to GTS' activities in Denmark and are said to be profitable. The profits are used to cross-subsidise activities in Denmark. This provides benefits to the Danish economy while offering customers abroad technical services from a competitive supplier operating at scale. There seem only to be winners in this arrangement.

A second motive for GTS' internationalisation is the ability to provide R&D support to Danish companies abroad. We have only case study evidence that this is occurring, but – as with technical services – there is every reason to believe it is a good thing. Another major objective for GTS' international operations is to acquire knowledge from abroad and to make it available to Danish industry. With a substantial part of GTS' international operations focusing on technical services rather than R&D, it is unlikely that such knowledge acquisition is happening on a large scale. Increased international R&D activity would be necessary in order to do this.

The European Framework Programme is a key source of knowledge from abroad. It tends to focus on 'pre-competitive' activities relevant to building knowledge platforms and capabilities and to provide access to quite large networks of cooperating organisations, which may act not only as knowledge sources but also as future business and research partners. Other institute systems stress the importance of participating in the Framework Programme in order to develop and quality-assure their knowledge assets. GTS is aware of the importance of Framework participation but its current difficulties in finding the matching funding needed for participation are a barrier to the development of the network and should be reduced. However, entering and working within the Framework Programme is demanding: the competition for projects is tough; and the quality standards are high. Strong national capabilities are needed in order to qualify. It is not possible to enter the Framework collaborations without these, so the core component of GTS funding needs to be big enough to enable GTS staff to reach the required quality threshold.

As GTS' own pattern of customers shows, companies are no great respecters of national borders when they seek technical and R&D support, so GTS is effectively in competition with institute systems of several times its own size in nearby countries. As trade in GTS' type of services becomes increasingly international, GTS will need to specialise and correspondingly to leave the supply of certain specialist services to foreign institutes. To the extent that GTS still wishes to provide a polytechnic and all-encompassing set of services to its Danish customers, therefore, it will need international alliances. At least for the time being, such alliances are likely to be found in small countries – it is difficult to see the Fraunhofer Society, for example, feeling much need to ally at this stage. This need aligns with renewed policy interest in 'restructuring' the EU knowledge infrastructure within the European Research Area. In this sense, GTS is unusually well positioned to take a lead in moving to a more internationalised position: strengthening certain specialisations of especial relevance to Denmark and customers abroad while eventually improving Danish access to other specialisations through international partnerships. Partnerships will also be important in offering the increasingly holistic and polytechnic solutions customers need.

The example of IMEC in Flanders shows that small countries can gain considerable benefit from hosting internationally capable research institutes. The widespread use of the EU Framework Programmes by institutes as a key component of their knowledge acquisition processes confirms that international R&D cooperation offers important opportunities for institutes to build

capabilities and to test themselves against international demands and quality standards. There is therefore every reason for GTS to build on its strong international services position to do more international R&D collaboration, thereby increasing its absorptive capacity and ability to serve Danish as well as foreign clients.

Europe is not the only level at which international cooperation makes sense for GTS. The strong Nordic tradition of cooperation in research and in areas like metrology and standardisation provides a foundation for increased specialisation by GTS and engagement with partners close by, who can provide complementary services to Danish industry. There is scope for GTS actively to build relations with partners holding complementary competences in the Nordic knowledge system and to seek Nordic support for these efforts.

The current situation where European RTOs in general remain national while their corporate customers globalise is unstable, as well as coming under increasing policy pressure through the European policies and support instruments that aim to build a European Research Area.

We recommend that

- GTS should be encouraged to continue its internationalisation trajectory
- Continuing to build scale and international customer bases in self-funding, routine technical services
- But complementing this with increased international activity in R&D and R&D-related services
- GTS core funding should be strengthened by specific resources that support greater participation in the EU Framework Programme and eventually other European and global collaborations that have a similar knowledge-developing and knowledge-sharing character
- VTU and GTS should explore opportunities for partnerships with other non-Danish institutes. These should include initiating action at the Nordic level and exploring the opportunities to use new or existing EU actions to support the emergence of regional institute partnerships that promote increased specialisation with the purpose of sharing knowledge and improving the fit with customer needs

6.3 Increasing knowledge intensity

In Denmark, most government funding for research goes to the university system – a focus that has been increased by the recent merger of the government research institutes into that system. By and large, this leaves GTS as the institutional mechanism through which government supports innovation in industry and among other producers. It is crucial therefore that the GTS system is adequately funded and capable of providing the highest quality of relevant knowledge inputs into the productive economy.

As in other institute systems, the Danish applied industrial institutes' roles have shifted over time and the way they have been funded has shifted correspondingly. Increased technological capabilities among companies in

developed countries mean that the need for institutes to undertake new product and process development for their customers has decreased. The institutes have increasingly played their role of de-risking innovation and helping customers go beyond the limitations of their existing capabilities by becoming deliverers of more advanced inputs to their customers' innovation processes. As customers' technology support needs have become more refined, so their willingness and ability to pay for the more traditional kind of support has increased.

However, users' growing average level of technological sophistication places greater technological demands upon the institutes as their knowledge acquisition must continue to address areas that go beyond most users' abilities. The degree of specialisation and the costs of providing that extended knowledge platform are rising as economic production becomes more knowledge intensive. For this reason, there is now a new tendency for core funding to increase as a proportion of institutes' turnover, for example in Finland and Sweden.

The context of industry in Denmark and abroad demands an increasingly research-based offer from GTS. The new Alexandra institute is an interesting move in this direction, but its small size means it has so far had little effect on GTS' centre of gravity. It follows that GTS needs more core funding, in order to build the needed knowledge platforms. This should come as a mixture of funds that can be used strategically by the management and funds channelled through 'focusing devices' such as innovation consortia or other more societally orientated mechanisms. Close interaction with Danish and foreign universities (and research institutes) is also necessary, in order to strengthen the knowledge content of GTS.

However, funding the institutes solely to develop their individual, separate knowledge acquisition strategies will continue the pattern of fragmentation within GTS and will mean that the GTS system as a whole does not optimise at the level of Danish needs but of institutes convenience. It provides insufficient incentive to the institutes separately or together to address national needs or to align with national policies. As has been recognised in The Netherlands, there is a need to complement the institutes' perceptions of need with incentives to tackle areas of agreed national need, which will include not only the medium-term support needs of existing industry but also the need to build strength to tackle (and commercially to exploit) major challenges such as environment, ageing and new energy technologies.

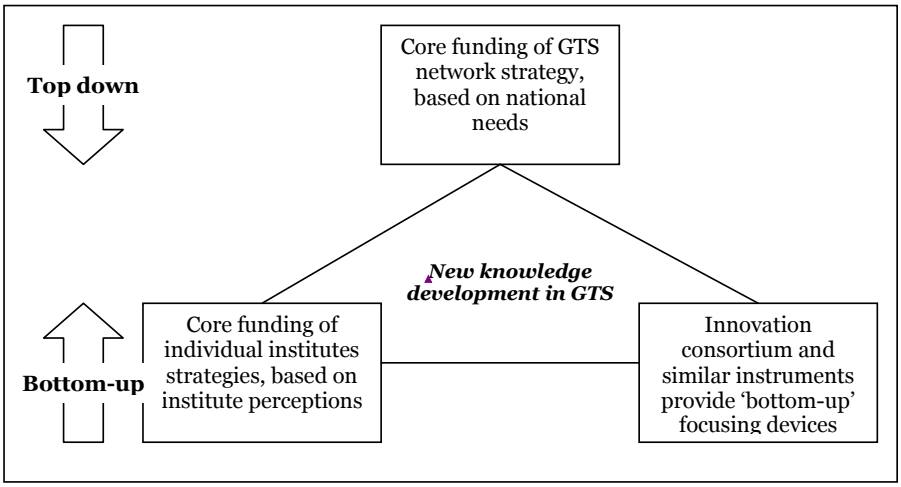
There is a separate need for mechanisms that focus the institutes' attention bottom-up on areas of industrial and societal need. Here, Denmark has a long and strong tradition through the Centre Contracts programme, which in recent years has been continued via the Innovation Consortia programme. The projects in these programmes involve a cluster of users with a common problem, university and institute research to solve the problem and the generation of capacity at the institute to deliver future technology services based on the solution. A more elegant combination of de-risking innovation and generating spillovers is difficult to conceive.

We therefore recommend that

- VTU should increase the average proportion of total funding subsidy to the GTS institutes towards the 20% level emerging as the new Scandinavian desideratum. The higher level of services in GTS turnover means that the proportion of core funding should remain lower than that in the more R&D-focused continental institutes (Fraunhofer, TNO)
- The higher level of core funding should have two components: an institute-specific part, equivalent to today's core funding and therefore accounting for perhaps 50% of the core funding, which should be negotiated between the institutes and VTU or the RTI; and another similarly-sized component, aiming to tackle national needs and challenges, that should be based on a collective strategy of the GTS institutes. This will be informed by foresight, road mapping and other forms of strategic intelligence that go beyond the institutes' existing, market-focused planning processes. Both types of core funding should be usable as co-finance for Framework Programme projects
- The core funding should continue to be complemented by the successful Innovation Consortia programme, which uses industrial problems as focusing devices, building reusable knowledge resources within the GTS institutes, and potentially other instruments yet to be invented. The funding for these should be additional to the 20% core funding

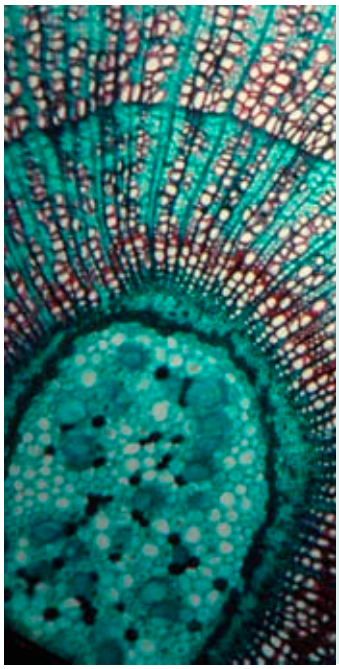
This will result in a three-cornered funding system for the GTS institutes. The institute-based core funding will help keep the system closely aligned to customers' medium-term needs. The Innovation Consortia will play a similar role, but provide an external mechanism that complements the internally driven strategies of the institutes, which will be reflected in their requests for core funding. The national needs funding through the GTS network will provide a top-down counterweight to these bottom-up aspects, encouraging the GTS system to tackle themes of longer term and wider societal (including industrial) needs.

Figure 24 Top down and bottom up character of future GTS funding



6.4 Position in the knowledge system

Acting only on core funding is not sufficient to tackle GTS' increasing knowledge needs. Closer links should be built with both Danish and foreign universities in order to take account of the increasingly fundamental or science-based content of engineering and other industrial knowledge. Research and industry are becoming increasingly PhD-based, and so must the GTS institutes. The GTS offers a good way to draw universities' attention to societally relevant research themes and to provide a source of research-trained manpower able to work in areas of national and industrial need defined by the strategy of GTS. GTS institutes already (in varying degrees) have links with the universities but these need to be deepened, by reference to practice abroad.



We therefore recommend that

- The GTS institutes forge tighter links with the universities, such as increased teaching by GTS staff at the universities and increased placement of PhD students within the institutes in applied fields of research
- GTS institutes raise the proportion of their staff with PhDs by exploiting the industrial doctorand scheme and EU mobility schemes such as Marie Curie
- VTU programming of research and innovation be adjusted to provide incentives for increased cooperation between the GTS institutes and the universities
- A proportion of the increased core funding for GTS should be allocated to PhD training for GTS staff, funding GTS staff to take up Adjunct Professorships in universities and eventually funding joint positions shared by universities and institutes
- Where possible, these measures should apply to universities outside as well as inside Denmark

6.5 Organisation and governance

In recent years, there have been significant numbers of mergers among GTS institutes, which have made a start on tackling the issue of de-fragmenting the technology offer of the GTS system. The Alexandra Institute and AgroTech represent a new trajectory of increasing the breadth of GTS' technological offering – but at the cost of reintroducing fragmentation and new institute boundaries that may constrain GTS' flexibility for optimising its service portfolio in future. Differences in ownership, and to a lesser degree in the focus of some institutes on applied research while others are more strongly services orientated, are important obstacles to the creation of the optimal share of capabilities or a single GTS institute, which – given the experience of TNO, VTT and others – is a thinkable option. Recognising that it would tend to go against the Danish way of doing things, we do not recommend a merger to form a single institute. However, there is an acute need for the GTS institutes to have a common strategy, which meets the future needs of society. This will show their ability to act together to meet the challenges of holism and polytehnicity to which we have referred. If they fail in this respect, we have a strong presumption in favour of merging them to produce an organisation more comparable to TNO, VTT or SINTEF.

The GTS agenda is in constant change. This is partly negotiated with VTU/RTI through the three-yearly process of writing performance contracts, which specify the new areas of knowledge that the institutes will develop as future bases for their businesses. During the course of this evaluation, two exercises have been conducted that aim to provide insight into future technology needs and opportunities. Both constitute a basis for developing a strategy for Danish needs and the collective GTS challenges by coupling to the specific situation of GTS and Denmark.

As our discussion of core funding suggests, we believe there is a need for consideration of future needs and knowledge acquisition strategy at a level between that of the individual institutes and that of the world (or Denmark) in general: hence the proposal that the GTS network itself should play a bigger role in acquiring strategic intelligence, doing foresight and setting collective strategy for the institutes. This implies a much more active role for the GTS organisation and its use as a policy-setting arena by the individual institutes and VTU/RTI.

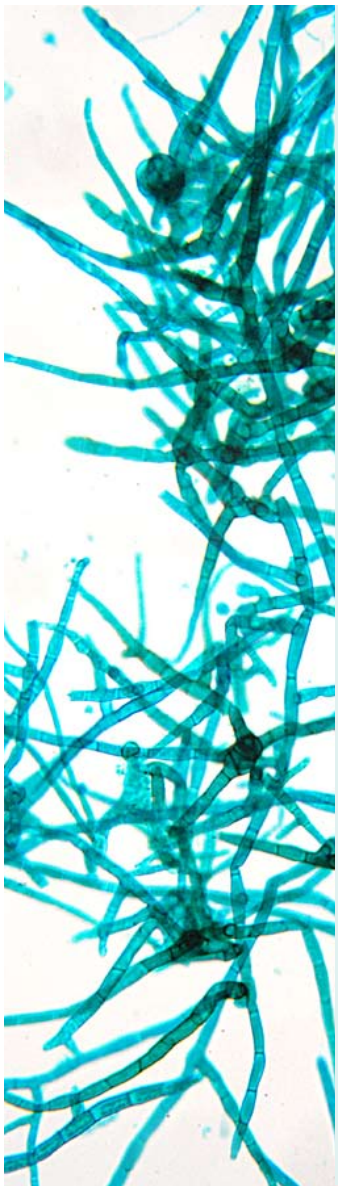
In order to play the 'top down' role of connecting the institute system with societal needs, GTS needs to become a negotiating partner with VTU/RTI on strategic issues and future plans.

The extent to which most non-users feel GTS has little to offer them and are unable to navigate the system in order to find the right specialists indicates that there is also a need for a more active marketing and new-customer interface for the institutes collectively, referring customers who need such help into the relevant institutes and, where necessary, connecting needs to more than one institute in order to satisfy them.

The performance contracts are currently 3 years long, which is a rather short time in the context of the increasingly knowledge-intensive nature of GTS' work. It would be better to plan and contract in longer periods. A four-year cycle would bring the institutes into line with the rest of the government planning and funding cycle.

There are no performance indicators attached to the current performance contracts. While it would be possible to add more industrial and commercial output indicators, collecting these numbers would imply more work and the risk to leave VTU and RTI asking "What does it mean when such an indicator reaches a particular value?" To a very considerable extent, the turnover of the institutes is the best indicator of how well they meet short- and medium-term needs, though this should be supported by an indicator that identifies the proportion of turnover generated by routine technical services. More attention should be paid to the indicators of research output, to encourage GTS to become more R&D-intensive. We prefer not to be very detailed here, but we would like to note the potential in linking the additional and strategic core funding to the kinds of activities and performance dimensions that were addressed in the previous set of recommendations above.
In former times, the GTS institutes were subject to periodic peer review by a mixture of international scientists from both academia and industry and other experts in institute management. As the balance of GTS effort shifts towards R&D, it becomes increasingly important to look at the quality and relevance of that R&D to strategy and needs. Reinstating this process would provide not only some quality control but also some useful sparring and advice at the level of the individual institutes. It could be complemented by creating an international scientific advisory board at the level of the GTS system as a whole.

At the margins, GTS may overlap with, but does not seriously compete against, the private sector, and this is enforced by the objectives and contract terms, or rules of the game, underpinning the GTS institutions. Full costing of services combined with intelligent management are sufficient to ensure that GTS' position is not abused. Lead indicators of satisfying future needs should relate to the research and acquisition processes involved with generating new knowledge platforms. Relevant indicators such as publications are already collected but should be given more weight and should be deployed down to the level of individual staff appraisals. This will help the institutes 'raise their game' in terms of knowledge generation.



We recommend that

- VTU/RTI should periodically manage a foresight, road mapping or other similar strategic exercise to strengthen the role of the GTS system and for planning future demands of the GTS system
- VTU/RTI on the basis of their foresight and of negotiations with the GTS Board apply appropriate instruments and incentives in allocating the new half (10% of the turnover) of core funding to achive the strategic objectives
- The GTS Board (which comprises the directors of the institutes) should be responsible for developing the common GTS strategy and for collectively negotiating with VTU/RTI the general direction of the new half (10% of turnover) of core funding. Doing this will also involve a strategic process of foresight, road mapping etc
- The GTS Board should investigate and implement the means to increase the effectiveness of GTS as a strategic arena among the institutes and to improve visibility to customers as well as referral
- The GTS Board should consider whether to appoint a scientific advisory committee for the system as a whole. This could be a mixture of Danish and foreign experts and could meet annually to discuss the strategy and progress of the GTS system as a whole in national and international context, acting as a scientific and managerial sparring-partner for the GTS Board
- Core funding should be allocated in 4- not 3-year periods in future
- VTU/RTI should place greater weight on total turnover and on the indicators of R&D output already collected in deciding the allocation of core funding
- VTU/RTI and GTS should consider reinstating the practice of periodically peer reviewing the institutes, in order to obtain independent scientific advice on the quality and relevance of the institutes' work to both VTU/RTI and to the institutes themselves. This is especially important as the knowledge-intensity of the institutes' work increases

6.6 Deployment of the recommendations

The current performance contracts expire at the end of 2009. Our recommendations require a significant upgrading of the GTS network organisation's capabilities and role. There is too little time to do this effectively before the next round of negotiations, so we suggest that the current funding period be extended by one year so that GTS and VTU/RTI have time to prepare themselves for a new style of negotiating and contracting in 2010..

Terms of Reference >

Kommissorium for international evaluering af GTS

1. Baggrund

De Godkendte Teknologiske Serviceinstitutter (GTS-institutter) er vigtige aktører i spredningen af viden til især de små og mellemstore virksomheder. For at styrke dynamikken i GTS-institutterne har regeringens globaliseringsstrategi bl.a. som mål, at konkurrencen inden for den teknologiske service skal øges, og at der skal stilles større krav til resultaterne.

Som led i opfølgningen på globaliseringsstrategien skal der derfor gennemføres en international evaluering. Evalueringen skal samtidig danne grundlag for at formulere en strategi for den godkendte teknologiske service frem imod 2012, "GTS 2012". Strategien skal skitsere rollen for godkendt teknologisk service i Danmark, herunder hvordan rollen udfyldes. Desuden skal evalueringen bruges af Rådet for Teknologi og Innovation (RTI) som grundlag for udformningen af resultatkontraktprocessen for 2010-2012 med aktørerne i GTS-systemet.

2. Formål

Formålet med evalueringen er at vurdere det danske GTS-net. Evalueringen skal vurdere, hvordan de danske GTS-institutter samlet set indgår i det danske vidensspredningssystem, og hvordan GTS-institutterne holder sig på forkant med udviklingen og tilbyder services, der matcher fremtidens behov. Evalueringen består af tre adskilte grundanalyser:

1. Kortlægning af det danske vidensystem. Kortlægningen skal afdække, de væsentlige aktører, hvilken rolle de spiller, og hvordan samspillet mellem de forskellige aktører er.

2. Fremsyn for den teknologiske service i Danmark. Fremsynet skal pege på, hvor fremtidens behov og efterspørgsel for teknologisk service tegner sig.

3. Sammenlignende analyse af, hvordan de danske GTS-institutter udfylder deres rolle i forhold til lignende aktører i andre lande. Den internationale analyse skal identificere styrker og svagheder ved det danske GTS-system i sammenligning med udlandet og give inspiration til GTS-institutternes organisering og måde at fungere på.

På baggrund af kortlægningen, fremsynet og den sammenlignende analyse skal evalueringen komme med anbefalinger til,

- hvordan de danske GTS-institutters kompetencer og faciliteter bedst udnyttes til gavn for virksomheder, samfund og placerer sig i forhold til de øvrige videninaktører,
- hvad de danske GTS-institutter og RTI yderligere kan gøre for at sikre, at udvikling og serviceudbud til stadighed afspejler den nyeste teknologi og den fremtidige efterspørgsel,
- samt hvor fremtidens efterspørgsel på teknologisk service tegner sig.

3. Genstandsfelt

Evalueringen vil omfatte samtlige GTS-institutter og angå GTS-institutternes samlede aktiviteter både de kommercielle og medfinansierede.

1. Kortlægningen af det danske vidensystem og GTS-institutternes placering heri vil belyse de mange forskellige aktører, der deltager i produktion, omsætning og anvendelse af viden i samfundet, og samspillet mellem dem. Såvel aktører, der producerer viden, som institutioner, der spreder og anvender viden, vil indgå.

2. I fremsynet skal GTS-systemet vurderes op imod en bred vifte af mulig efterspørgsel på teknologisk service og innovation. Der gives også en vurdering af mulighederne for at etablere erhvervsrettet innovations- og vidensservice indenfor områder, der ikke dækkes af systemet i dag - så som humaniora og samfundsvidenskab. Endelig gives en vurdering af GTS-institutternes aktuelle muligheder, metoder og strategier for at sikre, at nye relevante områder tages op.

3. Internationalt sammenlignes det danske GTS-system med lignende systemer og den rolle de spiller i andre lande. Primært fokuseres på IRECO i Sverige, VTT i Finland og institutsystemet i Holland. Eventuelt inddrages SINTEF i Norge.

4. Metode

Udgangspunktet for kortlægningen, fremsynet og den sammenlignende analyse er eksisterende materiale fx analyser, rapporter og lign.

1. Kortlægningen af det danske vidensystem tager udgangspunkt eksisterende analyser og materiale fra de berørte institutioner. Desuden kan der gennemføres supplerende kvantitative og/eller kvalitative analyser. Kortlægningen skal forholde sig til de væsentlige aktører i vidensystemet.

2. Fremsynet formuleres som scenarieanalyser af, hvordan fremtidens behov og efterspørgsel vil udvikle sig og hvilken rolle GTS skal spille i og for denne udvikling. I dette arbejde vil indgå fx FORSK 2015 og lignende bud på den fremtidige udvikling. Der vil blive lagt vægt på, at fremsynet bliver struktureret og forsøgt gjort så operationelt at rapporten kan lægges til grund for vurderingen af fremtidige teknologi- og videnservice behov.

3. Den sammenlignende analyse af det danske GTS-system i forhold til andre landes teknologiske service systemer skal belyse følgende hovedområder:
    - Videnspredning
    - Kompetencer
    - Organisation
    - Økonomi

Den internationale analyse inddrager først og fremmest eksisterende dokumentationsmateriale, herunder performanceregnskaber, evalueringer, internationale rapporter og hjemmesider. Dette materiale kan suppleres af kvantitative og/eller kvalitative undersøgelser blandt de danske GTS-institutter og de udvalgte udenlandske aktører, samt uddybende interviews med internationale nøglepersoner.

Belysningen af, hvordan de danske GTS-institutter udfylder deres rolle i forhold til lignende aktører i andre lande sker med udgangspunkt i ovenstående områder.

Grundanalysernes resultater skal samles i en overordnet præsentation af anbefalinger fra ekspertpanelet. Anbefalingerne skal med afsæt i grundanalyserne adressere GTS-nettets fremtidige placering og rolle i vidensystemet, metoder til sikring af serviceudbudets vedvarende relevans samt give bud på fremtidens efterspørgsel på viden og teknologisk service.

5. Organisering

Der nedsættes et ekspertpanel, som skal stå for evalueringens gennemførsel. Ekspertpanelet skal konsulteres løbende i forhold til grundanalyserne. Særligt i forbindelse med fremsynet vil eksperternes konkrete viden og erfaringer spille en afgørende rolle.

Hovedopgaven for ekspertpanelet vil være, at komme med anbefalinger på baggrund af det samlede dokumentationsmateriale og de tre grundanalyser.

Ekspertpanelet sammensættes med medlemmer fra de nordiske lande. For at varetage rollen effektivt skal panelet samlet besidde såvel teoretiske som praktiske kompetencer inden for:

- Nationale og internationale kompetenceopbygnings- og videnspredningsystemer
- Forskning og universitetsverdenen
- Erhvervs- og samfundsmæssige behov og efterspørgselsmønstre
- Innovation samt udviklings- og fornyelsesprocesser
- Teknologi

Der tilknyttes et eksternt konsulentfirma til ekspertpanelet. Konsulentfirmaet skal yde sekretariatsbistand til ekspertpanelet, indsamle dokumentation, herunder gennemføre desk research og eventuelle supplerende undersøgelser. Desuden har konsulentfirmaet sammen med ekspertpanelet ansvaret for at udarbejde den samlede evalueringsrapport med primært fremadrettede anbefalinger.

Det skal sikres at konsulentfirmaet er uafhængigt og uvildigt i forhold til aktørerne i det danske videnssystem. Det taler for at engagere et udenlandsk konsulentfirma til hovedopgaven. Til kortlægningsopgaven af det danske videnssystem skal der tilsvarende sikres uvildighed, dog kan der være umiddelbare fordele ved at engagere et dansk konsulentfirma, idet der herved sikres det bedst mulige overblik over det danske teknologiske service-net og dets interessenter.

Det internationale ekspertpanel nedsættes af en arbejdsgruppen der har det overordnede ansvar for evalueringen. Arbejdsgruppen består af repræsentanter fra Forsknings- og Innovationsstyrelsen (FI) og GTS-nettet. Ud over at nedsætte ekspertpanelerne har arbejdsgruppen til opgave at udarbejde kommissoriet for evalueringen, vælge konsulentfirmaer og følge evalueringen. Arbejdsgruppen ledes af FI.

Der er ligeledes nedsat en referencegruppe bestående af repræsentanter fra erhvervslivets organisationer samt forskellige offentlige interessenter. Referencegruppen vil blive konsulteret i forbindelse med arbejdsgruppens arbejde for at sikre en bredt forankret proces.

Alle rapporter affattes og publiceres på engelsk.

6. Afrapportering

Grundanalyserne 1 – kortlægningen af det danske vidensystem, 2 - fremsynet og 3 - den sammenlignende analyse afrapporteres i delrapporter. Delrapporterne skal være så konkrete og operationelt fokuseret som analysens karakter giver mulighed for. Desuden udarbejdes der en anbefalingsrapport, der samler op på evalueringens forskellige delanalyser, og som indeholder de overordnede vurderinger og anbefalinger fra ekspertpanelet.

Den samlede rapport gør rede for den anvendte dokumentation og fremlægger ekspertpanelets vurderinger og anbefalinger. Ekspertpanelets rapport skal indeholde et resumé, der samler og redegør for de vigtigste konklusioner, vurderinger og anbefalinger.

Såvel delrapporterne som den samlede rapport sendes i skriftlig høring på GTS-institutterne med henblik på at få rettet eventuelle faktuelle fejl.

7. Tidsplan

Evalueringsrapporterne skal bruges af Rådet for Teknologi og Innovation som indspil til udarbejdet med strategien for GTS-nettet ”GTS 2012 samt til rådets kontraktforhandlinger med GTS-institutterne. Den samlede evaluering skal således foreligge primo 2009.

Acronyms and abbreviations >

ATV	*Akademiet for de Tekniske Videnskaber* – Academy of Technical Sciences
BERD	*Business Expenditure on R&D*
DBI	Fire and safety research institute
DFM	Danish Fundamental Metrology
DHI	Water technology, environment and health institute
DTH (now DTU)	Denmark's School of Technical Science
DTI	*Dansk Teknologisk Institut*
EU	*European Union*
EU-27	*27 Member States of the EU*
GDP	*Gross Domestic Product*
GERD	*Gross Expenditure on R&D*
GTS	*Godkendte Teknologiske Serviceinstitutter* - Authorised Technological Service
JTI	Jysk Teknologisk Institut
OECD	*Organisation for Economic Cooperation and Development*
R&D	*Research and Development*
RTI	*Rådet for Teknologi og Innovation* - Council for Technology and Innovation
RTO	*Research and Technology Organisation*
SINTEF	*Stiftelsen for industriell og teknisk forskning* - largest independent research organisation in Scandinavia
SME	*Small or Medium Sized Enterprise*
TI	Teknologisk Institut
TNO	*Dutch organisation for applied research*
VTT	*Major Finnish research institute*
VTU	Danish Ministry of Science, Technology and Innovation

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2009

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3. Performanceregnskab for Videnskabsministeriets Innova-tionsnetværk
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4. Performanceregnskab for Videnskabsministeriets Innovationsmiljøer
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