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Potential Roles of Technical Research Institutes for Promoting Innovation

A typology from a technological innovation systems perspective

Master of Science Thesis

JOHNN ANDERSSON

CARMEN VARGAS

Department of Energy and Environment
Division of Environmental Systems Analysis (ESA)
CHALMERS UNIVERSITY OF TECHNOLOGY
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Department of Energy and Environment
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 1000

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Abstract

Over the years, policymakers and economists have acknowledged innovation as a fundamental process for national competitiveness and wealth. It has been an area of intense research and various conceptualizations have been put forward. The technological innovation systems framework was developed as an analytical tool for studying the emergence of technological innovations. While the actors typically studied using this framework are firms, the subjects of this thesis are technical research institutes. The institutes are publicly subsidized organizations that conduct research in close collaboration with industry and offer various technology services. They can therefore be expected to play an important role in the development and diffusion of technological innovations.

The purpose of the thesis is to generate a typology of potential roles that the technical research institutes may adopt in technological innovation systems and to identify how they, in the different roles, promote innovation. A case study approach has been followed where three institutes have been examined on both the institute level, in order to identify the potential roles, and on the project level, in order to illustrate how they promote innovation.

The result is a typology of six potential roles (advisor, matchmaker, mentor, entrepreneur, consultant and researcher) that technical research institutes may adopt for promoting innovation. It is an addition to the technological innovation systems framework, which can be used for describing and analyzing differences between institutes as well as for formulating institute strategies and policy.

Keywords: technological innovation systems, technical research institutes, typology

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Johnn and Carmen

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1. Introduction

Innovation is a fundamental process for stimulating economic growth and increasing the competitiveness of nations (Marx & Engels, 1969; Schumpeter, 1934; Porter, 1990). Stimulating innovative activities has therefore been identified as a key task for national policymaking for decades. Recently, its importance has been further emphasized by the urgent and global challenge of climate change, which calls for the development and diffusion of new technological innovations (Bergek et al., 2008b). This thesis will hopefully provide some useful insights to how technical research institutes can promote their development and diffusion.

An innovation may be defined as an idea that has been developed, transformed into a product, a process or a service, and commercialized (Popadiuk & Choo, 2006). It is the result of complex and somewhat disorderly processes that involves interaction and collaboration between actors in the public and private sectors (Van de Ven et al., 1999; Kline & Rosenberg, 1986). There are numerous feedback loops between the different development processes, which give it a systemic nature (Kline & Rosenberg, 1986). Therefore, several conceptualizations of innovation systems have been presented in the literature. A fairly recent contribution is the technological innovation systems approach, which has been developed as an analytical tool for studying the emergence of innovations based on technology (Bergek et al., 2008a).

Technological innovation systems consist of structure and functions, which are involved in a mutually influencing relationship (Markard & Truffer, 2008). The structural components are actors, networks, institutions and technology. The functions refer to key innovation processes, such as resource mobilization and knowledge development and diffusion, which contribute to the system goal of developing, diffusing and utilizing technology. While the functions are emergent properties from the interactions between actors on the structural level, changes in the functional processes may affect the structural components in return (Markard & Truffer, 2008) with external factors also playing an important role (Hellsmark & Jacobsson, 2009).

The actors in technological innovation system are individuals, firms, universities, public bodies, industry associations etc. They not only constitute structural components of the system, but also have the potential of influencing its development by building structure and strengthening the various functions. In previous research, the technological innovation systems framework has been used for analyzing the emergence of a number

of technology areas, with firms commonly being the focal actors (Jacobsson, 2008; Jacobsson & Bergek, 2004; Bergek, 2002). Some studies have applied the framework to analyzing the role of other actors, such as academics (Hellsmark & Jacobsson, 2009) and universities (Jacobsson & Perez Vico, 2009). Little attention has, however, been paid to the potential role of technical research institutes for promoting innovation from a technological innovation systems perspective (Bergek et al., 2008a).

Technical research institutes can be expected to play a key role for the emergence of technological innovation systems, since they are publicly subsidized organizations that conduct research in close collaboration with industry and offer various technology services (Arnold et al., 2007). They are often described as links between academic research and commercial markets.

The purpose of this thesis is, therefore, to study the potential roles of technical research institutes for promoting the development and diffusion of technological innovations from a technological innovation systems perspective. More specifically, the aim is to generate a typology of different roles that the institutes may adopt, in terms of how they build structure and strengthen the various functions of a technological innovation system. The empirical part of the study consists of case studies of three technical research institutes and five projects in which they promoted innovation in different ways. The case studies are used to illustrate the different roles adopted by the institutes included in the study.

The purpose is further defined by the following research questions:

- Which potential roles can a technical research institute adopt for promoting the development and diffusion of technological innovations from a technological innovation systems perspective?
- How can these different roles be defined in terms of how the institutes build structure and strengthen the various functions of a given technological innovation system?

It follows from the purpose that this thesis is concerned with the potential roles of technical research institutes and how they may promote innovation by adopting them. It is, however, appropriate at this point to further clarify that the efforts are not directed to assess *how well* the institutes perform the tasks associated with the respective roles or to discuss *whether they should* adopt them. The study is descriptive in its ambition, even though the mentioned aspects will be discussed in the light of the conclusions.

Following this introduction to the topic, the theoretical framework is presented in Chapter 2, aiming to make the reader familiar with the technological innovation systems approach to innovation. Chapter 3 further explains the research method used in the study. In Chapter 4, the focus turns to the subjects of this thesis, the technical research institutes, which will be conceptualized based on previous research. The empirical part of the study, consisting of case studies of three technical research institutes and five projects, is presented in Chapter 5. In Chapter 6, the potential roles of the institutes are analyzed and a typology is presented. The results of the analysis are discussed in Chapter 7 and in Chapter 8 the main conclusions are briefly stated.

2. The influence of actors on technological innovation systems

This chapter describes the theoretical framework that will be used throughout the thesis. It aims to make the reader familiar with the technological innovation systems approach to innovation and how actors can influence the development of these systems. First, innovation and the systems approach it entitles are introduced. Then, the technological innovation systems framework is presented, together with a description of its structural components and functional processes as well as their inherent dynamics. Finally, innovation is discussed from an actor perspective in terms of how it can influence the development of technological innovation systems.

2.1. Characteristics of innovation

As already mentioned, innovation may be defined as an idea that has been developed, transformed into a product, a process or a service, and commercialized (Popadiuk & Choo, 2006). Thus, innovation is not necessarily a new product, but may also be a new production process, substitution of materials in an otherwise unaltered product, reorganization that leads to increased efficiency and improvements in the methods used for doing innovation (Kline & Rosenberg, 1986). Some innovations result in completely new products, and even sectors in the economy, while some are more incremental to their nature. A single innovation may also lead to changes in many different products, serving completely different purposes (Kline & Rosenberg, 1986).

Historically, innovation has been described as a linear process involving research, development, production and marketing. This view does, however, distort the reality of innovation in several ways, since it ignores its complexity and lacks the feedback loops that are inherent in and essential for development processes (Kline & Rosenberg, 1986). Instead of being smooth and linear, innovation is the result of a series of complex and somewhat disorderly processes (Kline & Rosenberg, 1986). It is not an isolated event, but rather involves interaction and collaboration between actors in the public and private sectors, which creates feedback loops within and between the development stages (Van de Ven et al., 1999; Kline & Rosenberg, 1986). For example, information from the market, such as sales figures, influences the direction of research and development efforts at firms. Successful innovations, in turn, add to the knowledge base in the society, which enables further research. Thus, innovation is a collective

achievement characterized by complex interaction and numerous feedback loops. This gives innovation a systemic nature that makes the study of innovation systems, and not merely innovation, of great interest.

A system is commonly defined as a set of interrelated components working toward a common objective, which, for an innovation system, is to generate, diffuse and utilize technology (Carlsson et al., 2002). Innovation systems are analytical constructs in the sense that they may not exist in the real world but are employed theoretically in order to increase the understanding of innovation (Bergek et al., 2008a). A number of conceptualizations have been proposed in the literature, for example national, regional, sectoral and technological innovation systems. Their differences are closely related to the issue of system delineation, i.e. how the system boundaries are defined, which depends on the purpose of the study.

National innovation systems, introduced by Freeman (1987) and further developed by among others Lundvall et al. (1992), use national borders as system boundaries. Regional innovation systems are delimited by first defining a geographically bounded cluster of businesses, supported by surrounding organizations (Asheim & Isaksen, 2002). Malerba (2002) defines a sectoral innovation system as "a set of new and established products for specific uses and the set of agents carrying out market and non-market interaction for the creation, production and sale of those products". Of particular interest in this thesis are technological innovation systems, which are socio-technical systems formed around the development, diffusion and use of a particular technology (Bergek et al., 2008a). The different concepts are potentially overlapping since one system may comprise several others, for example a given technological innovation system may be made up of several regional innovation systems working in the same knowledge area. This is illustrated in figure 2.1, which is based on Markard and Truffer (2008).

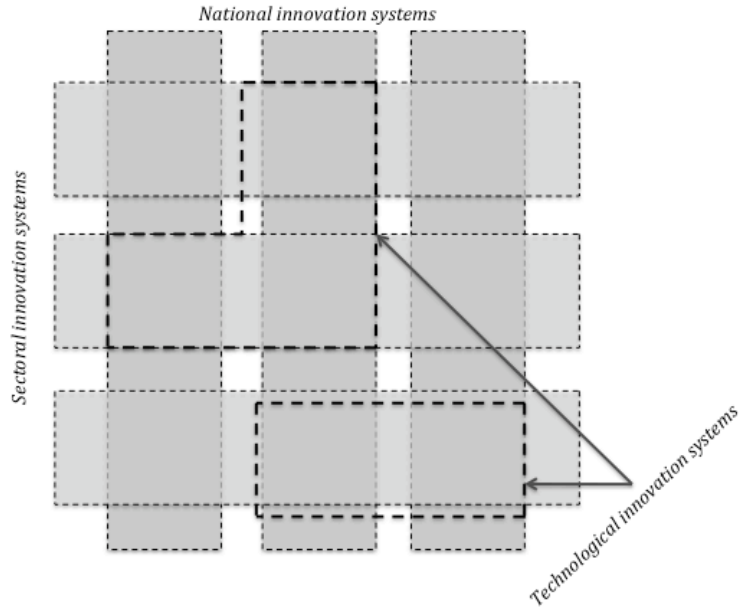

Figure 2.1 Potential relations between different innovation systems (Markard & Truffer, 2008)

Since this thesis concerns the potential roles of technical research institutes in technological innovation systems, the next section will further explain this particular systems approach to innovation.

2.2. Technological Innovation Systems

Carlsson and Stankewicz (1991, p. 111) define a technological innovation system (TIS) as "a network(s) of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse and utilize technology". Accordingly, it consists of structural components such as actors, networks, institutions and technology. Bergek et al. (2008c; 2008a) further developed the TIS framework to include a functional approach that employs a number of key processes for describing and analyzing the dynamics and performance of TISs. The processes, commonly labeled functions, emerge from and are strengthened by the interactions of the structural components, and are also influenced by exogenous factors. The structural components, functional processes and dynamics of TISs will be described in the following.

2.2.1. Structural components

On the structural level of TISs, four different components can be identified: actors, networks, institutions and technology (Bergek et al., 2008b). They will be explained briefly below.

Actors constitute the physical components of the system. They include firms along the whole value chain of the technology, dealing with everything from the production of raw material to distribution of products and provision of complimentary services (Bergek et

al., 2008a). Other actors are universities, industry organizations, public bodies as well as technical research institutes, the focus of this thesis.

Networks are the formal and informal connections between actors in TISs, which can be organized to perform a specific task or evolve in a less organized fashion (Bergek et al., 2008a). They can be knowledge networks within which learning processes take place, for example links between universities and industry or users and suppliers, as well as political networks, which have a political agenda with the objective of changing institutions (Hellsmark & Jacobsson, 2009).

Institutions consist of culture, norms and routines, which are embedded in the minds of people and actors, as well as laws, regulations and routines, set by the state (Bergek et al., 2008a). They are the "rules of the game" (North, 1990), which has co-evolved with incumbent technology. Therefore, institutions cannot be assumed to be aligned with emerging TISs and may accordingly need change to fit new technology. This is a highly uncertain process, which constitutes another field of competition for firms who compete not only in the marketplace but also over the nature of the institutional infrastructure (Bergek et al., 2008a).

Technology is introduced to the TIS by entering actors and evolves within it, making it both a structural component and an output of the system (Hellsmark & Jacobsson, 2009). The core of technology is knowledge, which is embedded in physical artifacts, drawings, patents, etc., and also in the experience of the human resources handling it (Bergek et al., 2008b).

2.2.2. Functional processes

Within TISs, key innovation processes contribute to the system goal of developing, diffusing and utilizing technology. Bergek et al. (2008c; 2008a) have defined seven distinct functions based on these processes. The functions of TISs are described briefly in table 2.1.

Table 2.1. Functions in technological innovation systems (Bergek et al., 2008a)

Knowledge development and diffusion	This function is concerned with the breath and depth of knowledge development and diffusion within the system. Knowledge development can take place on different levels: firms conduct internal R&D and learn when solving new problems; knowledge is developed when firms cooperate with other firms and customers; and universities provide knowledge in terms of basic and applied research. It can also be brought in from outside the system. Diffusion of knowledge can occur between actors that are a part of the system or between the system, other systems and society.
Influence on the direction of search	Incentives and pressures that make organizations more likely to enter a TIS are crucial for its development. They can be: visions, expectations and beliefs in the potential of the technology; regulations and policy; articulation of demand by early customers; crises in current business; and actors' assessments of technological opportunities and the relevance of knowledge. This function is the combined strength of all those factors; both when it comes to making actors enter the system and when it comes to influencing the direction of search within it.
Entrepreneurial experimentation	This function concerns experimentation with new technologies and applications by individuals and firms in the system. Though many will fail, a learning process unfolds, which reduces uncertainty in the TIS. Entrepreneurial experimentation drives the development of a TIS forward and keeps it from stagnating.
Market formation	An emerging TIS may lack or suffer from an underdeveloped market due to several reasons: market places may not exist, potential customers may not have articulated their demand, price/performance may be poor and uncertainties may prevail. Also, institutional change is often required.
Legitimation	Legitimation of new technology is essential for markets to form, for attracting resources, for actors to gain political strength and for influencing expectations, in turn influencing the direction of search. It is formed by conscious actions by various actors and it tends to meet resistance from prevailing technological paradigms, whose actors see the emerging technology as a threat.
Resource mobilization	A TIS needs to attract resources to keep developing. The resources can be financial capital in the form of investment, human resources in the form of skilled labor and various complementary assets.
Development of positive externalities	The last function is not independent but rather supports the system by strengthening the other six functions. It describes the positive externalities that develop due to the systemic nature of innovation. This function may in itself serve as an indicator of the overall system performance.

As mentioned, the functional processes described in table 2.1 emerge from interactions on the structural level. However, they also exhibit internal dynamics, in the sense that the functions influence each other, and receive influence from exogenous factors. The functional dynamics are, accordingly, likely to differ between different systems and to change over time (Bergek et al., 2008c; 2008a). The next section will explain the dynamics of TISs further.

2.2.3. Systems dynamics

Structure and function are two interrelated sides of a TIS, which are involved in a mutually influencing relationship (Markard & Truffer, 2008). While the functions are emergent properties from the interactions between actors on the structural level, changes in the functional processes may affect the structural components in return (Markard & Truffer, 2008) with external factors also playing an important role (Hellsmark & Jacobsson, 2009). Hellsmark and Jacobsson (2009) describe five main relationships in a TIS: (1) the dynamics between structural entities, (2) the influence of the structural entities on the functions, (3) the influence of exogenous factors on the functions, (4) the internal dynamics of the functions and (5) the feedback from the functions to the structure. These relationships are shown in figure 2.2.

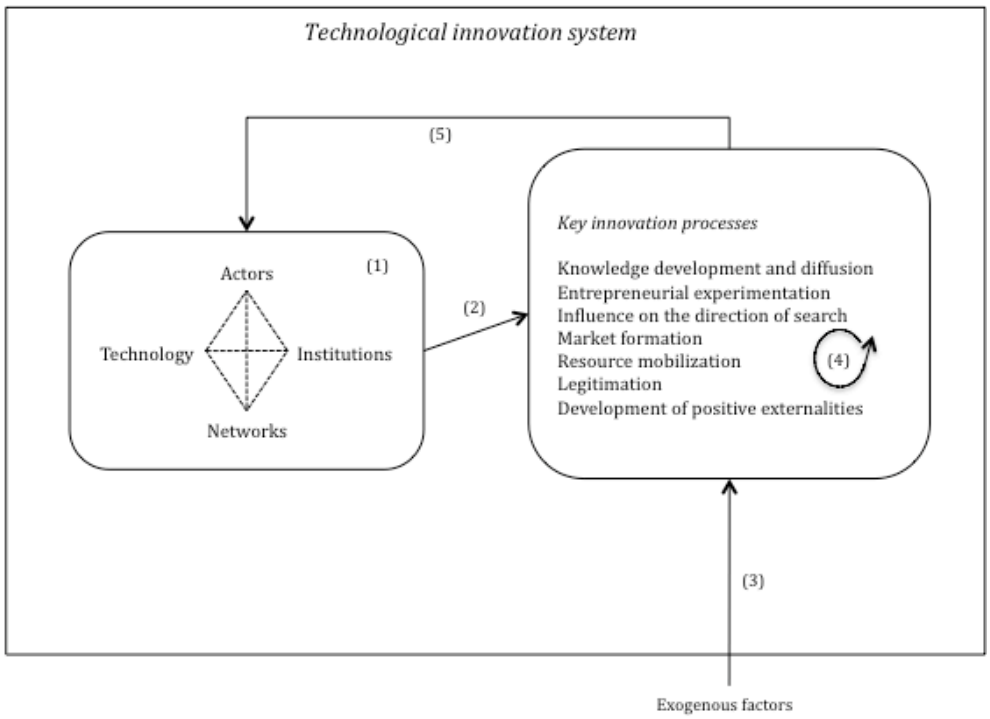

Figure 2.2. The dynamics of a technological innovation system (Hellsmark & Jacobsson, 2009)

The first relationship (1) illustrates how structural elements are involved in ever changing relationships that affect one another. For example, strong political and

knowledge networks may induce institutional alignment with emerging TISs. Structural elements may also affect the key innovation processes or functions (2). For example, increasing institutional support may strengthen resource mobilization to and the legitimation of the technology. The functions may also be affected by exogenous factors(3), such as EU legislation and the climate change debate, and ultimately by their own internal dynamics (4), as one function may strengthen or weaken the others. For instance, if the function of legitimation is strengthened, it may in turn strengthen the function of direction of search. The various functions also feed back and strengthen the structure (5). For example, strengthening knowledge development and entrepreneurial experimentation may result in a stronger technology structure of the TIS.

The described system dynamics may give rise to virtuous and vicious cycles. In virtuous cycles, there are positive feedback loops from structure to functions and back, creating a path of positive incremental changes that promote the technology (Hekkert et al., 2007). Vicious cycles on the other hand, stem from negative function fulfillment, which leads to a reduction of activities related to other functions, slowing down progress and ultimately stopping it (Hekkert et al., 2007).

In the end, it is the interplay between structure, functions and exogenous factors that determines the development of TISs. The next section focuses on one of the structural components – the actor – and its ability to influence structure and functions in order to promote innovation.

2.3. Actor perspective

As structural components, actors are unique in that they can, intentionally, influence the development of TISs through activities that build structure and/or strengthen the various functions. However, it is important to point out that the outcome of the TIS is not intentional, but rather the result of the complex dynamics described in the previous section. The activities undertaken by an actor may have both positive and negative influence on the system, since an actor can potentially both build and destroy structure as well as both strengthen and weaken functions. For convenience purposes, the influence of actors will primarily be illustrated and discussed in its positive sense. However, the logic could easily be reversed to be valid for activities that inhibit the development of TISs as well.

An actor builds structure when its activities create or develop the structural components of the system. It may create networks by engaging in collaborative relationships with other actors (Markard & Truffer, 2008) in order to solve a specific

task, fulfill a political agenda, influence the institutional infrastructure, etc. (Bergek et al., 2008a). It may attract new actors to the system by performing structural activities such as creating organizations (Bergek et al., 2008a). It may act to change or adapt existing institutions, or create new ones (Markard & Truffer, 2008), for example by creating coalitions which advocate for a new technology in political debates (Jacobsson & Bergek, 2004). And lastly, it may develop technological solutions along the entire value chain (Bergek et al., 2008b).

An actor strengthens functions when its activities influence the key processes that contribute to the system goal of developing, diffusing and utilizing technology. For example, a public body that launches an information campaign or a demonstration project about the benefits of an emerging technology strengthens at least the functions of legitimation and direction of search (Karlstrom & Sandén, 2004).

The system dynamics described in the previous section suggest that the impacts from an actor's activities on structure and functions can be direct and indirect as there are several feedback loops. A direct impact is a direct consequence of an activity, such as strengthened resource mobilization (impact) by educating engineers at universities (activity by university as an actor). An indirect impact, on the other hand, is the result of a prior direct impact. For example, introducing a new law (activity by policymaker) builds structure by aligning institutions with an emerging technology (direct impact), which in turn builds additional structure by attracting new firms to enter the system (indirect impact). Also, given the system's dynamics, a direct impact on either structure or functions may have indirect impacts on the other level. Throughout the thesis, the complete set of direct and indirect impacts of an actor's activities will be referred to as its impact pattern.

In previous TIS related literature, actors such as entrepreneurs (Bergek et al., 2008c; Carlsson & Stankiewicz, 1991), academics (Hellsmark & Jacobsson, 2009), universities (Jacobsson, 2002; Jacobsson & Perez Vico, 2009), firms (Jacobsson, 2008; Jacobsson & Bergek, 2004; Bergek, 2002), etc., have been subjects of structural and functional analyzes while various roles such as the system builder and the prime mover have been conceptualized or explored based on their impact patterns on structure and functions. System builders and prime movers invent and develop the structural components of TISs. They have the ability to "construct or to force unity from diversity, centralization in the face of pluralism, and coherence from chaos" (Hughes, 1987) and undertake key tasks in the evolution of a TIS such as raising awareness of a certain technology, investing in it, giving it legitimacy and diffusing it (Carlsson & Jacobsson, 1997).

This chapter has presented the TISs framework and shown that actors have the potential of building structure and strengthening functions in these systems. However, the potential roles of technical research institutes remain unclear. The next chapter will explain the research method that has been used when studying this topic.

3. Method

This chapter describes the research method that has been used to fulfill the purpose of the thesis. It begins with a description of the iterative case study approach that has been followed, continues with a motivation of the choice of case studies and ends with an account of the data sources and data collection methods that have been used.

3.1. An iterative case study approach

Since this thesis aims to generate a typology of how technical research institutes impact TISs, a case study approach has been adopted, which allows for capturing the complexities of this interaction. Case studies focus on understanding the dynamics present within single settings (Eisenhardt, 1989) and can be used for generalization purposes (Gerring, 2004) and for developing theory (Dubois & Gadde, 2002). However, they can also be used to improve an existing conceptual framework, which is the purpose of this thesis.

A total of eight case studies are presented on two main levels of analysis. On the institute level, three technical research institutes have been studied in order to give an understanding of the different roles that they adopt in TISs. Based on the findings from these case studies, a typology of potential roles will be created by segmenting the observed activities in a number of categories. On the project level, five more detailed case studies have been carried out in order to illustrate how the institutes, in the respective roles, build structure and strengthen the various functions.

The research method is iterative in two ways: First, the results from the institute case studies have been used for selecting the project case studies. Second, the results from the continuous analysis have fed back into the data collection process and influenced the focus of interviews, online searches etc. Dubois and Gadde (2002) call this way of alternating between research activities systematic combining and emphasize its benefits for understating both theory and empirical observations. The research method is illustrated in figure 3.1.

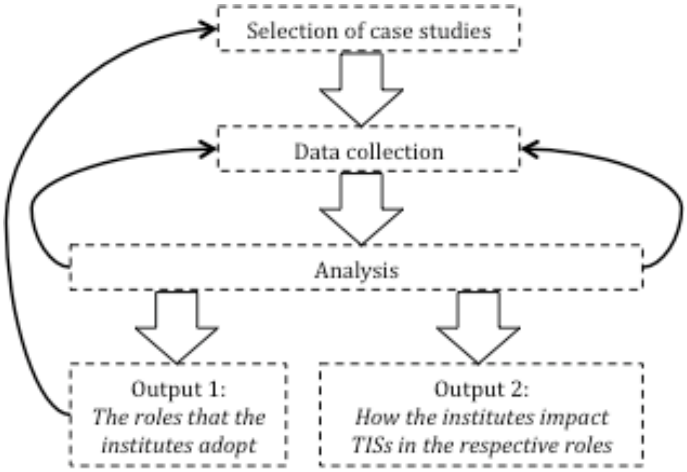

Figure 3.1. The iterative case study approach

3.2. Choice of case studies

As mentioned, the institute case studies aim to provide an understanding of the different roles that technical research institutes adopt in TISs. Five European technical research institutes were studied and based on the initial results, three of them were chosen as subjects for institute case studies. Since this thesis has been performed in collaboration with SP, which is also the dominating technical research institute in Sweden, it naturally became the focus of one of the institute case studies. The other two institutes that were finally chosen are VTT in Finland and SINTEF in Norway, which are both the dominating institutes in their respective countries. The project case studies were, as mentioned, selected to illustrate the different roles that the institutes adopt. Thus, the choice was based on the institute case studies, which in turn built on interviews and other sources of information. Three project case studies revolve around SP, one is about VTT and one focuses on SINTEF.

3.3. Data collection

The case studies are based on multiple data collection methods, which strengthen the evidence by triangulation (Eisenhardt, 1989), meaning that different sources of data strengthen the overall reliability. The data sources are interviews with representatives from the institutes and other organizations, publications by institutes and other organizations, and previous research on the topic.

The interviews have been semi-structured to allow for the interviewee's own reflections and opinions to come forward, while providing some structure and assurance that no important topics are left out (Bryman & Bell, 2007). Different yet related interview questions were used depending on the situation and the interviewee's talkativeness. During the interviews, the authors took notes, which were later transcribed supported

by recordings of the conversations. In total, 15 interviews have been conducted, seven face-to-face and eight by telephone, with an average duration of about one hour. Each interview is listed in Appendix I with the interviewee's name and position, the topic and date.

Publications by the institutes and other organizations have been retrieved mainly from electronic sources, such as the institutes' websites. They consist of information brochures, annual reports and other published material, created by the institutes, national funding agencies, companies etc. The previous research that has been used comes mainly from Sverker Sörlin's research on behalf of the Swedish government (Sörlin, 2006) and research reports compiled by the Swedish funding agency VINNOVA (Arnold, et al., 2007).

This chapter has described the research method that has been used to fulfill the purpose of the thesis. In the next chapter, the scene will be set for the case studies by providing a conceptualization of technical research institutes based on previous research.

4. Conceptualization of technical research institutes

Technical research institutes are commonly described as links between academic research and industry. They are organizations that are publicly subsidized for building capabilities, which are used for offering services that would not otherwise be offered in the marketplace (Arnold et al., 2007). This chapter aims to set the scene for the case studies, by providing a conceptualization of technical research institutes based on previous research. It begins with a basic typology of institutes, continues with a description of their purpose and the role of public funding, and ends with a description of their general business model and activities.

4.1. Different types of institutes

Sörlin (2006) distinguishes between three archetypes of institutes: sectoral research institutes, service institutes and technology push institutes. The sectoral research institutes commonly serve a sector or particular industry in the economy. They are often organized as business collectives where the members jointly finance and benefit from the research activities that are undertaken. The service and technology push institutes have a broader technological and industrial competence, which is not limited to or divided after individual sectors or industries. They are generally larger and may be geographically located in several places. Typically, they also have access to broader equipment and competence, which makes them able to engage in larger projects such as constructing demonstration and pilot facilities. As the name suggests, the service institutes offer research services to companies, and the research is accordingly driven by market demand. The technology push institutes are, in contrast to the others, not directly driven by the demand from or perceived need by companies. Instead, they conduct advanced technology driving research, aimed at building competence in strategically important areas.

The service and technology push institutes may also be referred to as polytechnic institutes, which in its strict sense means that they are involved in several technology areas. It is common that technical research institutes exhibit both service and technology push characteristics and there has been a general development towards a consolidation of the two types (Sörlin, 2006). For example, the Finnish institute VTT started out as a service institute but has, driven by policy, developed a technology push character (Arnold et al., 2007).

When discussing technical research institutes in this thesis, it will be implicitly about polytechnic research institutes that exhibit both service and technology push characteristics. The main technical research institutes in Europe, including the ones that have been studied, tend to follow this description (Arnold et al., 2007), albeit that some of them may lie closer to one of the ends of the spectrum.

4.2. Purpose and the role of public funding

The main purpose of technical research institutes is to promote industrial competitiveness by offering firms knowledge inputs that are superior to those available on the commercial markets (Arnold et al., 2007). Society invests in institutes in order for them to be able to develop and sustain the technological capabilities that are required for being able to offer these superior services. The investment is expected to pay-off since the value of the generated technological capabilities are passed on to the institutes' customers, whose performance improves (Arnold et al., 2007). This makes the industry more competitive and attractive for investment (Arnold et al., 2007), which leads to more jobs, higher tax revenues and increased quality of life.

Society invests in technical research institutes by subsidizing part of their development of and access to technological capabilities. Arnold et al. (2007) present three arguments for doing this: First, the characteristic of research gives rise to market failures, i.e. the marketplace alone provides a sub-optimal level of research and development. Second, the institutes are a part of the knowledge infrastructure, providing certain services and increasing the available research and development capacity, which supports the operation of industry. Third, institutes may compensate for some lacking capabilities in small and medium sized companies (SME) and by doing so increase their rate and efficiency of innovation.

The institutes are subsidized through a number of mechanisms. Arnold et al. (2007) distinguish between the following:

- Core funding; an un-earmarked subsidy allowing the institute to acquire or generate knowledge and equipment
- Specific funding; an earmarked subsidy, used for developing specific capabilities, that may be granted in competition with other actors
- Other funding; instruments that increase the institutes' capabilities, for example VINNOVA's competence centre programs that finance institute participation
- PhD scholarships allocated to the institute

- PhD scholarships allocated to others; but where the research takes place in collaboration with the institute
- Other resources; for example faculty time and equipment shared with universities

The subsidy mechanisms described, particularly the core and specific funding that are commonly referred to as basic funding, make it possible for the institutes to search for technological opportunities away from their customers' short-term needs. It enables them to be curiosity-driven rather than market-driven, to engage in research that is not yet commercially viable and to offer certain services that would otherwise be lacking in the marketplace. The subsidy mechanisms distinguish institutes from merely being technology consultants. And evidence also suggests that withdrawing subsidies from an institute makes it turn into a consultancy over time (Arnold et al., 2007).

4.3. Business model and activities

Technical research institutes are subsidized by public means and receive core funding for some of their activities. They are, however, also dependent on revenues from their customers. The institutes' business models describe how these two revenue streams are used and balanced, in order for the institutes to fulfill their purpose. The business models are closely linked to what is referred to as innovation models (Arnold et al., 2007), since the institutes' business is to support innovation.

Technical research institutes normally employ a business model consisting of three main stages: building capabilities, technology development and technology transfer (Arnold et al., 2007). In addition, some institutes commercialize research results, which can be seen as a deviation from the three-stage model. The different parts of the general institute business model will be further explained below.

4.3.1. Building capabilities

First, the institutes use basic funding to generate a platform of technological capabilities. It can be realized through exploratory research or through technology monitoring and acquisition. Oftentimes universities provide important inputs and collaborate with the institutes (Arnold et al., 2007).

4.3.2. Technology development

The institutes then use their technological capabilities to further develop knowledge, often together with industrial, academic and public partners. The research projects are

normally co-funded by public and private means, but they can also be conducted solely by the institutes (Arnold et al., 2007).

The companies that participate as industrial partners have to be large and sophisticated enough to be able to exploit the results of the research: they must have an absorptive capacity that enables them to develop the results into commercial products. To tackle this, many institutes have certain support services for SMEs that lack these capabilities in order to support innovation in these companies as well. For example, SMEs may be advised on technological opportunities and helped with applications for research and development grants (Sandström, 2010).

The institutes also create, manage and participate in various networks where actors jointly perform research and development. Within these networks resources and equipment are shared in order to increase the efficiency of the innovation process (Arnold et al., 2007).

4.3.3. Technology transfer

When the developed technology is mature enough to be put into specific applications, the institutes support the industry by offering technology services of different kinds (Arnold et al., 2007). They perform contractual research, advanced measurements and other consulting services that companies choose to outsource, oftentimes because they lack equipment and/or knowledge to perform them by themselves. In addition, the institutes provide testing and certification services in later stages of the innovation process (SP, 2010b; SINTEF, 2010b; VTT, 2010a).

When engaging in the activities described, the institutes' mode of operation resembles purely commercial technology consultants and it is easy to believe that they compete on unfair terms due to their basic funding. However, it is commonly argued that this is not the case since the institutes offer services that are much more advanced, or require more advanced equipment, than what purely commercial companies can achieve without public subsidy. Also, the institutes' services are more expensive for the companies, compared to ordinary consultants. In this sense, the institutes occupy a position on the market that private actors are not interested in since it would not be profitable (Arnold et al., 2007).

4.3.4. Commercialization

Also, some institutes commercialize their research results by selling and licensing intellectual property rights as well as by starting and owning spin-off companies.

Commercializing research results may turn into a source of revenue for the institutes, but this is not the only reason for why they engage in these activities. Starting spin-off companies, selling patents and offering licensing agreements are also ways of making potentially valuable technologies available in the marketplace, something that other companies can benefit from and that may lead to job opportunities. However, the commercialization activities may also lead to situations where the institutes compete with their own customers, which is something that could potentially be harmful (Arnold et al., 2007).

4.3.5. Public vs. private funding and the proximity to market

The range from building capabilities, via technology development, to technology transfer, can be seen as a continuum where the proximity to market, in terms of commercial viability, increases. In the same manner, uncertainties gradually diminish and risks are lowered. When approaching the market, the share of private funding in the projects becomes larger (Arnold et al., 2007). The initial development of technological capabilities that are far from commercial applications is rarely funded by private means at all, while the consulting services in the last stage are purely contractual and privately funded. In the same manner, the influence of the companies becomes greater (Arnold et al., 2007). This has implications for the type of research that is conducted; when the institutes are more independent, i.e. receive more core funding, they can search freely for technological opportunities that do not necessarily support the established sectors in the economy. The relation between proximity to market and aspects such as funding, uncertainty, risk and influence of companies, have been illustrated by the authors in figure 4.1, which also lists a number of institute activities that are typical for each stage in the business model.

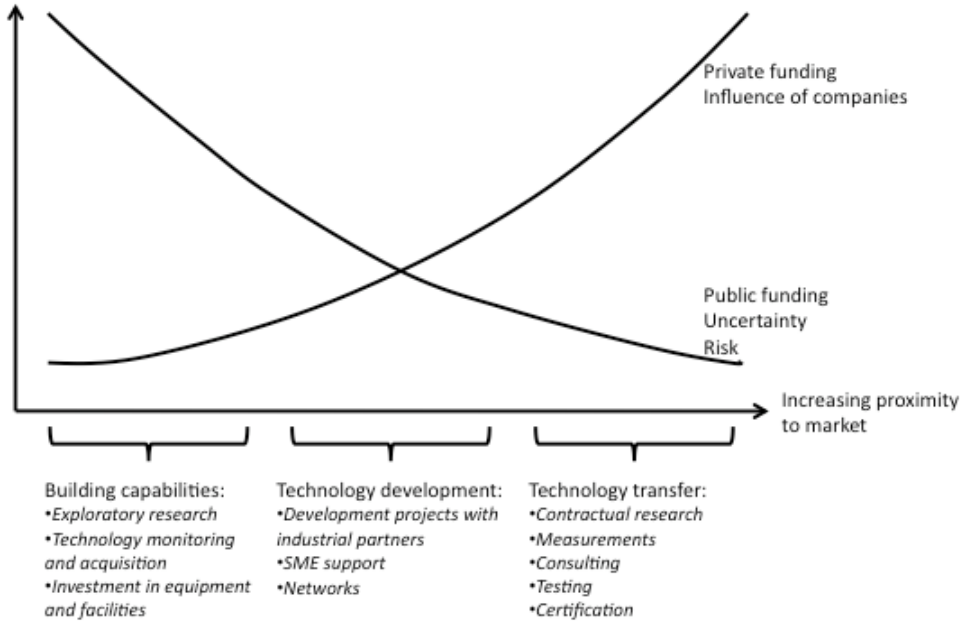

Figure 4.1 The relation between private and public funding, and the proximity to market

Hence, this chapter has argued that technical research institutes are complex organizations with multiple stakeholders, something that is manifested in their dependence on both public subsidies and customer revenues. They engage in a wide range of activities that support technologies in different stages of development, from exploratory research to product certification. This view is, however, a generalization and limited in its depth. The next chapter, therefore, contains a number of case studies of the role of existing institutes for promoting innovation.

5. Case studies of technical research institutes

This chapter contains case studies of three technical research institutes and five projects in which they promoted innovation in different ways. The case studies aim to give an understanding of the potential roles of the institutes in TISs and to illustrate how they build structure and strengthen the various functions. The chapter starts with a case study of the Swedish institute SP, including three project cases, and continues with case studies of the Norwegian institute SINTEF and the Finnish institute VTT, including one project case each.

5.1. SP

The first case study concern the Swedish technical research institute SP. It begins with a description of the national context in which it is embedded, continues with a general description of its activities and organization, and ends with three project case studies of the institute's role in three different situations.

5.1.1. The Swedish national context of innovation

The Swedish economy and R&D activities are dominated by large companies that typically subcontract SMEs for component production (Marklund et al., 2004; Ejermo & Kander, 2006). However, the large companies' value creation has been decreasing (Marklund et al., 2004). Regardless of this, Sweden is at the top of the list when it comes to innovation performance as measured by the European Innovation Scorecard (PRO INNO Europe, 2010).

Sweden's total expenditure on R&D, including both the industry's investment and public investment in institutes and universities, is high, but the institute sector is relatively small and receives substantially less basic funding compared to other countries (Arnold et al., 2007). This is due to a strong historical belief in the universities' ability to carry out tasks that are typically associated with institutes (Arnold et al., 2007; Sörlin, 2006). Nonetheless, recent political initiatives are aiming to strengthen the institute sector, for example by increasing basic funding and creating a common brand for the institutes (OECD, 2008c; RISE; Odell, 2008). Table 5.1 provides some indicators of the Swedish national context of innovation.

Table 5.1 Innovation indicators for Sweden (PRO INNO Europe, 2010; OECD, 2010a; OECD, 2010b; OECD, 2010c)

Innovation performance score, 2009[1]	0.636	1st in the EU27
R&D investment as percentage of GDP, 2007	3.62	2nd in the OECD
Researchers per thousand employed, 2008	10.6	5th in the OECD
Patents per million inhabitants, 2008	92.5	3rd in the OECD

5.1.2. Organization and activities

SP is Sweden's leading technical research institute, with its headquarters in Borås and complementing locations throughout the country. It is a limited company owned by the state through the holding company RISE Holding, which is also meant to serve as a common brand for the Swedish institute sector. SP employs a business model that follows the general institute business model, as described in Chapter 4. It builds capabilities using core funding, develops knowledge together with industrial, academic and public partners, and transfers technology by offering a variety of services. The revenues come from basic funding, research grants from government agencies and the institute's customers. SP, however, does not perform commercialization activities, such as starting spin-off companies or licensing technology. The reason for this is a belief that institutes should not hold patents in order to avoid unsound competition with their customers (Sandström, 2010).

SP works with research, development, testing, training and certification(Tullin, 2010). It is a polytechnic institute, which is involved in a broad range of technology areas; particularly when considering the quite recently acquired subsidiary institutes, which increase the range of technologies further[2]. SP has a complex organization based on core areas, serving as entry points for customers, and technical departments, conducting research and building capabilities. In addition, the institute participates in knowledge centers and EU-projects together with industrial, academic and public partners, which allow sub-task to be split among the participants with the best capabilities (SP, 2010a).

[1]In the innovation indicators tables presented for Sweden, Norway and Finland, the "Innovation performance score" field represents an annual index calculated by PRO INNO Europe that is based on three main innovation blocks that encompass seven dimensions: Enablers (Human resources and finance and support), Firm activities (firm investments, linkages & entrepreneurship and throughput) and Outputs (innovators and economic effects).

[2] Since 2004 SP has acquired six subsidiaries: SIK, YKI, SMP, CBI, GLAFO and JTI. The focus areas of these companies include, respectively, foodstuffs and biotechnology; applied surface and colloidal chemistry; testing, certification and inspection of products, machines and vehicles; scientific/technical research and development in the concrete area; glass research, development, education and technical support; and research, development and information in the areas of agricultural engineering and environmental technology (SP, 2010d).

SP also maintains close ties with universities through joint professorships and shared facilities (SP, 2010b). Table 5.2 summarizes key facts and figures about SP.

Table 5.2 Key Facts and figures about SP(SP, 2010c; SP, 2010b)

Turnover	98 MEuros
Employees	950
Basic funding	10 %
International locations	No
Ownership structure	Limited company owned by RISE Holding, in turn owned by the Swedish government
Services offered	R&D, consulting, testing, certification, training

The focus now turns to three project case studies that illustrate examples of roles that SP adopts in TISs.

5.1.3. Project case study: Waste Refinery[3]

Waste Refinery is a knowledge centre, initiated and managed by SP, which performs research in collaboration with industry, universities, institutes and society. The research projects cover a number of conversion techniques in the field of biological and thermal treatment of waste, and employ systems analysis as a tool for assessing the techniques in different scenarios. The aim is to optimize the use of waste in the production of energy products, such as heat and fuels. Waste Refinery currently has 20 partners, which are companies, universities, institutes, municipalities and other public bodies that share a common interest in waste conversion technologies and systems. The partners elect the board and secretariat of Waste Refinery at the annual partner meeting. The board makes decisions in between the partner meetings and the secretariat handles day-to-day activities and prepares board meetings. In addition to the board and the secretariat, there is a drafting committee that evaluates research applications, a scientific network and a communication network. All the research within Waste Refinery takes place at the partner level in joint projects and the results are assigned to the participating partners. The secretariat does not engage directly in these projects, but rather has a managing role, where it coordinates research projects, works with public relations and handles administrative tasks.

[3] This case study is based on interviews with Dr. Evalena Blomqvist (Blomqvist, 2010) and Mr. Martin Karlsson (Karlsson, 2010) as well as on information obtained from Waste Refinery's website (Waste Refinery, 2010).

SP established Waste Refinery in 2006, creating a network of actors that have an interest in the knowledge field, and has since then organized and managed its activities. The two managers that share the leadership of the centre are employed and localized at SP, which makes it practically responsible for the centre's function. However, SP also participates at the partner level, where it carries out research directly in the projects.

The activities within Waste Refinery are funded to 40 percent by public money through equal contributions by the Swedish Energy Agency and Region Vastra Gotaland. The remaining 60 percent comes from the centre's partners. About 10 percent of the budget is used for information, communication, quality assurance and administration; the rest goes directly to the research projects. Applications for research projects have to be supported by at least three partners in order to assure that the research will not distort competition by benefitting a single company.

Waste Refinery canalizes public and private funds to the most promising research projects and offers a network of actors with expert knowledge and key capabilities. The network gives rise to a research environment with unique opportunities of combining the knowledge and capabilities of different actors in order to perform research and development from modeling to laboratory and full-scale experiments.

This is also what attracts companies to participate in Waste Refinery. For example, the company Gotaverken Miljo chose to join the centre in order to get access to funding, network and knowledge (Karlsson, 2010). As a partner, they have participated in a successful research project where they had the opportunity to do full-scale experiments together with another industrial partner. In addition, they have gotten scientific support for the performance of their technology by collaborating with Chalmers University of Technology. According to Gotaverken Miljo, their participation in Waste Refinery has speeded up and facilitated their research and development efforts in this area (Karlsson, 2010).

Besides research, Waste Refinery works with public relations in several ways. Each research project leads to a report presenting the results, which is made available on the centre's website. Newsletters with updates on centre activities and research are published a few times a year for more general information purposes. And in addition, a more general report that summarizes the results from the centre's first three years is being produced. It will be written for a broader audience that does not necessarily have specific knowledge about the technology area.

As the creator and manager of Waste Refinery, SP brings actors together so that they can benefit from each other's specific capabilities and knowledge in joint research projects. This is made possible by funding from various government agencies, which is attracted by SP in its role as centre creator and manager. However, the network's influence on the development of waste conversion technology goes beyond the individual research projects. It stimulates learning processes by encouraging interaction between actors, not only in the research projects but also at partner meetings and seminars. Also, the actors in the networks could potentially constitute a coalition of proponents for waste conversion technologies, which can act to influence the development of institutions that are more aligned with these technologies.

5.1.4. Project case study: SP providing services to Heliospectra[4]

The Swedish company Heliospectra is developing a high brightness light emitting diode for use in industrial greenhouse applications. It emits light that is optimized for a specific crop, which makes it energy efficient and increases crop yield and quality. The company was founded 2005 by Mr. Sylvain Dube, a physiologist from Quebec, and spent its first year in an incubator in Borås. In 2009, it moved to its own location and currently employs ten people. Heliospectra collaborates with several Swedish universities, institutes and other actors in developing the technology.

Mr. Dube contacted SP several years ago because he needed help with some of the measurements in the ongoing research and development work (Andersson, 2010). According to Dr. Anne Andersson in the Radiometry and Photometry Department at SP, he turned to SP because of its expertise in the areas where he needed support (Andersson, 2010). SP mainly contributed with consulting in optics and metrology and constituted a discussion partner in the development work. It also supported the company in writing research grant applications, gave access to certain equipment and has helped with attracting a M.Sc. thesis worker to the project.

The development of the technology has mainly been financed by Heliospectra and its investors. The company has received some grants from public agencies such as Region Vastra Gotaland and ProEnviro. In addition SP has subsidized some of their services using an internal budget, since it found the technology interesting and has an organizational culture that appreciates supporting small companies (Andersson, 2010).

[4] This case study is based on an interview with Dr Anne Andersson (Andersson, 2010) and information obtained from Heliospectra's website (Heliospectra, 2010).

In the collaboration with Heliospectra, SP has acted as a subsidized provider of expert services. It has contributed to the research and development in the project and also to some extent canalized public funding by subsidizing some of the services. However, SP's influence on the direction of the project was quite marginal. As Dr. Andersson points out, Heliospectra knew what they were after in terms of competence and knowledge already from the start (Andersson, 2010).

5.1.5. Project case study: SP in a collaboration with GigaCom[5]

The Swedish company GigaCom was founded in Gothenburg in the end of the 1990s. It has since then worked with developing and marketing fiber optical components and systems. About five years ago, GigaCom came up with the idea of developing an expanded beam connector for optical communication fibers that was smaller, cheaper and more robust than the existing ones.

An unplanned meeting between Dr. Anne Andersson, a PhD in the Radiometry and Photometry Department at SP, and her former student Mr. Staffan Hemmingsson, the CEO and founder of GigaCom, became the starting point for the collaboration between GigaCom and SP. Dr. Andersson identified GigaCom as a potential customer and saw great potential in the company's idea (Andersson, 2010), while Mr. Hemmingsson considered SP to be an interesting development partner (Hemmingsson, 2010). Dr. Andersson further suggested that GigaCom should apply for a grant from VINNOVA in order to develop the expanded beam connector, and introduced Mr. Hemmingsson to a colleague at SP, which helped him write the application (Andersson, 2010).

In 2006, GigaCom was granted 490 000 SEK by VINNOVA (VINNOVA, 2010a) for a feasibility study of their innovation, which got the product development project going. The feasibility study was successful and later the same year GigaCom was granted an additional 2.15 MSEK by the same agency (VINNOVA, 2010b). This was supposed to fund 50 percent of the project while the rest was to be invested by GigaCom.

SP contributed to the development project in several ways. First, and perhaps foremost, it initiated and supported the application processes for the VINNOVA grants. In Mr. Hemmingsson's opinion, this was the main way that SP contributed to the success of the project (Hemmingsson, 2010). Without the grant from VINNOVA it is unlikely that the project had gotten started and SP played a key role in the process of attracting this

[5] This case study is based on interviews with Dr. Anne Andersson (Andersson, 2010) and Mr. Staffan Hemmingsson (Hemmingsson, 2010) as well as on information obtained from GigaCom's website (GigaCom, 2010) and Vinnova's website (Vinnova, 2010a; Vinnova 2010b).

funding. It identified the potential in GigaCom's idea, made GigaCom aware of the opportunity of applying and assisted in writing the application.

Other ways in which SP supported GigaCom include having representatives from the institute participating in project meetings as a discussion partner and thus supporting the continuous problem solving process. The institute also provided certain testing services that were more convenient to perform at its facilities and supported activities related to the patent application. Using its academic network, SP hired a M.Sc. thesis worker to the project and also connected GigaCom with people possessing valuable knowledge for the project. Lastly, the institute helped GigaCom procure advanced research equipment in the second-hand market.

Mr. Hemmingsson describes SP's role in the project as a coach rather than a provider of expert knowledge. In his opinion, GigaCom possessed the critical knowledge required for the project and was therefore reluctant to engaging SP too much, largely because of the high cost (Hemmingsson, 2010). Dr. Andersson agrees that SP mainly had a coaching function in the project, connecting GigaCom with the right people in research and testing, both internally at SP and externally. She does, however, believe that SP helped them raise the level of the technology and made them aware of the many potential applications (Andersson, 2010).

"GigaCom needed coaching because they didn't know how good their idea was and what it could do.."

- Dr. Anne Andersson, SP

The development project has led to numerous prototypes and the first production order will be delivered during 2010. However, a few obstacles remain before the innovation reaches commercial success. GigaCom needs to improve the production efficiency in order to be able to lower the price of the product, and in a longer perspective alternative business models and outsourcing needs to be considered. The project has exceeded the estimated budget and is approaching a total cost of 10 MSEK. Mr. Hemmingsson thinks that one reason for the substantial underestimate is a lack of competence, on behalf of both GigaCom and SP, when it comes to the commercialization stages in the product development process (Hemmingsson, 2010).

Though SP provided continuous support in several areas throughout the project, its contribution to the success of the project was most pronounced in the early phase, through the support of the grant applications. It is even questionable if the project had

happened without SP's engagement, something that draws attention to the need and importance of this type of initial support to SMEs that want to innovate.

5.2. SINTEF

The second case study concerns the Norwegian technical research institute SINTEF. It begins with a description of the national context in which the institute is embedded, continues with a general description of its activities and organization, and ends with a project case study of how SINTEF commercializes technology.

5.2.1. The Norwegian national context of innovation

Norway has moved from being one of the poorest countries in Europe in the 1870s to being one of the richest in the world (Fagerberg et al., 2009). The country has had the advantage of a rich natural resource pool from the sea and offshore oil and gas fields (Fagerberg et al., 2009). Thus, unsurprisingly, the Norwegian national innovation system has been dominated by resource-based innovations (Fagerberg et al., 2009).

After World War II, Norway established the Norwegian Research Council for Scientific and Industrial research, NTNF. The council set up several techno-industrial institutes, among them SINTEF, which later became separate foundations (Arnold et al., 2007). The Norwegian research institutes perform a higher proportion of total domestic R&D than in most countries (Arnold et al., 2007). This goes well in line with the Norwegian firms' character of low internal R&D spending, which makes them acquire technical knowledge from other sources, such as technical research institutes (Fagerberg et al., 2009). Table 5.3 provides some indicators of the Norwegian national context of innovation.

Table 5.3 Innovation indicators for Norway(PRO INNO Europe, 2010; OECD, 2010a; OECD, 2010b; OECD, 2010c)

Innovation performance score, 2009	0.382	Not part of the EU27
R&D investment as percentage of GDP, 2007	1.64	18nd in the OECD
Researchers per thousand employed, 2008	10.0	6th in the OECD
Patents per million inhabitants, 2008	26.4	17rd in the OECD

5.2.2. Organization and activities

SINTEF has its headquarters in Trondheim but also has other locations in Norway. In addition, it has international presence in Brazil, USA, Macedonia and Denmark. The SINTEF Group is the largest independent research organization in Scandinavia. Its vision is 'technology for a better society' and it views its role as 'creating value by applying knowledge, research and innovation' (SINTEF, 2010a).

SINTEF also employs a business model that resembles the general institute business model described in Chapter 4. However, the institute describes it as a three-stage process, consisting of idea generation, idea development and idea commercialization (SINTEF, 2007). Thus, SINTEF engages not only in capability building, knowledge development and technology transfer, but also in commercialization activities such as licensing research results and spinning off companies. The spin-off companies are managed by SINTEF Holding, which is a part of the SINTEF Group, and normally the institute aims to dispose of its ownership interest in these companies at an initial public offering stage (Arnold et al., 2007).

The organization is based on six independent technical research divisions that to some extent function as separate institutes (Pettersen, 2010). Within the divisions, SINTEF performs research and development by itself and together with industrial, academic and public partners, and offers various technology services. The institute also has close ties to the Norwegian University of Science and Technology and the University of Oslo, together with which it has established a number of Gemini Centers[6] (SINTEF, 2008). Apart from the collaboration within these centers, SINTEF and the universities share equipment and have joint professorships (Arnold et al., 2007). Table 5.4 summarizes key facts and figures about SINTEF.

Table 5.4 Key facts and figures about SINTEF(SINTEF, 2009; SINTEF, 2010b)

Turnover	330 MEuros
Employees	2145
Basic funding	21%
International locations	Yes.
Ownership structure	Independent foundation
Services offered	R&D, consulting, testing, certification, IPR and licensing

The focus now turns to a project case study in which SINTEF commercialized an idea sprung from research.

[6] A Gemini Centre is a strategic cooperation model where scientific groups with similar or parallel interests coordinate their efforts and resources (SINTEF, 2008).

5.2.3. Project case study: The SINTEF spin-off company Ecowat[7]

The Norwegian technical research institute SINTEF works actively with commercializing research results, in order to implement technologies, create jobs and earn money. The commercialization activities are performed by the subsidiary SINVENT, owned to a 100 percent by SINTEF and SINTEF Holding. It cooperates with SINTEF's research divisions and evaluates whether technological inventions that are not used for contract research are instead commercially viable. The inventions that have potential for commercial success are then transferred to venture companies or licensed to established companies. The revenues from selling shares in venture companies and licensing technologies go back to the research milieu behind the invention, which enables further research.

A successful example of a SINTEF spin-off company is Ecowat, which develops new water treatment technology. Ecowat's water purification technology turns traditional methods upside down. Instead of extracting the contaminants, pure water molecules are drawn out from the contaminated water, by transforming them to crystals that resemble ice. The technology is advantageous in that it enables small and energy-efficient systems, with very high quality purification. Ecowat is concentrating on customers that require ultra pure water for industrial processes, for example gas driven generators on oil platforms.

It all started in 2003 with a discussion among SINTEF researchers on how to meet new environmental targets in water treatment in offshore applications. The discussions led to initial research on the possibility to reverse the traditional way of purifying water, and eventually the researchers decided to patent the idea. After three years, the project was granted some funding, which was used to build a small-scale pilot plant. It proved successful and the technology was spun out in a venture company in 2007. The company is currently owned by SINTEF, the private venture capital firm Viking Venture and the employees, among others one of the founders that originally worked for SINTEF and took part in the initial research.

SINTEF created a new actor by choosing to spin out the technology in a venture company, instead of for instance making it available through license agreements or using it internally to build additional capabilities. This attracted investors, which got the opportunity to buy shares in the company. The invested money financed further technology and product development. The fact that SINTEF stayed a shareholder in the

[7] This case study is based on information obtained from SINTEF's (SINTEF, 2007; SINTEF, 2007; SINTEF, 2008) and Ecowat's website (Ecowat, 2010).

company, and not just sold the technology to a number of investors, is likely to have strengthened its legitimacy. Also, collaboration and synergies between SINTEF and the new actor could easily be realized, since the venture company is run by researchers formerly active at the institute.

5.3. VTT

The third case study is about the Finnish technical research institute VTT. It begins with a description of the national context in which the institute is embedded, continues with a general description of its activities and organization, and ends with a project case study of VTT as a government advisor.

5.3.1. The Finnish national context of innovation

Finnish investment in R&D is one of the biggest in the OECD countries (OECD, 2010a). It has been growing for decades and it was key in the strategy for surpassing the early 1990's economic crisis (Georghiou et al., 2003; Arnold et al., 2007). The investments are concentrated to certain manufacturing sectors, particularly electronics, and are dominated by a group of large domestic multinational companies. Nokia alone accounts for half of the Finnish industry's total R&D expenditures (OECD, 2008b). However, in 2008, a national innovation strategy was launched to improve this situation (Hyytinen et al., 2009; OECD, 2008b). The strategy aims to create more opportunities for innovation in areas such as services, by aligning innovation policy with this target (Hyytinen et al., 2009). Table 5.5 provides some indicators of the Finnish national context of innovation.

Table 5.5 Innovation indicators for Finland(PRO INNO Europe, 2010; OECD, 2010a; OECD, 2010b; OECD, 2010c)

Innovation performance score, 2009	0.622	2nd in the EU27
R&D investment as percentage of GDP, 2007	3.47	3rd in the OECD
Researchers per thousand employed, 2008	16.1	1st in the OECD
Patents per million inhabitants, 2008	60.6	7rd in the OECD

5.3.2. Organization and activities

VTT has its headquarters in Espoo with several other locations throughout the country. It has international presence in Russia, USA, Belgium, Japan, China and South Korea. VTT is a state-owned, independent research body that functions under the Finnish Ministry of Employment and the Economy (VTT, 2010a). It is a non-profit organization with a mission that involves achieving international competitiveness, innovative solutions and

new businesses (VTT, 2010b). VTT operates in a quite complex group structure, consisting of several companies and research areas (VTT, 2010a).

VTT employs a business model resembling the general institute business model described in Chapter 4. It uses core funding to build capabilities by itself and together with industrial, academic and public partners, and then benefits from these capabilities when offering a wide range of services. The offering covers services throughout the whole innovation chain; from technology foresight and concept development, to the development of products and services, testing, consulting and certification. In addition, VTT actively commercializes technology by licensing patents and spinning off companies, something that is seen both as a source of revenue and a way of developing the market by commercializing innovations (Mustranta, 2010a). Usually, a five-year exit strategy is employed when owning shares in spin-off companies (Mustranta, 2010a).

Although the institute and university sectors compete for some specific funding and have similar offerings in some areas (Mustranta, 2010a; Arnold et al., 2007), VTT has a strategic collaboration network with Finnish universities and has established several strategic agreements with top-rated international universities and research institutes (VTT, 2010c). It also participates in the Finnish Strategic Centers for Science and Technology and Innovation, as well as in numerous EU-projects and international collaborations (VTT, 2010c). Table 5.6 summarizes key facts and figures about VTT.

Table 5.6 Key facts and figures about VTT(VTT, 2010e; VTT, 2010a)

Turnover	269 MEuros
Employees	2700
Basic funding	31%
International locations	Yes.
Ownership structure	Non-profit organization owned by the Finnish government
Services offered	R&D, consulting, testing, certification, IPR and licensing, training

In the next section, a project case study of VTT as a government advisor will be presented.

5.3.3. Project case study: VTT as a government advisor[8]

Though VTT's main task is to perform R&D activities, it also has a role in supporting decision making relating to technology, as it is, along with the other research institutes, the main producer of the information needed by the Parliament, the Cabinet and the Research and Innovation Council for their decision-making activities (Hyytinen et al., 2009). As argued by Mr. Mustranta (Mustranta, 2010a; Mustranta, 2010b), policy input from institutes needs to be neutral, impartial, and concretet.

An example of when VTT provided important input to national policy-making is when the Finnish government and parliament approved a decision in principle to construct a new nuclear power unit in 2002 (VTT, 2003). VTT provided input on numerous topics relating to this complex and important decision, for example the benefits of a diversified energy production structure, the environmental impacts of each energy source, the reliability of the energy supply, safety analyzes, cost comparisons etc (VTT, 2003). While the institute was not responsible for the decisions, its research results played a significant role in the decision-making process. The impact of VTT's advice has enhanced its reputation to be regarded as one of the most reliable contributors to the energy discourse (VTT, 2003).

VTT is also supporting policymakers on an international level, where it has been working with EU policy projects such as the proposed limitation of greenhouse gas emissions, the structure of European energy production and the EU-FAIR ACTIPAK project, which aims to initiate amendments to relevant food-packaging regulation (VTT, 2003). In these projects, VTT has developed methods, performed testing, conducted consumer surveys and proposed certain amendments to the directives (VTT, 2003). However, the institute's influence is likely to have been different than at the national level, since the roles and functions of technical research institutes are less clear in an international setting (Hyytinen et al., 2009).

When supporting decision-making, VTT uses its technological capabilities and lack of private profit interests in order to provide background information and assessments, both on a national an international level. Accordingly, the institute is likely to influence laws and regulations that relate to technology. But the exact impact and importance of VTT's advice is hard to determine and certainly varies from situation to situation.

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[8] This case study is based on interviews with Mr. Antti Mustranta (Mustranta, 2010b), information obtained from from VTT's website (VTT, 2003; VTT, 2009; VTT, 2010d) and a research report about the Finnish innovation system (Hyytinen et al., 2009).

6. Analyzing potential roles of technical research institutes

This chapter presents an analysis of the potential roles of technical research institutes in a given TISs. It is based on the case studies presented in Chapter 5 and also draws on the conceptualization of technical research institutes provided in Chapter 4. The chapter begins with a comparison and brief analysis of the institute case studies. It then presents a typology of roles that the institutes can adopt in TISs. Subsequently, each role is analyzed in terms of the institute's impact on structure and functions. The chapter ends with a discussion of three generic strategies that the institutes can employ for further promoting innovation.

6.1. Comparison of case studies

When looking at the case studies, it is striking how similar the institutes are in terms of activities, business model and organization. They all employ variations of the general institute business model described in Chapter 4 and are organized in quite similar ways, albeit with different degree of complexity. When it comes to activities, they all perform research and build capabilities, internally and together with companies, offer technology services, such as testing and contract research, and work actively with supporting SMEs. They engage in different types of research networks and collaborate with universities and other institutes. And, they constitute research bodies that are able to advise policy makers on technology and industrial policy.

Nonetheless, there are certain differences between the institutes when it comes to for example turnover and funding. The main differences can be found in table 6.1, which summarizes facts and figures for the three institutes.

Table 6.1. Facts and figures for SP, SINTEF and VTT

	SP	*SINTEF*	*VTT*
Turnover	98 MEuros	330 MEuros	269 MEuros
Employees	950	2145	2700
Basic funding	10 %	21%	31%
International locations	No	Yes	Yes
Ownership structure	Limited company owned by RISE Holding, in turn owned by the Swedish government.	Independent foundation	Non-profit organization owned by the Finnish government.
Services offered	R&D, consulting, testing, certification, training	R&D, consulting, testing, certification, IPR and licensing	R&D, consulting, testing, certification, IPR and licensing, training

From table 6.1, it is clear that the institutes are different in the size of their turnover and number of employees. SINTEF is the biggest institute in this sense followed by VTT, both having turnovers around 300 million Euros. SP is substantially smaller, with a turnover of just below 100 million Euros. The number of employees seems to correlate well to the turnover, except for SINTEF that has fever employees in relation to turnover than the other institutes. This can potentially be explained by its close relationship with the Norwegian universities, with which it shares certain resources. When it comes to the amount of basic funding that the institutes receive, there are also quite large differences. VTT receives the most and SP the least, with SINTEF in between. The fact that SP receives little basic funding compared to VTT and SINTEF relates well to Sweden's small institute sector and reliance on universities, but there is no apparent reason for the difference between VTT and SINTEF in this aspect. Furthermore, SP does not have international locations nor does it view commercialization activities as part of its business model, which stands in sharp contrast to the other institutes. Both these differences may partly be explained by SP's small size, but there are certainly other reasons. For example, the task of commercialization has traditionally been given to universities to a larger extent in Sweden than in Finland and Norway (Sörlin, 2006).

The differences described above do not seem to influence the type of roles that the institutes adopt, except for the commercialization related activities. However, the differences are likely to influence how, and the extent to which, the institutes adopt the roles. For example, VTT is likely to be able to focus more on building capabilities compared to SP, since it receives more basic funding. A thorough discussion on the differences between the institutes in terms of how, and the extent to which, they adopt certain roles is beyond the scope of this thesis, but the topic will return in Chapter 7.

The project case studies show that the institutes support innovation in very different ways depending on which role they adopt. When VTT acts as a government advisor on technology related policy, it influences the development of institutions. When SP initiates and manages knowledge centers such as Waste Refinery, it creates a network of actors in the knowledge field. And when SINTEF spins off venture companies, such as Ecowat, it creates new actors. The institutes influence the various TISs that they are a part of by building structure and strengthening functions, but they do it in very different ways depending on the given situation. Therefore, the institutes' interaction with their environment will be segmented in order to create a typology of roles that can be analyzed individually. In the next section, a typology of this type will be presented.

6.2. Six potential roles of technical research institutes

When creating the typology, an effort has been made to make the set of roles mutually exclusive and collectively exhaustive. The exclusiveness is achieved by minimizing the overlap between the roles. However, some overlap is usually unavoidable and this case is no exception. The exhaustiveness comes from letting the set of roles encompass all the activities that the institutes engage in from an external perspective. It should also be pointed out that the roles are archetypes; it is unlikely to observe an institute that adopts exactly the defined behavior, in practice it will rather mix the roles in any given situation. The set of roles has rather been constructed to constitute a framework of analysis. The strength of the framework lies in that the impact of an institute in a given situation can be analyzed by looking at which roles it is adopting and to what extent it is adopting them. A set of six potential roles of technical research institutes has been defined and is briefly described in table 6.2.

Table 6.2 The six roles of technical research institutes

Advisor	The role of advising on technology related policy and developing product and technology standards.
Matchmaker	The role of creating and managing networks of actors within a given knowledge field or across various knowledge fields.
Mentor	The role of supporting SMEs in their innovation efforts.
Entrepreneur	The role of selling and licensing patents as well of spinning out research results in venture companies.
Consultant	The role of offering contract research and various technology services.
Researcher	The role of performing research, both internally and in collaboration with other actors.

In the different roles, the institutes carry out activities that impact TISs by building structure and strengthening functions in different ways.

When analyzing these impact patterns, the aim is not to give a complete and detailed understanding of all the direct and indirect impacts that result from the institutes' activities. Rather, the focus is on identifying the main impacts that can be presumed to be of most importance. The impact pattern associated with each role will be analyzed individually below.

6.2.1. Advisor

As advisors, the institutes advise governments and other public bodies on technology related policy, by for example evaluating technologies and policy instruments. When doing this, they benefit from being public organizations without private interests, since this would make them unable to provide impartial advice. Within the advisor role, the institutes also develop standards with regards to, for example, functionality, fire, safety and environmental impact.

In the advisor role, the institutes have the potential of building structure in TISs. They do not introduce or change laws and regulations, but influence this process by supporting policymakers in their decisions. Also, the institutes may influence norms and beliefs among the public, which in addition to affecting institutions strengthens the

functions of legitimation and influence on the direction of search directly. These functions indirectly build even more structure by influencing the institutional set-up. The new set of institutions, resulting from the described dynamics, in turn strengthens functions such as market formation, influence on the direction of search and legitimation. It may also attract new actors to the technology, which builds more structure in the system. As advisors, the institutes also strengthen legitimation, influence on the direction of search and market formation in a direct manner by developing standards. This in turn strengthens resource mobilization and may attract new actors, as potential customers and investors perceive the technology as less risky. An example of the advisor role is the project case study of VTT as a government advisor. In this case, VTT gave input to a policy-making process regarding nuclear technology.

Lastly, it should be emphasized the actual impact depends on several internal and external factors, for example the policy makers' willingness to listen to expert advice and the institutes' capabilities when it comes to promoting certain technologies that are perceived as beneficial for society. The potential impact of the advisor role on TISs is illustrated in figure 6.1.

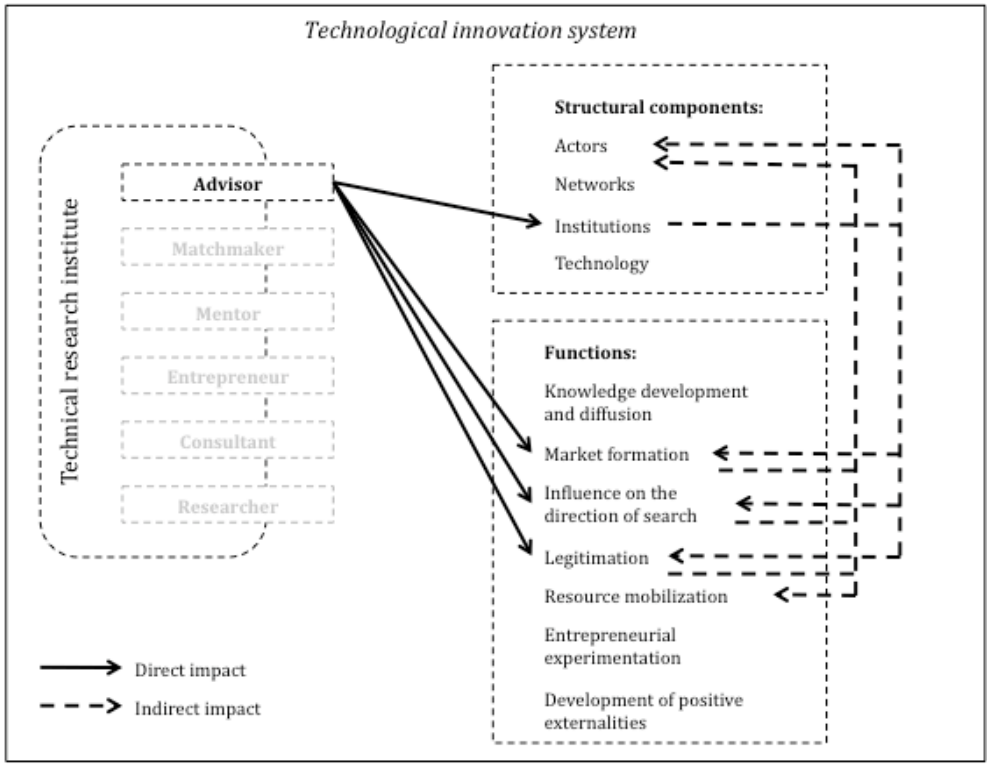

Figure 6.1. The impact pattern of the advisor role

6.2.2. Matchmaker

In the matchmaker role, the institutes create and manage networks of actors such as universities, public agencies, municipalities, companies and other institutes, which have

a common interest in a knowledge field or technology area. Throughout the networks, actors are brought together so that they can learn from each other and identify common problems and research challenges. The activities are normally funded by a mixture of public grants, basic institute funding and participating actors. In addition, the networks facilitate the creation of coalitions of proponents that together attract funding, diffuse knowledge and raise the awareness of the knowledge field. Thus, the institutes create both knowledge and political networks as matchmakers.

As matchmakers, the institutes build structure in TISs, by creating and managing networks. This also attracts new actors to the knowledge field and strengthens knowledge development and diffusion, since the networks constitute research platforms, used for enabling collaborative research and for diffusing information and research results. The networks also strengthen all the functions indirectly: knowledge development and diffusion by facilitating interactive learning in knowledge networks; market formation by connecting producers with potential users; influence on the direction of search and legitimation by creating political networks and through communication; resource mobilization by sharing facilities and equipment; entrepreneurial experimentation by allowing actors to combine their competence and knowledge, and share risks; and development of positive externalities by enabling the other functions to create virtuous feedback loops in the system. As matchmakers, the institutes also strengthen resource mobilization directly, since a key activity within the networks is to attract research grants and other types of funding. This in turn strengthens knowledge development and diffusion as well as entrepreneurial experimentation, since the attracted resources make investments in further research possible.

An example of the matchmaker role is the project case study of SP's involvement in the knowledge centre Waste Refinery. By creating and managing this network, SP brought actors together, attracted funding to the knowledge field and diffused knowledge, something that is likely to have given rise to the described impact pattern. The potential impact of the matchmaker role on TISs is illustrated in figure 6.2.

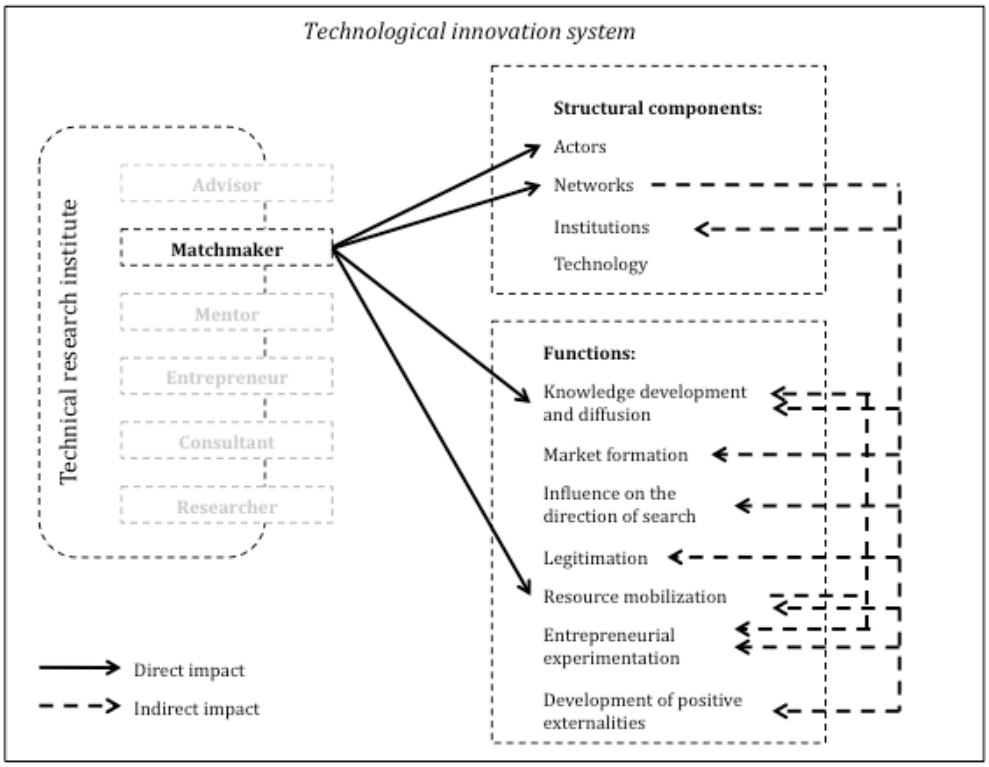

Figure 6.2 The impact pattern of the matchmaker role

6.2.3. Mentor

As mentors, the institutes support innovation in individual firms, for example SMEs, that lack some the capabilities necessary for innovating. They act as discussion partners in projects, where they provide advice and input. They broker knowledge and connect companies with skilled people, both within and external to the institute. They also advise companies on research grant opportunities and help them write applications. The activities within the mentor role may be funded by the basic institute funding, by small public grants for supporting SMEs or as a part of a research project funded by a public agency. However, an activity that falls under the mentor role may also be very minor, for example answering a quick question on the telephone, something that does not require specific funding.

In the mentor role, the institutes strengthen mainly the various functions of TISs, but also build structure indirectly. When being discussion partners and brokering knowledge, they strengthen knowledge development and diffusion and influence on the direction of search, which in turn builds structure by adding to the technology component. When encouraging and supporting grant applications, the institutes strengthen resource mobilization and entrepreneurial experimentation, which in turn strengthen knowledge development and diffusion. Resource mobilization is additionally

strengthened when the institutes connect companies with skilled people, something that indirectly build structure by initiating networks between actors.

An example of the mentor role is the project case study of SP's collaboration with GigaCom. In this case, SP mainly supported the application process for research grants, but also constituted a discussion partner and connected the company with skilled people. Though the extent to which SP strengthened influence on the direction of search within the system might be questioned, the overall impact pattern is likely to have resembled the one described above. The potential impact of the mentor role on TISs is illustrated in figure 6.3.

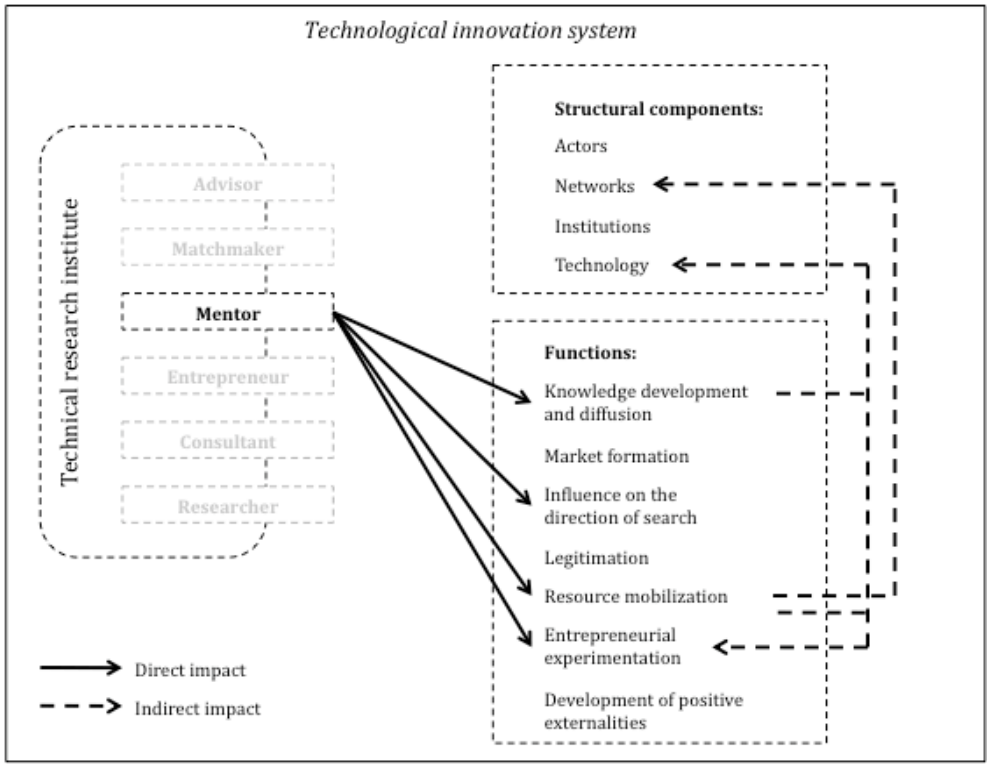

Figure 6.3 The impact pattern of the mentor role

6.2.4. Entrepreneur

As entrepreneurs, the institutes patent research results that they have reached in their own research, in order to sell or license the rights, or to spin off companies based on them. When a company has been spun off, the institutes own shares, often together with external investors. Normally, the institutes intend to dispose of their ownership within a limited period of time. From the institutes' point of view there are two main reasons for acting as entrepreneurs; it is a source of revenue that can be used for further research and it is a way of making technology available on the market, thus creating jobs and increasing the competitiveness of the industry.

In the entrepreneur role, technical research institutes build structure and strengthen functions in TISs. When companies are spun off, new actors are created, which builds structure in TISs. This may in turn strengthen market formation, if the technology or product thereby becomes commercially available, as well as resource mobilization, if the venture company manages to attract external investors. Additional indirect effects then arise that strengthen knowledge development and diffusion as well as entrepreneurial experimentation, as the new resources are likely to be used for capacity building in addition to public funding. When the institutes instead license and sell the patents, they strengthen knowledge development and diffusion by making knowledge available for the actors that are willing to pay for it, as well as by making it possible for others to use the knowledge in their research. However, as entrepreneurs the institutes also engage in knowledge development and diffusion and entrepreneurial experimentation when building the capabilities that are required for spinning-off companies and licensing and selling patents. This in turn builds structure by adding to the technology component.

An example of the entrepreneur role is the project case study of the SINTEF spin-off company Ecowat. In this case, SINTEF commercialized its research results in a specific technology area by creating a venture company, something that attracted external investors and made the technology available on the market. The potential impact of the entrepreneur role on TISs is illustrated in figure 6.4.

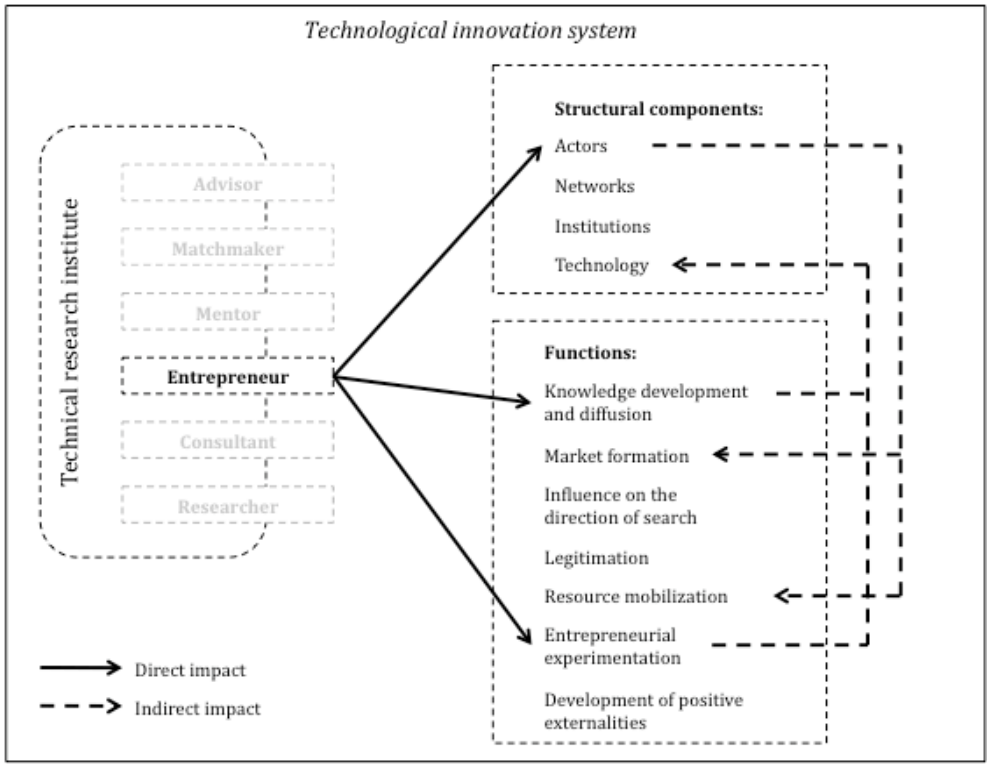

Figure 6.4 The impact pattern of the entrepreneur role

6.2.5. Consultant

In the consultant role, the institutes offer contract research and technology services such as testing, measurements, technology evaluation and certification, design, advanced calculations etc. They have customer-supplier relationships rather than collaborative relationships and the activities are funded directly by the customer. In the consultant role, the institutes are comparable to ordinary technology consultants. However, the offered services are superior in that they benefit from capabilities, knowledge and facilities that have been acquired using core funding. And, as previously argued, the services are so expensive that the institutes do not compete directly with private actors.

As consultants, the institutes strengthen knowledge development and diffusion by performing contract research and by offering other services that enable and complement the customer's in-house research and development efforts. This in turn builds structure by adding to the technology component. The institutes also strengthen resource mobilization, since the services benefit from skilled researchers, facilities and equipment that have been acquired using public subsidies. This in turn strengthens entrepreneurial experimentation by enabling the customers to conduct research in areas that they could not have engaged in if it were not for the institutes.

In the project case study of SP as a service provider to Heliospectra, the institute partly adopted the consultant role. Heliospectra came to SP looking for specific competence that they needed to complement their in-house capabilities. SP offered this competence, which is likely to have had the described impact on the TIS. The potential impact of the consultant role on TISs is illustrated in figure 6.4.

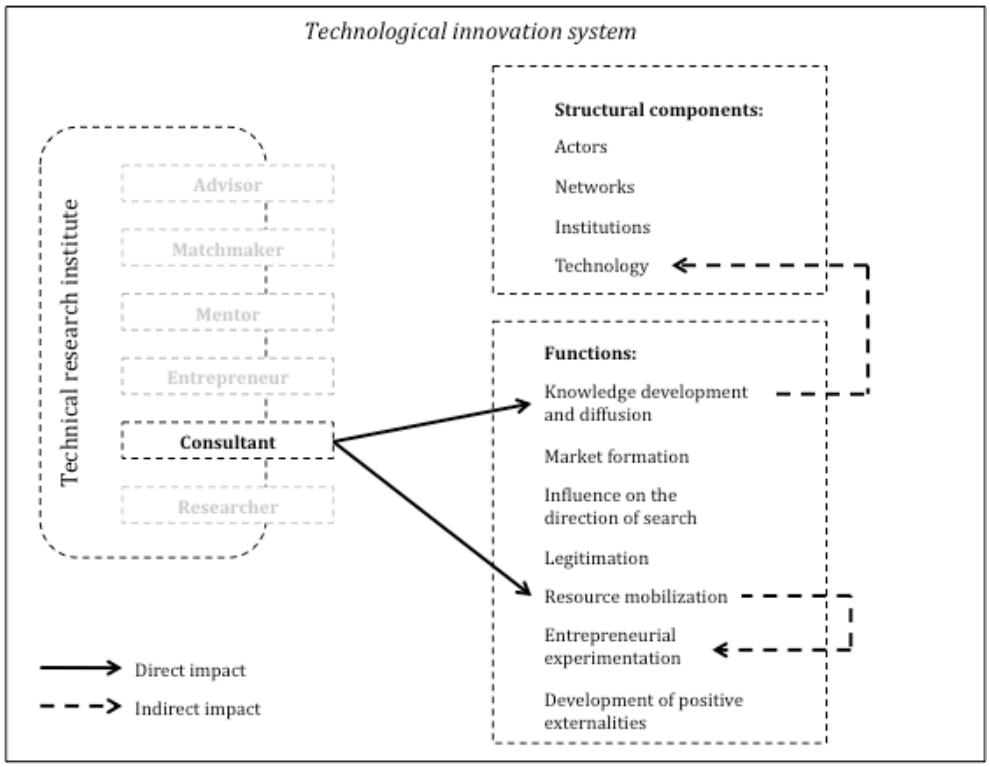

Figure 6.5 The impact pattern of the consultant role

6.2.6. Researcher

As researchers, the institutes use public and private funding to perform research, both internally and in joint research projects with industrial, academic and public partners. The researcher role is in this sense the core of the first two stages in the general institute business model, as presented in Chapter 4. It enables the other roles by building the capabilities that they require, but also includes research projects that mainly benefit the research partners. As researchers, the institutes also diffuse knowledge by publishing scientific articles and taking part in conferences.

In the researcher role, the institutes strengthen knowledge development and diffusion and entrepreneurial experimentation by conducting research and by experimenting with new technologies. This in turn builds structure by developing the structural technology component. They also strengthen resource mobilization by devoting resources the technology, an action that in turn strengthens legitimation and influence on the direction of search, since the institutes give credibility by manifesting a belief in the technology. Lastly, when publishing the research results in articles, knowledge development and diffusion is further strengthened, together with legitimation. The potential impact of the research role on TISs is illustrated in figure 6.5.

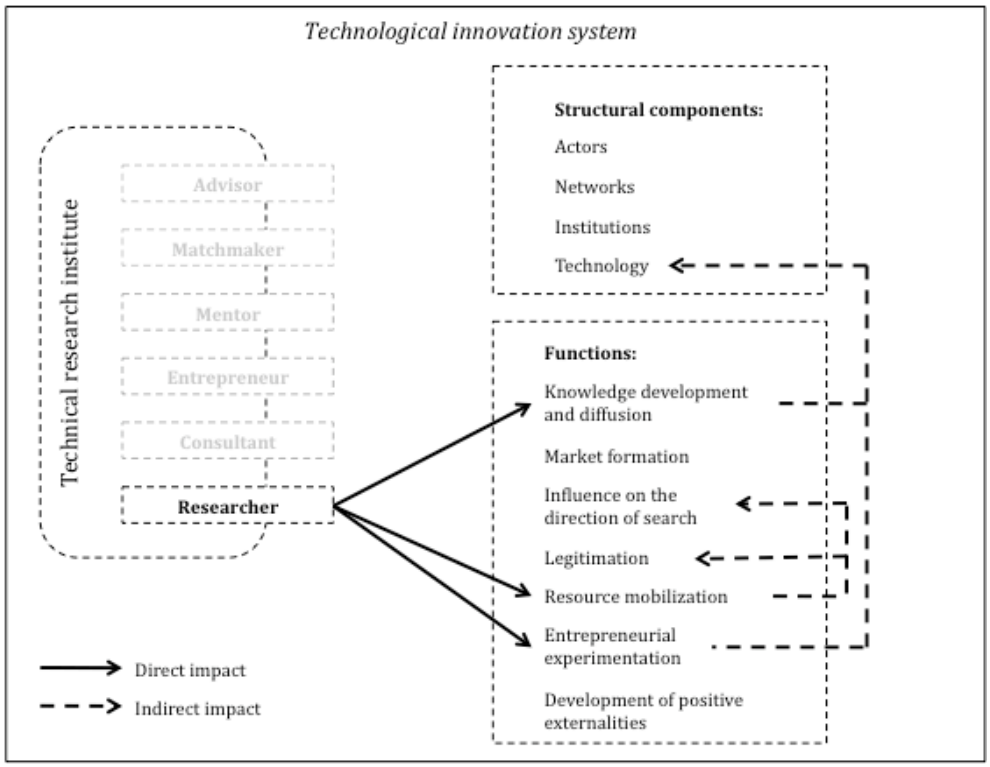

Figure 6.6 The impact pattern of the researcher role

6.3. Summary of impact patterns

The typology of roles presented above

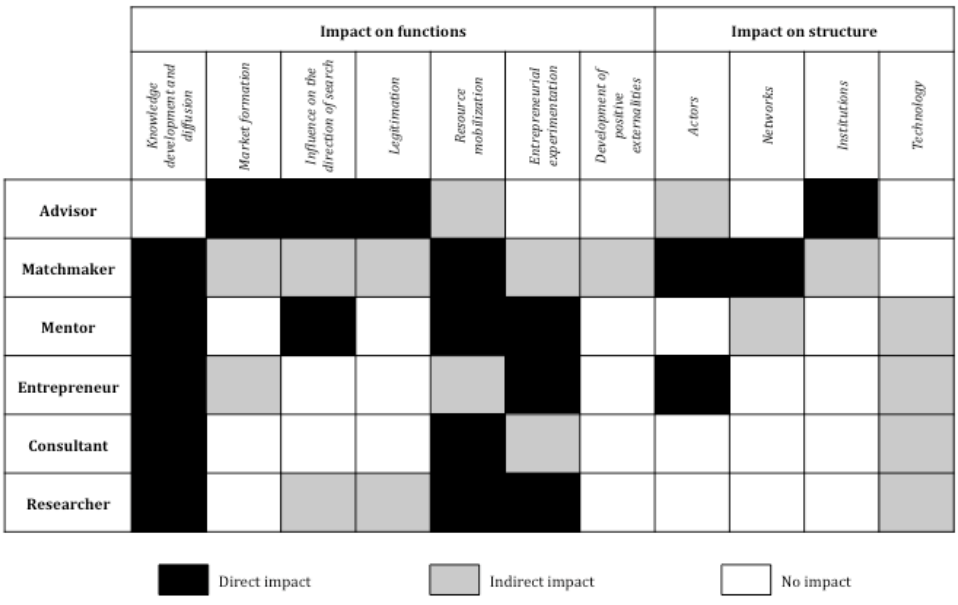

Figure 6.7 The impact patterns of the six roles

Figure 6.7 shows that the institutes have a broad potential impact pattern on TISs. As advisors, they influence the development of institutions and strengthen several related functions. As matchmakers, they create and develop networks and attract new actors to the system, and at the same time strengthen the functions of knowledge development

and diffusion and resource mobilization. As mentors, they strengthen several functions, which is likely to build structure indirectly. As entrepreneurs, they create new actors and also strengthen the functions of knowledge development and diffusion and entrepreneurial experimentation. As consultants, they strengthen the functions of knowledge development and diffusion and resource mobilization, which in turn may develop the technology component. And as researchers, they strengthen the functions of knowledge development and diffusion, resource mobilization and entrepreneurial experimentation, which also may develop the technology component indirectly.

As mentioned in Chapter 2, the actors that invent and develop the structural components of a TIS are commonly referred to as system builders (Hughes, 1987). The analysis shows that the institutes build structure directly when adopting the roles of advisor, matchmaker and entrepreneur, which is also apparent from figure 6.7. These roles can, accordingly, be labeled system-building roles. When the institutes instead adopt the roles of mentor, consultant and researcher, they do not build structure directly. They do, however, strengthen functions, which in turn may build structure. Within these roles, the institutes do not act as system builders, but rather have a system-supporting function.

It stands clear that technical research institutes take on both system-building and system-supporting roles, which promote innovations in different stages of development in terms of commercial viability. It has to be emphasized, however, that the fact that an impact has been observed does not necessarily imply that it is important or determining for the TIS's development, since the impacts may be uncertain or insignificant. Therefore, there should be room for improvement when it comes to the institutes' way of promoting innovation, even though figure 6.7 suggests that their impact patterns within the six roles develop and create all four structural components and strengthen all seven functions.

The analysis has shown that technical research institutes can adopt numerous roles and found that a typology of six roles is appropriate for describing the observed activities. Each role has further been associated with a distinct impact pattern, which describes how the institutes build structure and strengthen functions in TISs. From this analysis, it is apparent that the institutes have a broad potential impact and that they adopt both system-building and system-supporting roles. The next chapter contains a discussion of these results.

7. Discussion

The analysis presented in the previous chapter has provided a typology of roles that technical research institutes can adopt and the associated impact patterns, that is, how technical research institutes build structure and strengthen functions in TISs in the different roles. In this chapter, these results are discussed first in terms of their possible applications and then in terms of their limitations.

7.1. Potential applications of the typology of roles

The typology of roles and the associated impact patterns can be used for describing and analyzing differences between institutes, regardless of national context and technology area, using the TIS framework. From a Swedish perspective, this type of study has been called for (see for example Bergek et al., (2008a) footnote number seven) since the Swedish institute sector is small compared to other European countries. A detailed study of the differences between Swedish institutes and foreign institutes can potentially identify areas of structural and functional influence that are lacking and inhibiting Swedish innovation processes. The addition to the TIS framework provided in this thesis will hopefully be valuable in this type of research.

However, the typology can also be used for formulating institute policy. It places the institutes in a system context and allows for directing their impact pattern, which can potentially improve the quality of policy decisions regarding the institute sector. For example, it could be used for segmenting public funding to the institutes, which has been suggested by Arnold et al., (2007).

The typology of roles is based on what technical research institutes actually do and how it has been manifested in the case studies and in previous research. However, it also allows for characterizing alternative institute behaviors that may have a different and potentially more desirable impact on TISs. Given the typology of roles, there are three generic ways to change the way that the institutes promote innovation: they can adopt other roles than the ones described; they can carry out different activities within the described roles; or, they can change the composition of roles. These strategic options will be discussed respectively below.

Though the generated typology encompasses all the institute activities that have been observed in the case studies, it is easy to imagine other activities that an institute could carry out and accordingly more potential roles. For example, another potential role for the institutes is to be a distributor of research grants. This is partly included in the

mentor, researcher and consultant roles, since the institutes are able to use parts of their basic funding to support individual companies, but it could be extended to include larger grants as well. A potential benefit from the institutes adopting this role would be that they could use their technological competence to canalize funding where it does most good. However, an institute strategy that involves adopting entirely different roles is dependent on external factors embedded in the national context, since it involves changes on the system level. Therefore, this type of strategy is not feasible in the short term. However, if perceived as desirable, the institutes can certainly lobby for this type of change.

The second strategic alternative is to carry out different activities within the six roles, in order to strengthen the existing impacts and potentially give rise to new ones. Changing the way a role is adopted is a more feasible strategy from the institutes' point of view than adopting entirely different roles, since it is depending, at least partly, on internal factors to the institute. It may therefore be a better approach for institutes that wish to improve their way of promoting innovation in the short term.

The third strategic alternative is to change the composition of roles, which means changing the extent to which certain roles are adopted, without necessarily removing or adding roles. For example, the institutes could increase their system-building capacity by adopting the roles of advisor, matchmaker and entrepreneur, at the expense of the other system-supporting roles. Changing the composition of roles is likely to be dependent on external factors but there should also be ways for the institutes to modify the composition of roles within their current context. For example, adopting the mentor role to a large extent does not necessarily have to be dependent on increased funding, but may also be achieved by organizational and cultural changes within the institutes.

The strength of the typology of roles lies, not in that it can identify optimal strategies, but in that it can be used for formulating them. It will hopefully be a valuable tool for communicating the goals and visions of institutes as well as for making institute employees aware of how they are perceived by external observers and understand the impact of the activities that they carry out.

7.2. Limitations to the results

The typology of roles and their associated impact patterns are based on a quite limited empirical study of three technical research institutes, which has been complemented with previous research on the topic. Therefore, some caution is appropriate when using the results of our analysis. First, a more extensive study may find slightly better ways of

defining and differentiating between the roles. We do, however, argue for the usefulness of a typology of roles, since such a framework facilitates analysis and makes the complex actor that an institute is easier to understand. The typology that has been presented constitutes a first step toward this type of framework. Second, the analysis of the impact patterns associated with each role would benefit from a more detailed study with several complementing examples of each role. Our analysis of the impact patterns is based on a limited number of project case studies, essentially constituting illustrations of each role. A more extensive study, with several detailed case studies on each role, would certainly improve the reliability of the analysis and also be able to assess the certainty and significance of the individual impacts. Nonetheless, our analysis has provided a first attempt to describe the impact patterns on a general level, something that can be used for illustration and guide upcoming research on this topic.

In the next chapter, the thesis is finalized with a brief statement of the main conclusions.

8. Conclusions

The purpose of this thesis has been to study the potential roles of technical research institutes for promoting the development and diffusion of technological innovations from a technological innovation systems perspective. The specific aim was to generate a typology of roles that the institutes may adopt in technological innovation systems and to assess how they can be defined in terms of how the institutes build structure and strengthen the various functions. Therefore, the following two research questions were formulated:

- Which are the potential roles a technical research institute can adopt for promoting the development and diffusion of technological innovations in technological innovation systems?
- How can these different roles be defined in terms of how the institutes build structure and strengthen the various functions in technological innovation systems?

Based on previous research and case studies of three technical research institutes, a typology of six potential roles was created. The roles are advisor, matchmaker, mentor, entrepreneur, consultant and researcher. As advisors, the institutes influence the development of institutions and strengthen several related functions. As matchmakers, they create and develop networks and attract new actors to the system, and at the same time strengthen the functions of knowledge development and diffusion and resource mobilization. As mentors, they strengthen several functions, which is likely to build structure indirectly. As entrepreneurs, they create new actors and also strengthen the functions of knowledge development and diffusion and entrepreneurial experimentation. As consultants, they strengthen the functions of knowledge development and diffusion and resource mobilization, which in turn may develop the technology component. And as researchers, they strengthen the functions of knowledge development and diffusion, resource mobilization and entrepreneurial experimentation, which also may develop the technology component indirectly. The typology of roles is an addition to the technological innovation systems framework, which can be used for describing and analyzing differences between institutes as well as for formulating institute policy and strategies.

It is important to emphasize that this study has not focused on the extent to which the institutes adopt the different roles or whether they should adopt them. The former

aspect requires an extensive study of institute activities, preferably with a quantitative approach, which could reveal interesting differences between institutes. The second aspect is an interesting policy issue where the typology may be a useful tool for distinguishing between the tasks of different actors in the innovation system. Though this study leaves these areas for future research, it stands clear that technical research institutes play an important role for the development and diffusion of technological innovations.

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Appendix

The table below lists all conducted interviews for this study.

Conducted interviews

Date	*Interviewee*	*Organization*	*Position*	*Division*	*Type*
10-03-23	Tullin, Claes	SP	R&D Manager, Assistant Head of Department	Energy Technology	Face-to-face
10-05-06	Blomqvist, Evalena	SP	Director	Waste Refinery	Face-to-face
10-05-06	Wålinder, Magnus	SP	Centre Manager	EcoBuild	Phone
10-05-20	Mustranta, Antti	VTT	Councilor	International Affairs	Phone
10-05-21	Kindberg, Susana	SP	SP Small Companies manager	Innovation efficiency for SME:s	Face-to-face
10-05-24	Sandström, Matz	SP	Manager	Certification	Face-to-face
10-05-24	Sikander, Eva	SP	Head of building physics	SBUF	Face-to-face
10-05-25	Holttinen, Hannele	VTT	Team leader	Wind Energy	Phone
10-05-26	Lynov, Jens-Peter	Risø	Chief Advisor for Innovation		Phone
10-05-26	Karlsson, Martin	Götaverken Miljö AB	Process engineer	Fuel gas	Phone
10-05-27	Andersson, Anne	SP	Responsible for the National Metrology Institute	Photometry and Radiometry	Face-to-face
10-05-28	Kodde, Boy	TNO	Coordinator	SME oriented	Phone
10-06-01	Oksman, Kirsi-Marja	VTT	Technology Manager, Head of Medical Biotechnology	Green medical factory	Phone
10-06-04	Pettersen, Tanja	SINTEF	Research Manager	Materials and chemistry	Phone
10-06-07	Hemmingsson, Staffan	Gigacom	Founder & CEO		Face-to-face