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ANALYSIS OF CHAIN-LINKED EFFECTS OF PUBLIC POLICY

Effects on research and industry in Swedish life sciences within innovative food and medical technology

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About VINNOVA

VINNOVA, Swedish Governmental Agency for Innovation Systems.

VINNOVA´s mission is to *promote sustainable growth* by funding *needs-driven research* and developing *effective innovation systems*.

Through its activities in this field, VINNOVA aims to make a significant contribution to Sweden´s development into a leading centre of economic growth.

VINNOVA analyses innovation systems in order to safeguard the quality of VINNOVA's programmes. The analyses should support our efforts to strengthen the innovation systems in Sweden. By applying a systems perspective we ensure that all important factors are taken into account, including economic, social and political factors. The analyses identify and summarise knowledge on obstacles and opportunities relating to increased innovativeness and sustainable development in the innovation systems. The analyses are conducted partly by our own personnel and partly in collaboration with external experts, for example university researchers.

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Research and Innovation for Sustainable Growth.

Analysis of Chain-linked Effects of Public Policy

Effects on research and industry in Swedish life sciences within innovative food and medical technology

by

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Preface

This report presents the results of an Impact Analysis carried out by Jens Laage-Hellman, Maureen McKelvey and Mattias Johansson at the Institute for Management of Innovation and Technology (IMIT) and University of Gothenburg, on behalf of VINNOVA. The analysis concerns the impact of public research funded by VINNOVA and its two predecessors – *Styrelsen för Teknisk Utveckling* (STU) and *Närings- och teknikutvecklingsverket* (Nutek) – in two fields of life science, namely, Innovative food and Medical technology.

The report deals with impact on research and industry respectively. The main focus is on how and why public policy can induce changes over a long period of time within research and industry. A main issue is focused around the idea of using public policy to shift the trajectory, or the general direction of research and industry development, of an innovation system. The impact of STU/Nutek/VINNOVA's research initiatives are identified, described and analyzed using a so-called effect chain approach within a sectoral system of innovation, according to which different types of effects take place at several levels, with follow-on effects and feedback loops.

The results show that the programs in the study have stimulated interaction between research environments and collaborations with companies. It also shows the complexity of the projects and the need to see beyond the immediate results of one single grant. In the area of industry, the results point out the importance of spin off companies rather than established companies, for bringing research-based product ideas and inventions to the market, and that the companies – especially in the area of medical technology – are confronted by high risk and long lead-times when developing a successful firm. The most important effect is that the companies have gained access to new knowledge and competencies through collaboration with researchers in the studied programs, and that they have been able to use this knowledge and competence in their own R&D activities.

The results can be of importance to relevant organizations in their understanding of the impact of public policy on research, and of long term commitment to reach certain results.

Contacts at VINNOVA have been Joakim Appelqvist and Kenth Hermansson. Important input has been provided by program managers at VINNOVA and Nutek who were previously engaged in the programs and with projects that were funded. Many thanks to all those who have been involved in making this Impact Analysis possible.

VINNOVA in November 2009

Lena Gustafsson
Acting Director General

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Executive summary

This report presents the results of an Effect Analysis carried out on behalf of VINNOVA. The analysis concerns the effects of public research financed by by VINNOVA and its two predecessors – that is, Styrelsen för Teknisk Utveckling (STU) and Närings- och teknikutvecklingsverket (Nutek) – in two fields of life science, namely, Innovative food and Medical technology.

The present study deals with two 'areas of effect'– effects on research and effects on industry respectively. The main focus is on how and why public policy can induce changes over a long time period within these two research and industry. Another contractor has carried out a study of the effects on the society from a health economics point of view.

The effects of STU/Nutek/VINNOVA's research initiatives are identified, described and analyzed using a so-called effect chain approach within a sectoral system of innovation, according to which different types of effects take place at several levels, with follow-on effects and feedback loops. This approach has been used to identify key issues.

In terms of effects on *research*, the following key issues have been addressed.

I. How has the research policy pursued by STU/Nutek/VINNOVA affected:

1. development of research environments over time?
2. education and training provided by the supported research environments?
3. academic results in terms of publications and patents?

II. How does the industrial collaboration benefit the research environment?

III. To what extent do the research environments engage in venture creation?

In terms of effects on *industry*, the following key issues have been addressed:

I. How has the research policy pursued by STU/Nutek/VINNOVA affected:

1. how and why existing industry interacts with research environments?
2. development of industrial applications (e.g. new products or production methods) based on results from the academic research?
3. development of competencies in technology, research and science?

II. Do academic spin-off companies from previous periods play a role as R&D intermediaries between the existing industry and universities?

III. What types of company account for growth in Sweden?

The innovation systems approach constitutes an important part of the theoretical frame of reference for analyzing these complex and long-term effects of public policy. The university departments and research institutes, which are the principal receivers of the research grants, as well as the food and medtech companies are parts of sectoral innovation systems (SSIs). The research financed by STU/Nutek/VINNOVA and related innovation activities are carried out by actors in the system who are interacting with each other in various ways. Hence, our theoretical framework and empirical analysis show that the effects take place both within individual actors and at the level of the SSI.

In the case of Medical technology ("medtech"), the study takes its starting point in eight programs and two competence centers which were run during the period 1987 – 2006. In Innovative food the analysis focuses on two more recent research programs, the first of which started in 1998. The report describes the main characteristics of the two sub-sectors in terms of public research and industry, as background material, as well as basic information of these focal research programs. A combination of different methods has been used for collecting and analyzing empirical data. This includes document analysis (project reports, earlier evaluations and other previous studies of relevance), interviews with research leaders and company managers, case studies, telephone survey and bibliometric and econometric analyses.

In the sub-sector of Innovative food, key empirical findings can be summarized as follows:

Effects on research:

- The key Swedish academic actors with competencies in the innovative food area have been active. Most of the funding has gone to existing research environments in the three geographical areas of Lund-Malmö (Lund University including Lund Institute of Technology, and the University Hospital MAS in Malmö), Gothenburg (SIK/Chalmers) and Stockholm-Uppsala (Uppsala University and the Swedish University of Agricultural Sciences). Some other actors like Karolinska Institutet (KI), which had not previously had VINNOVA funding, did enter into these programs, first as participants and then as project leaders. Hence, encouraging research related to the nutritional and medical effects of food supported existing research environments with new competencies as well as stimulate new actors in these fields.
- In terms of linkages, the programs have stimulated new linkages regionally and also with diverse companies. The programs have

stimulated interaction between existing key research environments, but more often within the regions than across regions. Moreover, the research environments have important linkages and collaborations with companies. Interestingly, these partners are not confined to the food industry, but are instead across several industries. This can be explained by the fact that some challenges, regarding DNA analysis for example, are shared with other industries.

- The research environments often had multiple sources of funding – when analyzed at one time period or over a period of several years. Individual projects often laid the groundwork for successful applications later on. Hence, the cumulative nature of competencies and of grants was identified as important to the development in the area of innovative food. The accumulation of competencies allowed the researchers to work on a particular track over a longer period of time. An implication is that policy-makers need to consider the 'real projects' of the environments rather than only evaluate the immediate impacts of one grant.
- For many projects an important part of the work has been carried out by PhD and Master students, often in close collaboration with companies. This has enabled the students to obtain practical experience and also allowed companies to test and transfer ideas at a low cost.
- Analysis of labor mobility showed that companies' hiring of PhDs is a strong mechanism for knowledge transfer and building linkages in the SSI between industry and academic environments. The main reason for hiring PhDs was to gain access to competencies and scientific skills that could be applied to the companies' own development projects (rather than hiring them to continue the research they had done at the university).
- The project leaders are highly published and cited, indicating clear research strength in the field. The econometric analysis indicates that funding has positive effects on publications. This supports the idea that the ability to access additional funding is crucial for the development and (and survival) of the research environments.
- Patents were not common, which probably indicates that this is a field of science where few academic patents are taken.

Effects on industry:

- The food industry has not grown in terms of employment in Sweden, and instead employment has gone down in this industry. Related trends are increasing exports and international ownership of companies.
- The research programs were designed for collaborative research with industry. An important benefit for some companies is that publishing of scientific results in academic papers enabled them to demonstrate the positive effects of their products, which later helped in sales.
- There is not so much evidence of venture creation in the projects, which does seem worrying – given the overall trend in the food industry to

rationalize and cut employment. Venture creation may be hampered by certain structural characteristics of the food industry, such as economies of scale and large costs of initial investment.

- However, university spin-offs from previous research have participated in several projects and taken advantage of the results. Some spin-off companies from previous periods have played an intermediary role between academic research and industrial R&D. These firms tend to retain close links to the research environments, and they apply their specialized knowledge to the specific needs of the established industry – thereby contributing to the technology transfer from universities.
- The large number of companies and other organizations involved suggests that the programs were successful in making sure that the needs of a wide-range of actors became known to the academic researchers. The development of methods, techniques and instruments is of particular importance to the food industry. This explains why, in addition to the food manufacturers themselves, firms from processing and instruments were also involved in the research projects.
- The rationale and type of industrial involvement varies, ranging from monitoring of the research to providing special materials and products, to actively participating in performing the research. Few firms seem to directly commercialize the research results into products. This is due to considerable time lags and that product development takes place later, internally in the company with use of firm-specific knowledge. Thus, these programs contribute to solving complex problems, rather than directly leading to new products.
- The results also suggest that policy-makers cannot expect companies to start paying for collaborative research, upon conclusion of the public policy initiatives. The companies seem only willing to pay for projects (and people) that are directly related to their products and commercialization. The collaborative research programs contribute in other and more complex ways to increase competencies, develop technologies, and so on.

In the sub-sector of Medical technology, key empirical findings can be summarized as follows:

Effects on research:

- The policy pursued by STU and Nutek in the 1980s and 90s had tremendous importance for the development of several medtech research environments in different parts of the country. This includes the establishment of external collaborative links with clinicians and with industry, a key prerequisite for successful innovation in this field.
- Policy changes from the mid-1990s forced several of the research environments to search for new financiers of their medtech research, which as a long-term effect made them less dependent on VINNOVA and resulted in a more diversified financing situation. With hindsight, we can see that these research environments have in general been

successful in securing continued funding from a variety of sources, even though this was an unintended consequence of the policy.

- The research grants have resulted in a fairly large number of PhD theses in supported technology fields. The graduates have played an important role both in strengthening the academic environments and in raising the scientific competence level in industry (through recruitments by firms).

Effects on industry:

- Over the years, many medtech companies have been involved one way or another in research programs and centers financed by STU/Nutek/VINNOVA. Despite this, many research environments have experienced difficulties in making the established firms interested in more extensive collaboration and in commercializing research results. A main conclusion is therefore that the foundation of spin-off companies is the main route for bringing research-based product ideas and inventions to the market (rather than licensing the rights to existing firms).
- In line with this conclusion, engaging in venture creation has become an increasingly important activity for many of the research environments. Since the late 1980s, a relatively large number of firms have been founded. However, few of them have become commercial or economic successes during this time period. This illustrates the large difficulties and risks associated with this type of business creation and the long lead-times needed to build a successful firm.
- A survey of the large, established medtech companies showed that a majority of them had collaborated with medtech research environments during the past 20-year period and that this collaboration was in general highly valued. The most important effect is that these companies have gained access to new knowledge and competencies that they have been able to use in their own R&D activities. Better monitoring of scientific and technological trends is another major effect of the collaboration. By contrast, development of new products based on specific research results is a relatively rare event.
- The strategy of medtech start-up companies is usually to develop new products and bring them to the market. It is unusual that these firms position themselves as a R&D intermediary between universities and the established industry, as one sees in the biotechnology field. This may change in the future, leading to new business models for medtech companies.
- During the past 20-years economic growth *in Sweden* has not come primarily from the old, established firms (some of which, like Gambro for example, have expanded substantially abroad). Instead, there is a group of other companies, which were comparatively small in the late 1980s, that account for the lion's share of growth. Most of these companies, some of which are university spin-offs, were founded many years ago for the purpose of commercializing results from academic research (medtech and/or clinical). And moreover, they have in many cases benefited from the STU/Nutek/VINNOVA research initiatives

focused in this study. This observation of the growth patterns proves the crucial importance of public research for the long-term development of the medtech industry.

Moreover, this analysis should provide input to discussions of the effects of public policy on research and on industry in other technologies and countries. Hence the final chapter develops a policy tool-kit for chain-linked effects on research and industry. This should advance the discussion about how and why public policy can affect industrial competitiveness and economic growth, in the two targeted fields of life science and more generally. This policy tool-kit includes relevant concepts, analytical framework and models, which are useful to the analysis. The chapter presents two models, one for research and one for industry, describing how different types of desirable effects are related to each other in a chain-linked manner. Furthermore, the tool-kit includes a number of key research issues that are important to address in the policy-making process.

The final chapter also raises the question as to what role that public policy plays within a larger national and sectoral innovation system. The discussion is based upon the assumption that public policy is only one of several variables explaining growth. Still, our conclusion is that public policy can shift the direction (or trajectory) of SSIs, by causing long-term effects on research and industry. The chapter outlines different changes in the SSI that need to be analyzed, including for example changes in knowledge base, actor types, network linkages and information flows.

Contents

1 Introduction

This report ‘Analysis of Chain-linked Effects of Public Policy: Effects on Research and Industry in Swedish Life Sciences within Innovative Food and Medical Technology’ describes and analyzes the long-term developments in research and industry, in life sciences applied within innovative food and medical technology in Sweden. In both of these industrial sub-sectors, Swedish government policy has had the objective of stimulating competitive advantage in firms, through research and innovation policy. Hence, this report should contribute to our understanding of public policy on sustainable growth, by focusing upon the diffuse, indirect and long-term effects.

This report contributes to the debates about public policy and sustainable growth in two ways. Firstly, it provides insight into the Swedish historical developments in two industrial sub-sectors of innovative food and medical technology. These empirical insights are provided through a combination of methods, including case studies, in-depth interviews with participants, surveys, and quantitative indicators. Most studies of life sciences concentrate upon the human healthcare sector as examined in McKelvey and Orsenigo (2006). This report instead concentrates upon life sciences used in relation to innovative foods within the food industry and in relation to the medical technology within the human healthcare sector

Secondly, this report contributes by proposing a public policy tool-kit, which consists of an analytical framework, with a set of related indicators and research questions. This tool-kit provides a way of structuring our discussion of these diffuse, indirect and long-term effects of public policy on research and industry. More speculatively for understanding diffuse, indirect and long-term effects, the analysis underlying this report therefore also provides a structure to analyze how public policy may shift the sectoral system of innovation to a new or improved regime, by stimulating competencies and building network relationships.

The analyses of such effects are theoretically important, due to the complex relationships between private and public spheres to stimulate knowledge and innovation in the modern economy. Moreover, a better analysis of effects is important for the development of a more effective and evidence-based public policy, due to the millions spent around the world to stimulate competitiveness.

The principal purposes of this report are:

1. To detail the methodology and research design used to carry out the study, as this facilitates comparison and similar initiatives for other programs and in other countries.
2. To analyze the large amount of empirical material which has been gathered about the targeted research projects in life sciences, i.e., the two targeted areas innovative food and medical technology.
3. To identify and answer the key issues, in order to propose and analyze the empirical results in terms of the concepts and analytical framework of interest to the public policy debates.
4. To contribute to public policy, by developing a tool-kit. This public policy tool-kit should include relevant concepts, analytical framework, and models, which are useful to analyze and discuss long-term effects of public policy on research and industry.

This report is part of a larger study commissioned by the Swedish Governmental Agency for Innovation Systems, here shortened to its Swedish name VINNOVA.[1] There have been a series of Swedish government agencies – specifically STU, Nutek and VINNOVA – which have financed public policy into research and innovation, since at least the 1970s in the areas studied here. The Swedish government and constituent agencies are interested in the long-term effects of such policies. Hence, this report is part of a series of several different reports, commissioned by VINNOVA for the Swedish Ministry of Industry. This specific report concerns an analysis of the long-term effects of research and innovation efforts, with a focus of the effects on *research* and *industry*.[2]

This report 'Analysis of Chain-linked Effects of Public Policy' follows the initiatives by VINNOVA, to change the perspective from short-term evaluation to the long-term stimulation of processes. Hence, the perspective taken in this report is how to follow the chains of causality over more than 10 years, and within an innovation system perspective. Public policy is increasingly interested in the long-term and more systemic effects, due to interdependencies and substitution effects amongst the actors and processes involved (Smith 2000; Metcalfe 2005; Metcalfe 2007). One aim here is to provide a more structured model for identifying the 'effects' of public policy on industry and for improving methodology for analyzing the results.

[1] For more information on VINNOVA, see www.VINNOVA.se.

[2] These are the two effect areas for which the Institute for Management of Innovation and Technology (IMIT) has been assigned to carry out the analysis. VINNOVA is also interested in a third effect area, that is, effects on *society*, including health-economic calculations, which was assigned to another contractor, Center for Medical Technology Assessment at Linköping University.

A related starting point is the current focus of VINNOVA's work on the development of internationally strong "research and innovation environments". This implies that the Effect Analysis should deal with broad efforts during long periods of time, where life science is a good example of Swedish public policy. Another essential point of departure is that it should give an input to the policy discussion (VINNOVA 2007a). However, this report is not expected to include policy implications.

Based upon the four principal purposes defined above, this report will therefore provide empirical insights into long-term developments in research and industry in innovative food and medical technology. This detailed empirical material will be analyzed in relation to the chain-linked effects of public policy. We use the concept of 'chain-linked effects', in order to identify selection mechanisms at different levels in the overall sectoral system of innovation. Public policy can affect these selection mechanisms – and the competencies of actors and network relationships – in such a way as to facilitate the development of a new or improved regime, relative to temporal external conditions.

This chapter provides an introduction to this report. Section 1.1 defines the main concepts of innovative food and medical technology. Section 1.2 provides background information of the initiatives within Swedish public policy to develop Effects Analysis. This section introduces main concepts used in Swedish debates, methodological approaches, and public policy lessons. Section 1.3 describes the structure of this report.

1.1 Definitions of Innovative Food and Medical Technology

This report focuses upon the use and development of life science related knowledge, as public policy influences research and industry. The two sub-sectors studied are innovative food and medical technology. Because the public policy stimulates research and innovation, both sub-sectors are defined in terms of the application of the knowledge to specific areas of goods and services.

VINNOVA considers the life science industry to be an important branch of industry, of economic and political significance to today's Swedish society (VINNOVA 2007c p. 6). Life science companies are classified by VINNOVA in three different sectors: Medical technology, Biotechnology and Pharmaceuticals. In this report, we are only examining a narrow part of life science – and also other bodies of knowledge – in relation to innovative food within the food industry and in relation to the medical technology in the human healthcare industry. Hence, the goals of the public policy studied here have not been to stimulate life sciences per se. The point of the public policy is instead to use a combination of life sciences and other technologies/fields, in order to promote competitiveness and social well-being.

'Innovative food' is the name of one of two food-related programs analyzed in this study (see further Chapter 4). This concept is useful here as an overall name for these two public policy programs and for this type of development in the food industry. There are no generally accepted concepts, although concepts like 'functional foods', 'intelligent foods', and 'nutritionals' have been popular at different time periods, for specific types of new food.

Hence, our use of the concept of Innovative food reflects the direct attempts to stimulate more competitive products and goods, often through research within a series of related products, competencies, and specific technologies, instruments and similar aspects. Most of the focus is upon improvements in health, food safety, and measuring effects, but achieving these broader social goals often requires developments in specific technologies such as sensors and biomarkers to identify the characteristics of the grain being used and its relationship to health, and so on. This may also includes parts of the agriculture sector, such as agricultural biotechnology, if applied to healthcare concerns. Hence, the actual research conducted to achieve these goals goes well beyond what would be traditionally considered 'life sciences'.

Moreover, the food sector is broad and comprises a large number of firms operating at different levels in the value chain and producing various types of inputs and of food products. This study does not cover the whole food area, but instead focuses on companies and research institutions involved in the development of "innovative food", especially where life science is used. Given the consumers' increasing interest in food for health, this is assumed to be a growth area – both nationally and internationally. The analysis thus focuses on actors that perform research and development (R&D) of relevance for the development of new food products with health-enhancing properties.

In a recent study, VINNOVA defines the *medical technology* ("medtech") sector as companies that develop medical products that are not drugs (VINNOVA 2007c). Another recent study provides a more specific definition, which includes both medical devices and diagnostics: "Products/solutions/systems used in hospitals, other care centers or for out patient/home care" (ActionMedtech 2007, p. 65).

This includes:

- High-technology devices (equipment and supplies) and/or solutions/systems used to (a) diagnose, prevent, supervise, treat or alleviate a disease, injury or handicap and (b) examine, modify or replace the anatomy or a physiological process.
- “Lower”-technology devices mainly used to assist healthcare professionals in their care of patients, e.g., (a) infection control, patient hygiene etc and (b) hospital beds, patient lifts etc.

In other contexts it is common to define medical technology as a list of relevant technologies, which are applicable to medicine and medical practice. For example, an international evaluation of Swedish research in biomedical engineering (Swedish Research Council 2006, p. 14) identified fifteen sub-fields (see Appendix 1). *Biomedical engineering* is another frequently used term that we will consider as synonymous with medical technology.

A more ambitious discussion on the terminology can be found in Sidén (2003, p. 13-19). This author mostly uses the term “medical device(s)” as a general term for the products of the medical technology industry (p.15).

In summary, this report started with an evaluation of the long-term effects of public policy on two areas of life sciences, namely innovative food and medical technology. The actual goals of policy were to stimulate new knowledge, also of economic and social importance (rather than to support research per se). Hence, the definitions of the sub-sectors starts from the specific products and goods, but when we examine the actual research required to achieve those goals, it turns out that research may be carried on in a variety of disciplines, technologies, and companies.

1.2 Relating to Swedish public policy and previous effect analyses

This report should be seen in the context of developing Swedish public policy. Our view is that Swedish public policy has dealt more with experimental, systemic competencies development and networking than more narrow demonstrations of effects (see Chapter 2). This broader perspective also allows for a discussion of the broader and more long-term effects of public policy. This report is a further development of specific national discussions, set in relation to the international literature. This section first describes the overall context, and then specific learning experiences from previous Effect Analysis.

In terms of the national innovation system, Swedish public policy related to science, technology and innovation has worked for many years to promote connections and interactions between private actors like firms and public actors like Ministries of Education and Industry. VINNOVA is literally the Swedish Agency for Innovation Systems. Similar public policy initiatives can be found in predecessor agencies, especially STU (Swedish National Board for Technical Development[3]) and Nutek (Swedish National Board for Industrial and Technical Development[4]).[5] Sweden has a long history of identifying industrial and technological areas of interest to public policy makers and to industry, and to stimulating needs-driven research as well as in more recent years, collaborative public-private research agendas. The aims of these initiatives can be broadly said to stimulate the development of science, engineering and technology which can help increase the competitiveness of the nation and its industries.

The background to this study is that VINNOVA is required by the government (i.e. *Näringsdepartementet*) to carry out, annually, so-called Effect Analysis in two areas. For 2008, it was decided that two sub-sectors within life science should be analyzed, namely, medical technology and innovative food. Both these research areas have received extensive financial support from VINNOVA and its predecessors (STU and Nutek) over the years.

VINNOVA has worked to conceptualize and codify the effects of public policy, and differentiates short term evaluations from the long-term effects studied in this report. (VINNOVA 2007a). It differs from other types of evaluations and effect studies that VINNOVA carries out related to individual programs, such as final evaluations of the outputs of a specific project or program.[6] The concept in Swedish is *Effektanalys* ('Effect Analysis'). VINNOVA defines Effect Analysis as studies carried out in order to map the long-term, overall effects of its efforts on industry and society, especially as related to sustainable economic growth.[7]

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[3] In Swedish: *Styrelsen för Teknisk Utveckling*.
[4] In Swedish: *Närings- och teknikutvecklingsverket.*
[5] When VINNOVA was established in 2001 the science and technology part was broken out of Nutek and merged into VINNOVA. What was left of Nutek is now (January 2009) called the Swedish Agency for Economic and Regional Growth (in Swedish: *Verket för näringslivsutveckling*) and focuses on industrial and regional development more generally.
[6] These are effect logic testing ("effektlogikprövning"), mid-term or final evaluation ("utvärdering"), and the continuous follow up during the execution of the program ("uppföljning"). These four tools constitute integrated parts of the total effect valuation process. See VINNOVA (2007a) for further details. So-called *Följeforskning*, a kind of interactive research, has in recent years been introduced as a complementary tool in certain programs. Its main role is to facilitate learning for involved actors and support the program management.
[7] The following text mainly builds on VINNOVA (2007a).

According to VINNOVA, the purpose of Effect Analysis is to use many-dimensioned, multiple indicators and independent information as a means to highlight the achieved effects of needs-driven research and to create increased understanding of research and innovation dynamics and factors that affect success and failure. The Effect Analysis should provide conclusions regarding the effects of the agency's efforts, support public investments in research and development (R&D), and give necessary information as a basis for strategic policy decisions.

This type of analysis is carried out by independent, external experts, usually 5-10 years after the completion of the research – sometimes even 15-20 years afterwards. The Effect Analysis should comprise broader efforts than individual programs and cover a longer period of time. VINNOVA commissioned external experts and has completed five Effect Analysis studies during the period 2002-2007.

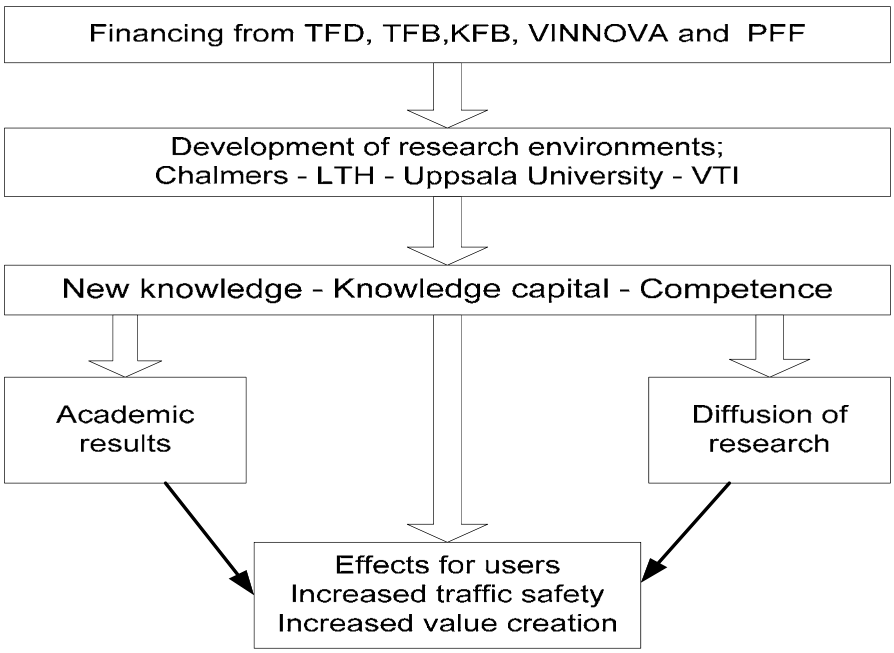
We agree with VINNOVA that a body of knowledge for public policy about the long-term developments and about Effect Analysis is useful. Similar concepts and discussions are being used in other countries and in the Organisation for Economic Co-operation and Development (OECD). Simple linear relationships between two variables are generally not possible in these contexts. One reason is that the innovation systems are open to many other variables and processes, outside the control of policy. Hence, the existing body of knowledge about Effect Analysis – as linked to innovation research more broadly – demonstrates the need to address complex interactions across actors, institutions and knowledge.

Thus, the learning experiences from the previous Effect Analysis commissioned by VINNOVA are relevant to the current report. Three aspects of the learning experiences can be roughly categorized into 1) broad lessons, 2) concepts and relationships, and 3) methodology. They will be discussed in turn below.

A first aspect is the broad lessons. Generally, the experiences are very positive, in the sense that the studies do indicate that public policy evolves. Public policy can develop tools and concepts which go beyond the very specific, almost standardized indicators generally used for evaluations of the immediate outcomes of projects and programs. Thus, the previous studies have generated valuable knowledge about the effects and also provided detailed empirical cases and data about specific areas of industry and research. Taken together, the completed analyses have illustrated how publicly funded R&D can produce valuable effects on the research system, on the industry's innovation capability, and on the society at large. Another general lesson is that Effect Analysis studies covering a longer time perspective and more than one individual program can be successfully performed.

A second learning experience is the discussion and further refinement of concepts, frameworks, and relationships. Previous Effect Analysis studies have proposed different conceptual approaches. One of them, from a study of the Swedish traffic safety research, will be presented and discussed here. The analysis focused on so-called *effect chains* stretching from research financing via the research environments' behavior and knowledge diffusion to end-results in the form of reduction in the number of deaths and injuries and increased value creation in Swedish industry (VINNOVA 2007b). Figure 1.1 shows a simplified version of the analysis model used in that study.

Figure 1.1. Effects from publicly financed traffic safety research – a model of effect chains



Source: VINNOVA (2007b)

Figure 1.1 indicates that financing from research funders can help develop research environments, which in turn develop new knowledge, knowledge capital, and competence. By stimulating academic results and diffusion of research, this has effects on the users, such as increased traffic safety and increased value creation.

Figure 1 demonstrates that effects can take place at several levels, with follow-on effects. The specific case on traffic safety provides a powerful example of the positive effects of publicly financed research on firms and on social welfare. It also indicates that public policy can affect a variety of actors and processes in society, which is in line with the innovation system approach.

This model thus illustrates that financing of needs-oriented research through public policy can lead to the development of research environments at universities and research institutes. These in turn create new science, knowledge capital and competencies, which lead to academic results, effects on users, and diffusion of research results.

A third aspect is the methodological lessons. In the past, three main approaches have been used by the evaluators to varying degrees (VINNOVA 2007a, p. 73-75):

1. Descriptions of the field of study in the form of embedded stories aiming at deepening the understanding
2. Presentation of individual cases in the form of "success stories"
3. Cost-benefit calculations

The different reports included in the overall study of innovative food and medical technology include all three approaches. Each specific report also details some problems and alternative methodological issues.

Moreover, methodological lessons from previous studies indicate the importance of setting up the studies in a particular way. Lessons include having evaluators with competence both in the subject field and in evaluation technique, using and assessing written documentation about the programs and projects (such as the original applications, evaluations), and the importance of discussion and interaction between the commissioned experts and the actors concerned (in academia, industry and society). Furthermore, experiences from previous work show that it has taken 18-24 months to carry out an Effect Analysis, and that it is advantageous to divide the work into a pilot study and sub-studies (i.e. different parts of the main study). Still, the choice of theoretical and methodological approach has crucial importance for interpreting the results.

In summary, this report has been written in a specific context of Swedish public policy, with three types of lessons from previous effect analyses applied here – namely broad lessons, concepts and analytical frameworks, and methodological lessons.

1.3 Structure of report

Chapter 2 outlines the concepts, framework and key issues. We start by defining what we mean by a public policy tool-kit and premise for the public policy context. In terms of the existing concepts and analytical frameworks introduced above, we felt that they were too linear and also not so clearly related to the empirical material. Chapter 2 therefore details our development of the concepts and analytical framework, set in relation to the sectoral system of innovation. This provides a guiding framework, in order to sort-out and focus upon specific issues in the study. These key issues are identified at the end of this chapter. This framework thus helps us concentrate on how to integrate and synthesize our understanding of public policy on sustainable growth, by focusing upon the diffuse, indirect and long-term effects.

Chapter 3 details methodology and research design, including data. We mention the team members who have contributed, as well as how we started with a pilot study and after that carried out a main study which resulted in this report. In the pilot study, we spent much time sorting out background documentation such as overviews and project details, and in developing complementary methodologies including interviews with researchers and company people, and in relating that data to the analytical framework. This chapter explains our choices and ways of working and documenting the process, as well as validity and limitations.

Chapter 4 provides insight into relevant public policy initiatives studied here and the sub-sectors of innovative food and medical technology. Of course, one relevant aspect is the existing overview of research, policy and industry, in order to know whether anything has changed or not. This overview provides insight into the characteristics of the sectoral systems of innovation and identifies key actors in Sweden (both firms and research units).

Chapters 5-7 present and analyze the empirical data that we have collected by various means. Chapter 5 focuses on the effects from the perspective of academic research, while Chapter 6 does the same but from the perspective of industry. In Chapter 7 we summarize our findings in terms of the key issues that we have identified in Chapter 2.

Chapter 8 rounds off the report, with more abstract models and ideas. This chapter first presents our 'Tool-kit for Chain-linked Effects on Research and Industry', which includes a series of models and key research questions. The final section then discusses our results in the more abstract form of whether and how public policy may shift trajectories within sectoral systems of innovation.

2 Concepts and Analytical Framework

2.1 Introduction

Together with Chapter 8, this chapter fulfills the fourth purpose of this report, namely ‘To contribute to public policy, by developing a tool-kit. This public policy tool-kit should include relevant concepts, analytical framework, and models, which are useful to analyze and discuss long-term effects of public policy on research and industry.’

This chapter contributes to the report, by providing a structure for analyzing the broad picture of what has happened in research and industry in the specified areas of life sciences over a longer period of time. The two selected fields of life sciences are medical technology (“medtech”) and innovative food. The report also relates these long-term developments to efforts made by STU, Nutek and VINNOVA. This is under the assumption that analyzing the focal phenomena – that is the effects of public grants on research and industry – in a structured manner can contribute to our understanding of public policy in sustainable growth. This is done by focusing upon the diffuse, indirect and long-term effects

While one can discuss the sectoral system of innovation (SSI) for biotechnology and life sciences (McKelvey et al 2005), we apply this concept specifically to the two focal sub-sectors.

This chapter therefore first discusses some public policy issues and provides concepts of sectoral systems of innovation, before moving on to a useful analytical framework, and then the key issues to be studied here.

2.2 What is a public policy tool-kit?

One of the main purposes of this report is to develop a tool-kit, which will contribute to public policy. Our proposed one is called ‘The Tool-kit for Chain-linked Effects on Research and Industry’.

The idea of a ‘policy tool-kit’ has gained popularity in recent years, as a Google search will verify, but mostly in the world of the practitioners. Many of those available enable stakeholder involvement in particular policies – such as telecommunication regulation or water disputes in California – or else they are flow-charts, which specify courses of action, to aid decision-making.

For the purposes of this report, we have specific views upon what we mean by a policy tool-kit, specified below in terms of what, why and how.

What is a policy tool-kit?

We interpret that a policy tool-kit usually has overlapping objectives. It should provide basic definitions and understandings. It should frame the understanding of the process of interest. And it should provide the reader with ways of thinking about key variables influencing that process and about different outcomes (or scenarios).

Therefore, in the context of this report, our policy tool-kit includes the following elements, which are based upon the techniques of social-science research:

- Definition of concepts and variables (Chapter 2)
- Outline processes whereby policy may lead to specific effects upon research and industry (Analytically in Chapter 2; Empirically, Chapters 4-6)
- Propose general model for effects (Chapter 2)
- Identify flows and feedback mechanisms (Analytically in Chapter 2; Empirically, Chapters 4-6)
- Identify chain-linked effects of public policy on the sectoral systems of innovation (Analytically, Chapter 8)

These elements then contribute to the 'Tool-kit for Chain-linked Effects on Research and Industry', as specified through models and discussed in Chapter 8.

Why propose a policy tool-kit?

We feel that the academic innovation literature is rich with concepts and hypotheses about the role of public policy and about the complex nature of innovation in the modern knowledge economy. However, these conclusions are at time very abstract. Although they have greatly influenced policy – such as 'knowledge economy' or 'innovation system' at the aggregate level, there may be a gap to specific choices made by specific politicians and policy-makers. Therefore, for innovation processes studied here, we felt a strong need to identify and relate specific phenomena and expected effects upon other phenomena and other levels of analysis.

Hence, our tool-kit should help clarify the processes identified in this report. It should also be designed in such a way to be an input into deciding, implementing and following-up similar policy in other sectors and technologies.

In other words, the concepts, framework and models should help us to sort out the variables studied in the empirical material, including priority, impact and mechanisms on other levels of analysis.

What does the policy tool-kit look like?

A flow-chart, to structure the phenomena and levels of analysis, as well as the expected effects on research and industry.

Chapter 8 synthesizes our results about how and why public policy can impact upon research and industry. It does so in terms of a model of process flows and feedbacks among different levels of effect, whereby public policy impacts the actors' activities, resources, competencies and outcomes as well as the sectoral innovation systems as such.

The tool-kit can be used in two ways. Firstly, it can be used to design studies, which can be an input into policy learning. Therefore, it also discusses some issues related to the handicraft of doing such studies, with illustrations of additional questions and types of data. Secondly, it can be used to position where – within this larger process – that a particular policy is expected to have impacts. Hence, this should help public policy-makers to design more specific protocols and instruments, to make more fine-tuned interventions within the innovation system.

Of course, many existing policy tool-kits in other fields are based upon software. Although our tool-kit is embodied in this report, it is possible that future developments jointly with VINNOVA could be turned into a web-based tool.

2.3 Public policy context

This section considers what we mean by public policy for innovation, set in the Swedish context.

Our theoretical view focuses upon the innovation system and actors, as further elaborated in the next section. This view is related to an understanding of the process of what happens after policy has been initiated. The modern understanding of political action and processes is that policies involve many stakeholders, with various degrees of coordination and negotiation between public and private actors. This has implications for how to better design and implement policy.

Richard Nelson wrote a book in 1977 called *The Moon and the Ghetto*, which reflected upon why American public policy could send a man to the moon, but could not solve the socio-economic problems of the ghetto. This may seem far away from our focus upon effects on research and industry.

But instead he used this comparison to propose a specific view of how to conceptualize public policy, which is of direct relevance here.

According to our interpretation of Nelson (1977), in relation to the current literature and in this study, public policy can be better understood – and also better designed for the future – if we see it in terms of:

- Enhance the understanding of the problems, based upon the premise that the objective of policy analysis is not to find an optimum. Rather than striving for optimization, policy should focus upon identifying reasonable moves to be made next, and which will lead the development in the right direction.
- Influence the discourse and bargaining of democratic politics. In today's language, that means that stakeholders should be more directly involved in setting policy.
- Design an organizational structure for public policy which is flexible. The organizational structure should be capable of learning and also of adjusting behavior and programs, in response to what has been learnt.
- Understand the interlinked nature of modern public policies. They cannot be seen as a straight substitute for market failure, where the state only intervenes when market coordination mechanisms do not work. Instead, public policies today require a mix and interlinked set of interactions between public-private, firm-government, market-non-market, and so on.

Therefore, this understanding of what public policy is – and how it should be better designed and implemented in the future – guides us in proposing elements of our tool-kit. We will return to this discussion in Chapter 8.

Innovation policy has become a buzzword for policy-makers to stimulate growth, due to the demonstrated impact of knowledge and innovation upon long-term growth. Because of that, innovation policy has become a vital arena for policy-making in many countries and in international forum such as EU and OECD. It is often linked to science/research policy and to competitiveness issues.

Definitions of the types of policy which may influence innovation are often extremely broad.[8] For example, Kuhlman (2001:954) defines innovation policy as 'the integral of all state initiatives regarding science, education, research, technology policy and industrial modernization, overlapping also with industrial, environmental, labor and social policies'. Kuhlman (2001), Edquist (2001), and similar definitions thus start with the total set of public policy initiatives which potentially affect innovation. Other definitions focus

[8] A PhD dissertation from University of Manchester was very useful in helping us to frame the debates about innovation policy. See Paraskevopoulou (2008).

more upon the capacities of firms. For example, Georghiou (2006) sees innovation policy as ‘any policy which seeks to help firms, singly or collectively, to improve their capacity to innovate’. From starting at the firms’ capacities, he then also identifies many types of relevant policies, but places innovation and firms in the center (rather than policy per se).

Hence, these definitions of innovation policy are clearly relevant to the ambitions of the STU/Nutek/VINNOVA policy initiatives which are studied here. At the same time, these definitions are very broad, and give little insight into which types of policy to prioritize or even, which aspects of innovation policy may influence which aspects of the innovation system.[9]

In this report, the broader efforts and the public policy initiatives which are analyzed should contribute to innovation and competitiveness.[10] In that sense, the specified initiatives are also part of and directly relevant to innovation policy. However, the initiatives which are studied here do not cover all the broad areas outlined above. They have more focused objectives and mechanisms for reaching the stated goals.

This report focuses upon public policy initiative from Sweden from the 1980s, 1990s and to some extent 2000s. This view about the core role of knowledge and innovation for growth has become more prevalent in Sweden in recent decades. For the broader Swedish policy, one key event in diffusing this perspective was the report ‘Innovative Sweden: A Strategy for growth through renewal’ released jointly by Ministries of Industry and Education (Ds 2004:36). Note, however, that the Swedish government agencies STU, Nutek and VINNOVA have pushed this view for many decades – partly influenced by the early Swedish academic research on innovation processes, innovation systems and science policy evaluation.[11] These Swedish initiatives studied in this report can thus be seen as an element of innovation policy as defined above, but they are also more specific to how and why to stimulate innovation in the economy.

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[9] See VINNOVA (2006a) for a recent review of how far Sweden has come in developing an innovation policy.

[10] We use the word ‘initiatives’ to refer collectively to the projects and programs studied here. We also use the word ‘efforts’, which should cover not only the initiatives that we study, but also the broader set of public policy attempts to influence innovation and the sector. Efforts are used to reflect the Swedish word ‘satsningar, which is widely diffused in policy circles to cover this broader concept.

[11] These statements are difficult to verify, although some PhD theses have recently followed the early developments of public policy (Schilling 2005). Moreover, the statement is also based on our experiences, in that the authors have been involved in these academic-public policy interactions throughout their professional careers. We are confident of the validity of these statements, because Sweden is a small country, with tight personal linkages across many areas of society. At that time, few persons worked on innovation, and they were usually linked to specific environments.

In the interpretation of the authors, the policy initiatives analyzed in this report share the following common characteristics. These initiatives are most likely based upon implicit assumptions that have run through Swedish policy during these decades that innovation is a complex process, involving heterogeneous actors. They are focused upon developing research and capabilities, which should help stimulate innovation and competitiveness. They are primarily needs-driven (and possibly, user-driven), in the sense that they are focused towards specific sectors and sub-sectors in the economy. They often require industrial interaction, forms of collaborative research and centers of excellence that should stimulate complex feedback mechanisms between actors.

This knowledge is general in the Swedish context, but often created by specific policy-makers and in relation to specific objectives. Therefore, we feel that more specific ways of conceptualizing specific elements of innovation policy are needed to design, implement, and evaluate specific policies. Our proposed one is called 'The Tool-kit for Chain-linked Effects on Research and Industry'.

The policy initiatives studied here are of course the result of a broader policy process in Sweden. We recognize that a rich literature exists about policy analysis, policy processes, political action, and so on, but cannot go into details about the literature here, nor do we study political processes per se. Still, we wish to say a few words about how our analysis is positioned relative to other discussions on public policy, in order to be more specific about our contributions.

One approach to public policy related to innovation systems is to identify the main actors, connections, and so forth. Two examples of this approach are 'Using evolutionary theory to delineate system of innovation' (McKelvey 1997) and 'Functionality of an innovation system' (Bergek et al 2008). This provides an analytical overview of the whole innovation system. To place this in relation to policy, one could then identify which actors, elements, and functions of a system are most relevant to policy and how to intervene. The latter reference above is specifically focused as a tool for policy-makers. This type of approach is useful, if the purpose is to analyze the overall system and how to improve it. However, the purpose of this report is different, in that we are analyzing long-term processes within the innovation system, and we also wish to identify specific effects of public policy on specific phenomena.

One concept used in discussions of policy is that of 'additionality'. It has been widely used in especially the EU but also in many other countries. The basic concept is that public policy ought to have an impact, or 'additionality', which would not have occurred, if the policy had not been implemented. Theoretically, this concept can be interpreted as referring back to the market failure idea, such that public policy should only be implemented if the market fails and thereby there is a specific need to intervene through policy. Testing the idea of additionality usually assumes that you can distinguish in your samples. If you use a historical and/or case study approach, you would have to analyze the counterfactual case (e.g. the 'what if' this did not happen in this case). If you use a quantitative study, then you have control samples as well as the sample where the change occurred, so that the control sample could be the pre-policy phase or a population which is similar but did not implement the policy change.

Additionality is usually discussed in terms of 'input additionality' and 'output additionality', and has been applied to innovation and technology policy, especially EU programs (Buisseret et al 1995; Luukkonen 2000). Kim and Song (2007) provide a specific definition (based upon Georghiou 2002). Input additionality is a concern with whether resources provided to a firm are additional, that is to say whether for every Euro provided in subsidy or other assistance, the firm spends at least an additional Euro on the target activity. Output additionality is the proportion of outputs which would not have been achieved without public support. In our context, an example of an 'input additionality' would be that firms invested more money into R&D (an input) than they would have, if the policy had not been there. An example of 'output additionality' would be that more products were commercialized than before (assuming the variables are fixed).

More recently, the concept of 'behavioral additionality' has been introduced for technology and innovation policy. The concept of 'behavioral additionality' is more similar to the analysis developed in this report (Georghiou 2002; Georghiou 2003; Kim and Song 2007). An example of a 'behavioral additionality' would be that actors changed their behavior, so that the firm started to invest in R&D during the program and then continued to invest in more R&D than previously, after the policy is finished.

The normal concepts of 'input additionality' and 'output additionality' would be more appropriate to a study of direct causality and immediate impact of policy. They are also based on a somewhat different theoretical understanding of the underlying processes. Therefore, the main reason for not presenting our conclusions and analysis in terms of 'additionality' is that our concepts, analytical framework, models, key issues have a much broader objective. They are not limited to direct and immediate outcomes of a specific project. Instead, our tool-kit is designed to capture our understanding of public policy on sustainable growth, by focusing upon the diffuse, indirect and long-term effects.

Of course, much more should be done to consider the concept of additionality, and how it differs from our proposed concepts and policy tool-kit. This work would be a very important contribution to discussions of policy. However, that work will have to wait for a later study, as it goes too far beyond our objectives with this report.

In summary, this section has presented our view of how to think of policy as processes of defining reasonable ways forward (rather than an optimal solution). We have also placed our view relative to other views, such as that of additionality.

2.4 Analyzing the chain of effects in SSI

This section presents our view of the relevance of how and why concepts such as ‘sectoral system of innovation’ and ‘actors’ competencies’ from innovation studies are relevant to our purposes. This section therefore presents some concepts and theories, which can help link public policy to the desired changes in the Swedish innovation system.

What are sectoral systems of innovation?

The concept of ‘Innovation Systems’ has been developed since the early 1990s, through a rich interaction between academic goals and public policy (Sharif 2006). One of the main objectives of the approach has been to contribute to novel insights and ways of understanding long-term economic growth, usually set in a perspective of Schumpeterian-inspired transformation (Edquist and McKelvey 2000). Three main levels of analysis are the more common ones, namely national, regional and sectoral.

The concept of ‘Sectoral systems of innovation’ (SSI) is used here for two reasons. The first is that we are in this study interested in sets of knowledge (especially scientific and technological) which are used and transformed into economic value by firms (in innovative food and medical technology in our case). The second is that this approach is fundamentally dynamic, at a level suited for our analysis. The SSI is based upon evolutionary economic theory, and thereby links the sector specificities of knowledge and institutions to competitiveness and production in those firms and sectors.

According to Malerba (2002) and further elaborated in Malerba (2004), the following definitions include the core elements of an SSI:

> A sectoral system of innovation and production is composed by the set of heterogeneous agents carrying out market and non-market interactions for the generation, adoption and use of (new and established) technologies and for the creation, production

> and use of (new and established) products that pertain to a sector ("sectoral products").
>
> A sectoral system has a knowledge and a technological base, and key links and complementarities among products, knowledge and technologies, which greatly affect the creation, production and use of the "sectoral products".
>
> The agents composing the sectoral system are individuals and organizations. These organizations may be firms (such as users, producers and input suppliers) and non-firm organizations (such as universities, financial institutions, government agencies and so on), as well as organizations at lower or higher levels of aggregation (such as consumers, R&D departments or industry associations). Agents are characterized by specific learning processes, competences, structures and behaviors. They interact in a market and non market way through processes of communication, exchange, cooperation, competition and command, and their interactions are shaped by institutions (rules and regulations).
>
> A sectoral system changes over time through co-evolutionary processes.

Hence, the definition is rich and broad. For us, key aspects of the sectoral system of innovation includes its constituent actors, institutions and networks (Malerba, 2005).

The sectoral system of innovation approach provides a useful starting point for our study because it:

- Specifies that it is useful to identify the key actors and relationships amongst them as related to processes of innovation and competitiveness
- States that analyzing a sector is not restricted to only the firms per se. Instead there are multiple and heterogeneous actors – such as firms, public policy agencies, users, universities and so forth – of relevance.
- Identifying knowledge as a key input and helps determine the competitive base of the industry;
- Specifying the market and non-market interactions which are of direct relevance
- Identifying that the sectoral system co-evolves over time, in the sense that there are strong feedback loops between different elements, networks relationships, and levels of analysis.

To develop the sectoral system of innovation (SSI) approach relative to the aims and understanding developed in this report, we need to further understand the development of actors, competencies and relationships across the system.

What about the division of labor between science/universities and technology/firms in the SSI?

There is one traditional aspect for science and innovation policy, which still applies to some extent. One way to think about the role of specific actors – especially firms and universities – within the SSI is the idea of division of labor in knowledge production. Nelson (1959) and Arrow (1962) analyzed knowledge as a particular type of public good. In economic terms, public policy invests particularly into basic research, because private firms have a 'paradox of appropriability'. Firms have incentives to invest less into R&D than the 'social optimal level', because knowledge (and especially basic research) can transfer, or spill-over to many actors. The investing firm will therefore capture only a share of the societal benefits of new knowledge. Public policy may therefore play a role. Public policy avoids the problem of 'underinvestment', or to put it the other way around, the role of public policy is to make sure that the total amount of money that society invests into science, technology and innovation is at an 'appropriate level' so that society as a whole benefits from economic growth (Scherer 2000). The explanation is likely that the government finances more basic, long-term work, which is relevant to many different actors, and can thereby potentially have a large effect over many actors and sectors. Whereas in contrast, the firms tend to finance work which is closely related to their own current products, and therefore have a more restricted total impact.

Here, however, we cannot assume this ideal view that public actors invest in basic and long-term research whereas companies invest only in development close to products. Indeed, theoretically, several papers have demonstrated that that science and firm R&D often take on overlapping roles (Pavitt 1998; Rosenberg 1994). Moreover, the empirical situation differs and one cannot make these assumptions about division of labor. The research projects are the result of pooled investment of both public and private monies, with the universities usually being project leaders. VINNOVA is now explicitly designed to promote 'needs-driven research', which is useful as an input into sustainable growth, and its predecessor often had an implicit mandate for similar types of goals. Empirically in these research programs and projects, we can observe that researchers from universities and research labs work closely with R&D units of large firms as well as small spin-offs on the same projects. Thus, we must think more closely in the future about what the view of the division of labor for knowledge production means in collaborative context and projects.

For this report, two important points arise from the above discussion about division of labor. One is that even if there is a not a clear division of labor, the researchers at the universities and research institutes will still have different incentives, rational and competencies than the industrial researchers, to bring to the joint projects. We need to differentiate what each partner expects, and also obtains, from collaborative research projects, even ones designed as needs-driven research. The other point is that working together can lead to a wide range of benefits (and problems), such that each partner can do research, development and product development that they would not otherwise have performed. Examples can include assess to laboratory equipment, biological materials, and new scientific research questions (Harvey 1994). This can be examined empirically, as well as theoretically.

How do innovation processes occur, within SSIs?

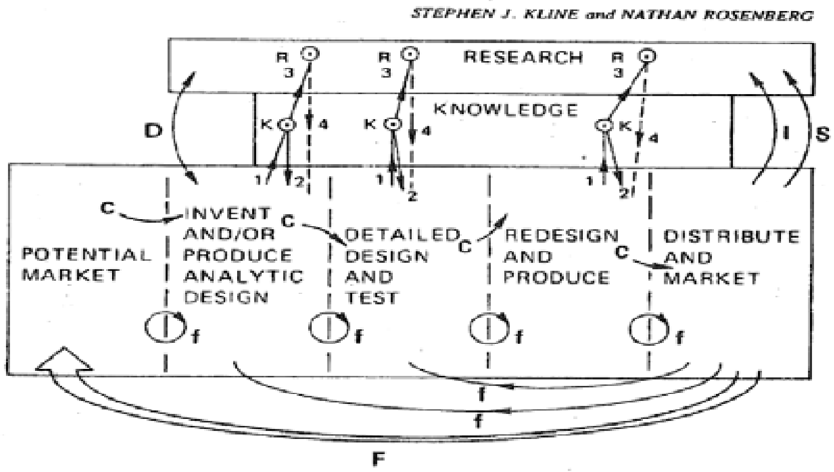
Innovation is a concept which has become quite commonly used. According to Schumpeter (1934), innovations may consist of novelty in a number of dimensions of relevance to the economy. These can be new goods, a new quality of a good, new method of production, the opening of a new market, new sources of supply of raw-materials and half-manufactured goods, new organizations, new business models, new services, and new marketing techniques. This is a very broad definition of an innovation of relevance in the economy.

Literature on the economics of innovation and on science and technology stress that actors exhibit a diversity of competencies and rationale for engaging in open innovation processes (Dodgson et al 2008). This implies that people and organizations involved in, respectively, university research and in firm commercialization will have different incentives and knowledge bases. Public and private actors must collaborate, and labor mobility helps stimulate spill-over.

For more specific aspects such as network relationships, additional theories contribute to the understanding of how and why such interactions occur. Industrial networks, networks of innovators and distributed innovation systems are clearly relevant concepts here, as they draw attention to issues about distributed competencies, linkages, and coordination issues (see, e.g., Håkansson 1989; Freeman 1991; Coombs and Metcalfe 2000).

Therefore, we wish to place the SSI approach, relative to the view of innovation processes within such systems. A key result of the network literature is that one cannot expect to identify direct effects of public policy to directly lead to commercialization in products but must instead build more complex models to understand innovation processes. One of the most relevant ones for this analysis is the Kline and Rosenberg model, which presents elaborate feedback mechanisms amongst different actors and processes within the innovation system (see Figure 2.1). Moreover, this model is particularly relevant here, because the Swedish policy-makers at STU, one of VINNOVA's predecessors, were influenced by the Kline and Rosenberg model when it was presented.[12]

Figure 2.1. Chain-linked model



Source: Kline and Rosenberg (1986)

The findings of the innovation literature (at the overlap and intersection of business, economics and sociology) have lead to a number of basic theoretical starting-points, which are also relevant here (Fagerberg et al 2005). Among other key theoretical and empirical results, this research has led to the rejection of the idea that innovation proceeds in a straight forward way from the discovery of new science through development and finally to commercialization in companies.

Smith and West (2005) have summarized some key aspects of relevance for innovation policy to Australia as follows. These aspects are also of relevance to Sweden, which is also a small and open economy. Moreover, these statements can be seen as a summary of the literature, which also represent assumptions underlying our empirical analysis as well as our public policy tool-kit:

- Continuous interaction and feedbacks occur between perceptions of market opportunities, technological capabilities and learning processes within firms.

[12] 'Pasteur's Quadrant' (Stokes 1997), with its discussion of the complex relationships between basic and applied knowledge, is another book which seems to have been read by many Swedish policy-makers.

- Research and development (R&D) should be seen as problem-solving activities within already existing innovation processes, within firms.
- To succeed in innovating, firms must make sustained investments under conditions of uncertainty.
- Innovation capabilities – at the levels of firms and innovation systems – are cumulative.

Smith and West (2005) draw out implications for public policy, of relevance here. This implies that to become a successful economy for innovating, one must be able to identify mechanisms and institutions which help sustain investment into capabilities, manage collaboration, and to cope with risk and uncertainty in a business context.

What about university-industry interaction? Is it only about patents and starting companies?

One category of relationships in a SSI which influence the innovative capabilities of firms – and thereby their long-term competitiveness – is university-industry interactions. Results from these studies points to that firm size is positively related to interactions with universities (Laursen & Salter 2004) as well as the R&D intensive of firms is also positively correlated (Mansfield 1998). Studies using different proxies such as R&D expenditures over sales and number of scientist in a firm, R&D intensity of the firms have been found to generally be positively related to interaction with universities and institutes (e.g. Laursen & Salter 2004).

There is a vibrant stream of literature, which demonstrates that university-industry interactions occur in many ways. We have organized later chapters in terms of, respectively, the perspective of research, on-going at universities and research institutes and the perspective of industry, on-going in diverse types of firms.

Feldman and Breznitz (2008) provide a rich overview of technology transfer, from the perspective of universities. The formal mechanisms that they compare and contrast include sponsored research agreements, invention disclosures, patents, licensing out IPR, and formation of academic spin-off companies.

Existing literature is also useful in providing lists of mechanisms which can be examined empirically, from the perspective of industry. In terms of specific ways of interaction, for example, Cohen et al (2002) show that the key channels for university research to impact industry are publications, public conferences and meetings, consulting and informal information exchange. Their research thus shows that these are key ways in which the knowledge and capabilities of firms are enriched through interactions with researchers.

For the purposes of this report, we therefore feel it is vital to specify the findings in terms of how one might expect that university may influence industry to innovate. One of the most robust findings can be summarized in terms of a review article of the relevant literature, which went through findings from many other studies.

Salter and Martin (2001) identify six major mechanisms for diffusion of university research to industry. In our interpretation for this report, this means that this interaction can be valuable to the innovative capabilities of the firms by:

- Increasing the stock of useful knowledge
- Educating skilled graduates
- Developing new scientific instrumentation/methodologies
- Shaping networks and stimulating social interaction
- Enhancing the capacity for scientific and technological problem-solving
- Creating new firms

This is a different perspective than the current focus of debate – and also easily measured outputs – of start-up companies and patents. Note that creating new firms is only one of six mechanisms, and that patents are considered one way to increase the stock of useful knowledge.

In summary, this section has presented a specific view of innovation processes, including definition of concepts, key phenomena, and the complex mechanisms where university and industry may interact. This overview thereby contributes to our model of how public policy may affect research and industry, and also helps us identify the key issues to be addressed in the empirical work.

2.5 Analyzing the chain of effects in innovative food and medical technology

Hence, based on these theoretical approaches, we have chosen to develop a particular perspective on Effect Analysis for the empirical analysis and public policy tool-kit.

Firstly, the focus of the report is on how and why public policy can induce changes over time in an innovation system, in such a way as to affect both academia and industry.

The logic found in Table 2.1 was used to structure the report, as well as to draw out implications in terms of comparisons across the two sub-fields within life science as well as between the effects on research and industry. The four fields in the matrix are undoubtedly interlinked in the effect dimension, but separating them out allo+ws us to consider them separately in order to also be able to clarify points of interaction.

Table 2.1. Effect Matrix

	Innovative Food (IF)	Medical Technology (MT)
Effects on Research (R)	R/IF	R/MT
Effects on Industry (I)	I/IF	I/MT

Source: Modified from Laage-Hellman et al (2008)

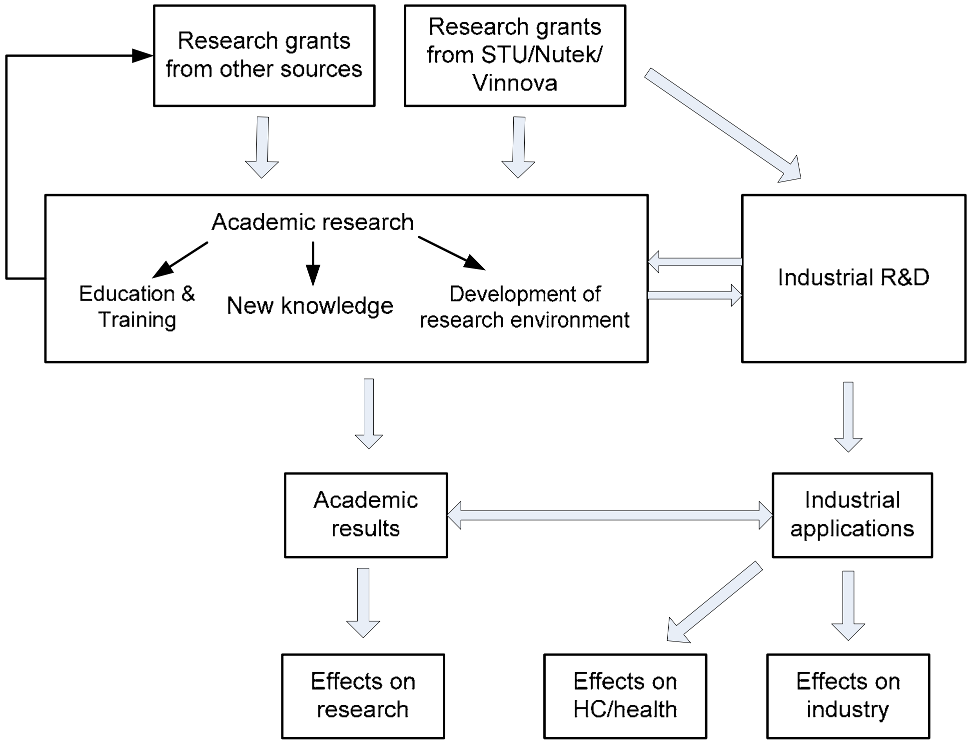
Secondly, the empirical analysis and the public policy tool-kit need to take into consideration some aspects introduced above. Namely, when using research efforts to induce change public policy must understand that ‘causality’ and ‘additionality’ in terms of effects will be affected also by other variables, such as feedback loops, interactions, uncertainty, and environmental conditions.

Thirdly, this implies that the Effect Analysis model discussed in Chapter 1 needs modification, in that it is too linear. We started from a general model proposed in a VINNOVA report, because it provided a somewhat richer picture than one which only focused upon inputs and outputs. However, we have changed it to fit with other mechanisms for commercialization and additional theoretical assumptions. These changes were needed in order to link public policy to developments within the Swedish innovation system.

Figure 2.2 presents a model developed in the pilot study (Laage-Hellman et al, 2008) and applied in the analysis. It provides a broad picture of how heterogeneous actors and processes in the SSI may be related, with feedback loops and development of competences. Moreover, the model should be relevant for studying the general effect chains in both target areas, innovative food and medical technology, and likely also in other areas.

Figure 2.2 may give the impression that the research and innovation process is linear, for example, assuming that there is a simple cause and effect relationship between funding of academic research and economic growth. This is not the case. As indicated there are some feedback loops. One example is when the needs and problems in industry trigger the start of new research projects in academia and when companies contribute to development of scientific knowledge. Therefore, we have added the element ‘Industrial R&D’, in parallel with ‘Research Activities’ at universities. Another feedback loop is when the development of research environments generates new sources of funding. We have therefore added a feedback arrow, as well as arrows representing additional sources of funding for the research team.

Figure 2.2. Our proposed broad chain of effects of public policy for life sciences



Source: Laage-Hellman et al (2008)

Our model of chain-linked effects in life sciences thus represents public research grants affecting the two parallel – and sometimes interlinking – processes of research activities at universities and in companies. Industrial R&D refers to research and development carried out at established companies as well as at start-up business ventures (some of which may be university spin-offs). These activities are normally financed internally by the companies and aim at developing new products and applications (as well as the needed manufacturing processes). Some companies also carry out more fundamental or exploratory research or basic technology development. This is especially the case for large corporations and for certain small technology-based companies specializing in research. As shown in the figure companies may sometimes be receivers of public research grants. At the same time, companies may also fund and participate in research carried out at universities, for example, by co-funding academic projects together with public agencies or assigning contract research.

This interlinking of academic and industrial R&D has implications for the present study. The model thus starts with the research grants from VINNOVA and its predecessors, STU and Nutek. These grants are used to finance research activities carried out mainly at academic institutions but sometimes also at research institutes. In some cases, grants may go to companies. Furthermore, the academic researchers may receive grants also from other sources, such as the Swedish Research Council[13], the Foundation for Strategic Research[14] and other public or private financiers. Usually the grants are used for funding specific research projects, but sometimes grants may be awarded for other purposes, such as purchase of laboratory equipment or funding of conferences.

These research grants from STU/Nutek/VINNOVA and others thus affect research activities at universities and institutes as well as industrial R&D. Regarding the former, these activities have three main types of effect of relevance to our study. One main effect is the creation of new knowledge, which may be explicit and codified as well as tacit. Explicit and codified knowledge usually ends up as published papers, and can be communicated at distance. This is included in what we call academic results (on the next level in the model). Tacit knowledge is more aligned with skills and competences, and "how to do things", and hence associated with developing the skills of individual scientists. The new knowledge will ultimately lead to effects on research (academia) but also on industry and healthcare/health to the extent that it is transferred to companies and used for development of new products and processes.

Another main effect is development of the "research environment" at the receiving institution. This means building of strong and sustainable research groups characterized by a critical mass of skilled leaders and staff, state-of-the-art laboratory facilities and well-developed contact networks, both within the scientific community and with industry.

A third effect of the academic research activities, closely related to the creation of a strong research environment, is education and training. This may include, for example, PhD programs in the research field supported by STU/Nutek/VINNOVA and effects on courses given at the undergraduate and graduate levels.

As indicated in the figure, an indirect effect of the research is that further funding from other sources can be attracted. Hence, it is possible that good academic results and the strength of the research environment created through public policy can in turn lead to additional funding, as symbolized by the arrow.

If the academic research is judged to have commercial potential, the results may be picked up by the industry and become incorporated in the firms' more applied R&D activities. This requires, however, that the scientific

[13] In Swedish: *Vetenskapsrådet*
[14] In Swedish: *Stiftelsen för strategisk forskning.*

knowledge and associated intellectual properties are transferred to the firms in some way or another. There are a number of mechanisms used for doing this, such as licensing, collaborative projects, recruitment of researchers by companies, and many others. The commercializing firm may have been involved as a partner in the research project, making contributions in cash or in kind (or a combination). But it can also be that the company enters the scene at a later stage, when there are available results (e.g. in the form of new discoveries or inventions) that can be taken as starting point for new product development projects and new ventures.

It can be noted that industrial firms may not only take advantage of specific research findings that can be commercialized and turned into new products or processes. They may also benefit in other ways from the building of strong research environments. They may, for example, be able to acquire new knowledge or competencies, recruit new personnel with specific skills (e.g. PhDs), use special laboratory equipment, or draw on the academic partners' scientific networks – nationally as well as internationally. This may have positive effects on the firms' innovative activities more generally – that is, effects that are not necessarily linked to the specific results of the projects funded by STU/Nutek/VINNOVA.

On the next level in the effect chain, the research activities lead to certain "visible" academic results manifested, for example, in publications, patents, degrees and new educational programs. Through these means the new knowledge coming out of the funded research is spread within the academic community and to other parts of society.

In parallel, the companies' use of the research results (new knowledge) or acquired competencies in their own innovation activities may lead to industrial applications in the form of new products (i.e. goods and/or services) or new production processes. In addition to the applied R&D carried out in industry, this important step in the innovation process requires, normally, that the companies make extensive investments also in start-up of production and in market introduction activities.

On the last effect level in Figure 2.2, the academic achievements based on the STU/Nutek/VINNOVA-funded projects can be said to affect the relevant part of the research system in terms of accumulated scientific knowledge, research and teaching capability, reputation in the academic community and in society, and competitiveness when it comes to applying for new research grants.

The industrial applications will have two types of effect, as indicated in Figure 2.2. First, the development and commercialization of new products and processes lead to improvements in the health of the population –

through better healthcare in the case of medtech and better food in the case of innovative food. In the former case, we can add improvements to the healthcare system itself, for example, through introduction of new diagnostic and therapeutic methods that contribute to increase productivity or capacity.

Second, successful application of research findings and new competencies will have positive, economic effects on the industry itself. In other words, it will help firms to increase competitiveness and provide opportunities to expand. The resulting economic growth may in turn contribute to create new jobs in developing firm and/or in other firms, such as suppliers, contract manufacturers or distributors.

The final issue that we would like to address in this section is whether and how the two sub-sectors of life sciences are similar or different. Figure 2.2 provides the meta-analysis for life sciences, useful for both. The two fields of study are similar, yet with some differences in how the effect chains work. Thus, it is true that the effect chain described above is in principle the same for the two sub-sectors. Practical applications of new scientific knowledge, for the benefit of the population and the society at large, usually presupposes involvement of firms, performing the task of transforming new knowledge into final products which can be industrially produced and sold in the market. However, there is one difference that it might be worthwhile to mention here, although it has not affected our work (since we do not study the effects on society). Medical devices are sold to healthcare providers (e.g. hospitals), which use them for carrying out medical services. In the case of medical technology, however, the scientific knowledge may under certain circumstances also be directly applied in healthcare. This is because some medical research is carried out by clinicians who are working in the healthcare system, e.g. as physicians. It may thus be that some of the knowledge coming out of clinically oriented research projects can be applied directly without developing new industrial products. For example, it may be possible to implement a new diagnostic or therapeutic method by using existing apparatus. This effect mechanism is not shown in the figure, since this type of effect (on the healthcare system) has not been included in our part of VINNOVA’s Effect Analysis.

This effect chain model thus provides a broad approach, which is used below to specify the specific issues that we have addressed in our effect analysis.

2.6 Identifying the key issues to study for effects on research and industry

Based on the effect chain model in Figure 2.2 and our previous discussions a large number of interesting research issues can be identified. Although we have tried to catch many types of effects, both on academic research and on industry, we have placed the main emphasis on a smaller number of key issues, which we perceive to be particularly important from a policy development point of view. These issues which to varying degrees have been dealt with for the two sub-sectors – innovative food and medical technology – are in terms of effects on *research*:

I. How has the research policy pursued by STU/Nutek/VINNOVA affected:

4 development of research environments over time?
5 education and training provided by the supported research environments?
6 academic results in terms of publications and patents?

II. How does the industrial collaboration benefit the research environment?

III. To what extent do the research environments engage in venture creation?

In terms of effects on *industry*, we have primarily focused on the following partly overlapping issues:

I. How has the research policy pursued by STU/Nutek/VINNOVA affected:

4 how and why existing industry interacts with research environments?
5 development of industrial applications (e.g. new products or production methods) based on results from the academic research?
6 development of competencies in technology, research and science

II. Do academic spin-off companies from previous periods play a role as R&D intermediaries between the existing industry and universities?

III. What types of company account for growth in Sweden?

3 Methodology and Research Design

The present Effect Analysis was carried out in two steps, that is, first a pilot study ran from December 2007 to mid-February 2008, and a main study ran from March 2008 with a final report delivered in January 2009.

IMIT – the Institute for Management of Innovation and Technology– has administered the project, to facilitate cross-university collaboration as well as access to expert competence.

3.1 The team

The project leader for this project and final report is Professor Maureen McKelvey, IMIT and School of Business, Economics and Law, University of Gothenburg. The main collaborator throughout is Associate Professor Jens Laage-Hellman, IMIT and IM-Gruppen AB.[15]

Many others have contributed, within the team, giving research assistance and input. Initial discussions with VINNOVA about their objectives and about research design included Johan Brink (IMIT and Chalmers University of Technology) and Daniel Ljungberg (Chalmers University of Technology). Mattias Johansson (IMIT and University of Gothenburg) worked extensively on Innovative Food during spring 2008, and is therefore a co-author of this report. Jenny Mossberg worked on the survey on university-industry collaboration in medical technology. Evangelos Bourelos (University of Gothenburg) worked on the quantitative analysis during fall 2008.

The project team has met regularly during these 14 months. Initial ideas and results from the project have been discussed at workshops. The pilot study was published as a RIDE – IMIT working paper.[16] [17] One paper ‘Can public policy create sustainable and long-term effects on industry? Conceptual issues and the case of life sciences for innovative foods in Sweden’ was

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[15] IM-Gruppen is a research and consulting company wholly-owned by Öhrlings PricewaterhouseCoopers.

[16] See www.imit.se.

[17] RIDE is a center focused upon innovation studies, in relation to economic growth (see under www.chalmers.se). RIDE has been supported by partners and by VINNOVA, to stimulate research and excellence as well as the the development of competencies and training.

presented at the ISPIM conference in Singapore. Additional scholarly papers are underway.

3.2 From pilot study to final report

This section provides an overview of how we implemented the learning experiences, as this project moved from a pilot study to a final report. Both the pilot study and final report required continual discussion and development of concepts, analytical frameworks, empirical material and analyses. Comments on the input from stakeholders are also included, given that VINNOVA states that they should help stimulate the interplay among academia, industry and society in effective innovation systems

The pilot study was completed in early 2008, based upon several months work, and the main report in early 2009. After completing the pilot study, we proposed that VINNOVA could either focus upon one specific issue or case or, alternatively, we could take the challenge of discussing the long-term, overall effects of the efforts upon research and industry in these two sub-fields of innovative food and medical technology. VINNOVA agreed to the larger, more ambitious study, in line with principle purposes and issues discussed in Chapters 1 and 2.

Based on experiences from previous Effect Analysis[18], we agreed with VINNOVA that a specific set of government public policy initiatives should be analyzed. Hence, we started from the list of programs and projects, as detailed in Chapter 4.

The 2008 Effect Analysis on life science should target three different "effect areas". These three areas are: effects on *research* (excellence), effects on *industry* (competiveness and employment), and effects on *society* (growth and economic benefits). The different character of the three areas implies that in order to create a full and coherent picture of the effects a multi-methodological approach needs to be applied.

From previous effect analyses, we found that broad lessons, existing concepts and analytical frameworks, and methodological learning could be directly relevant, but all required further development. From interaction with stakeholders, many aspects were improved.

In terms of broad lessons, we agreed to do the study, as experts with specific methodological techniques and with specific knowledge of innovation in the target research and industry. We concentrated upon the methodology and

[18] See discussion in Chapter 1.

the research design for analyzing the effects on research and on industry, given that other experts have been commissioned for the societal benefits.

In terms of concepts and analytical frameworks, we found the existing ones to be useful starting points – but with clear needs to further develop them. We also quickly identified that addressing the issues was a rather complex task, based on different data. Completing this task also leads to a longer, detailed empirical report, which is of a different format than typical social science journal articles, but of importance to society and public policy. These aspects have already been covered in Chapter 2.

In terms of methodological lessons, some key aspects are discussed below, given the multi-dimension and multiple indicators used in this study.

We used the pilot study to identify the advantages and disadvantages of possible methodologies and also examined the availability of material. One reason for this effort is that innovation studies can use multiple methodologies. Another reason is that much material was found in archives, scattered amongst actors, and so on, although other material could be found in project reports or through secondary sources. During the pilot study, we started to collect relevant secondary data, background reports and articles and identified some key informants. This work was extended in the main study, to provide useful background overviews as well as material for the analysis.

An important purpose of the pilot study was to develop a methodology for the main study. We proposed to use a combination of methods, involving quantitative and qualitative ones, depending upon which is most relevant for the specific effects or question of interest. During the pilot study, we examined the relevance and the data constraints for each of the following methodologies:

1. Document analysis. This means that we use secondary data in the form of, e.g., program documents, project reports and previous studies carried out by VINNOVA or other organizations. Some issues about access and types of material available have been raised during the pilot study.
2. Interviews. These can be used to generate relevant background information and exploratory insights, as well as very specific information. These can be personal or by phone.
3. Survey. This means a web-based, mail or telephone questionnaire distributed to a larger number of receivers.
4. Bibliometric studies. This means that we analyze publications and other quantitative data, primarily about academic results. These are primarily SCI data.
5. Patent analysis. This means using our Swedish part of the KEINS database on academic patents, in order to examine patents where

academics (e.g. working at universities) are inventors.[19] Company involvement can be identified.

6 Use of existing databases for specific analyses. In particular, we have been investigating the relevance of variables and terms of access to databases.
7 Case study. Data can be collected through interviews with complementary use of written documentation when available.

The main study uses all of these methodologies, as outlined below, in order to conduct a broad analysis related to specific issues. These methodologies are used in order to give a more complete picture of overall developments in research and industry, in relation to the key issues identified in Chapter 2.

As case studies are one aspect and are of particular interest to this type of study, we wish to say a few words about them.

Quite early on, we decided not to follow the methodological approach to cases found in the Swedish traffic safety research (VINNOVA 2007b). The methodology in that report is one case study, explicitly focused upon how a specific piece of research was later commercialized and affected firms and sales. These types of successful case studies are very useful for public policy discussions, as they indicate one role which public policy can play – e.g. stimulating new products. However, these types of stories only focus upon one mechanism (direct product development) and suffer from selection bias. A very linear approach is also visible in the reasoning about the potential effects of public policy.

This report has a series of shorter case studies, which illustrate key points about the overall developments in research and industry. The case studies are of two main types. For innovative food, the cases often focus upon the results or processes of a specific research project. For medical technology, the cases are of the research environments and of the closure of one major international firm of its Swedish operations.

Finally, a few words about why interaction with stakeholders and experts has been prominent during both phases. We the authors – as well as the extended members of our team – have interacted regularly with public-policy makers from spring 2007 through spring 2009, including phone conversations, emails and meetings in Stockholm, Oslo and Gothenburg. This includes meetings with VINNOVA officials, with technical expertise. We have also interviewed main stakeholders in research and industry.

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[19] KEINS was an EU project, resulting in a Swedish database. We examined patents at the individual level (of persons working at HEIs), where the patent can be assigned to the individual, a company or a HEI (Higher Education Institutions).

The interaction with stakeholders – as well as our theoretical understanding of innovation studies and of the empirical areas – lead us to go beyond single case studies of product commercialization, which were used in previous VINNOVA studies. We decided, therefore, that it was more interesting to tackle the larger and more complex ways in which universities and companies interact. Modern literature shows that there are many ways in which university-university interaction stimulates innovation – and these mechanisms go far beyond the commonly measured ways of firm start-ups and of patents, as discussed in Chapter 2 (Salter and Martin 2001). Hence, we felt that given the unique set of competencies and material available, we should come further in discussing how public policy initiatives can shift the trajectories of sectoral systems of innovation. The stakeholders and experts had deep empirical understanding of the phenomena.

Another aspect that was improved through stakeholder interaction was the set of concepts and ways of analyzing the empirical material gathered. The pilot study proposed a new analytical framework and key issues, including a range of more specific questions. This was used in several discussions with representatives from stakeholders (including VINNOVA), to identify the key issues of interest to the Swedish public policy debate.

In summary, the pilot study led to the identification and assessment of the feasibility of a number of data and methodologies of relevance. Although previous lessons were applied, many new aspects had to be developed, as well as specific knowledge interaction with stakeholders and experts as we moved from pilot to final report.

3.3 Data and Methodology

This section specifies the data and methodology used in this report.

Data and methodology are particularly important in research which is explorative in terms of both theoretical and empirical material. Many types of social science rely upon existing sets of data, which are then analyzed using sets of techniques. This study used many types of secondary data but also developed new sets.

A first issue was access to relevant data. One reason that the task commissioned here was difficult was because no pre-existing sets of data were available nor was it initially clear which types of systematic material could be collected at reasonable effort. VINNOVA did not have all the data required – or if they had it, it was scattered through various agencies, private files and archives. One important first step with VINNOVA was to identify the targeted public policy initiatives, and agreed to narrow the study to two larger programs within life sciences for food and eight programs within medical technology, as discussed in Chapter 4.

We examined all program information and to the extent possible, project information, including databases. We also discussed how to access main characteristics such as duration, amount of money, researchers involved, specific university, college or specialized institute, companies involved and so on. Basic information was not immediately available, but instead this project had to devote time and resources to access them, in collaboration with VINNOVA.

The basic data is not symmetric. The two fields of innovative food and of medical technology were run in different time periods and by different government agencies. Moreover, innovative food only covered two programs whereas medical technology covered eight programs. Within each program, there was a range of about 10 to 40 projects funded. This has lead to some differences in the level of detail of the data.

For Innovative food, we discussed with stakeholders and experts, and also accessed files related to each project. VINNOVA provided a complete list of programs and projects. We then used them, in order to specify the objectives of each program and to identify all the project granted and self-evaluation assessments and reports within the two programs. This was a huge amount of paperwork, examined in Stockholm, so the front page was copied and brought to Gothenburg. We had set up an Excel sheet with variables, to structure the relevant material that we wanted at the project level. This included, for example, the name of project leaders, other participants, reported results, etc. This database has been used extensively for the analysis in Chapters 5 and 6.

For Medical technology we chose a different approach. There were eight programs (between 1987 and 2001) to be covered by the effect analysis. In addition, we decided to include two 10-year competence centers. Instead of focusing on individual research projects, which were numerous and in many cases carried out long ago, we decided to take important medtech research environments as our starting point. We knew that many of them had during certain periods been highly dependent on funding from STU, Nutek or VINNOVA.

A second issue is how the list of relevant methodologies identified in the pilot study was used in the main report.

For Innovative food, five main data and methodologies were used, namely: document analysis, interviews, bibliometrics, patent analysis and cases of specific companies and/or commercialization of research.[20]

For Medical technology, five main data and methodologies were used, namely: document analysis, interviews, surveys, databases and cases of research environments. Complementary bibliometrics and patent analysis were used on partial data.

Table 3.1. Data and methodology used for innovative food and medical technology

	Innovative food	Medical technology
1. Document analysis		
Existing reports, evaluations, policy documents, analyses	XXX	XXX
Program information	XXX	X
Detailed project information	XXX	
2. Interviews		
Stakeholders	XXX	XXX
Discussions about background information and cases	XXX	XXX
Interviews with persons involved	XXX	XXX
3. Survey		
Phone survey (interview) with total sample of large firms		XXX
4. Bibliometrics		
Analysis of Web of science (Science citation index) and of Scopus	XXX	X (Programs on Biocompatible materials and Biocompatibility)
5. Patent analysis		
Analysis based on EPTO / KEINS database	XXX	X (Programs on Biocompatible materials and Biocompatibility)
6. Databases		
Company information	XX (Excel)	XX
7. Illustrative cases		
Research environment	X	XXX
Specific project	X	
Specific company and/or commercialization of research	X	X

[20] However, there were very few patents, so as discussed in Chapters 5 and 6, so more advanced analysis was not possible.

Table 3.1 details the methodology and data used. The number of ‘x’ indicates the relative importance of the methodology, so that xxx indicates that the method/data was used in full whereas x or xx indicates that it was used complementarily or on partial data.

The document analysis was used in both areas. It has already been introduced, in relation to finding and analyzing basic data about programs and projects. We also spent much effort and consulted with stakeholders and experts, in order to find written materials such as government inquiries and reports, evaluations by experts and financiers, analyses and so forth. These are included in the reference list.

The interviews were used in both areas. Those conducted were of two types. One type was with stakeholders and experts for background information, understanding, identification of cases and persons, and so. The second type is long interviews, following a semi-structured interview guide common for the project. These were generally with project leaders at universities and research institutes; with VINNOVA program directors; and with company R&D managers. List of persons interviewed can be found in Appendix 2. A survey based on telephone interviews was done with representatives of the largest medtech firms in Sweden. More details on the methodology are provided in Chapter 6.

The bibliometrics and patent analysis were primarily used for Innovative food, and partly for Medical technology. The bibliometrics were based upon searches of all project leaders in Innovative Food (all projects) and for the Biocompatibility materials and Biocompatibility program in Medical technology. Project leaders were searched for by name in two databases (Web of Science and Scopus), for a time lagged period. The database thus included complete data for the years 1973 to 2008. The patent analysis was of the same programs, and used the KEINS database of academic patents (from EPTO).

The databases were examined. Innovative food used some existing databases to help develop our new one. Medical technology used a VINNOVA database as a basis for characterizing the industry.

The cases were developed, based upon all other sources of data. They were constructed from a variety of first and secondary data, into a coherent story of the issues of interest to this report. The cases have been discussed with the stakeholders, experts, and Advisory Board for this project and with the persons interviewed.

As already commented, there are major differences between the methodological approaches used for Innovative food and Medical technology respectively. The main reason is the difference in time (as further discussed in next section), but also with differing conditions in several dimensions. Compared to Innovative food, the medtech research efforts to be analyzed took place over a longer period of time and consisted of a larger number of programs and projects. This meant, for example, that the number of projects that have received STU/Nutek/VINNOVA-grants was significantly larger.

Both projects included different types of firms. The Innovative food analysis dealt with a sub-set of companies belonging to the food business, we tried to cover an entire industry in the case of medical technology. In both cases, the industry involved in projects or in the industrial overview comprises a large number of companies, but it is also characterized by a high degree of heterogeneity – e.g. with regard to technologies, products and applications. One result of our initial analysis is that over time, the research areas focused on by the key medtech research environments received support from various sources (in parallel or successively). Therefore, it would be difficult in many cases to link, in a meaningful way, long-term effects to individual grants. For these reasons, we draw the conclusion that it was better to analyze the effects by focusing on organizational units rather than individual research projects.

3.4 Validity and limitations

The principle purposes of this study should contribute to our understanding of public policy on sustainable growth, by focusing upon the diffuse, indirect and long-term effects. Hence, the discussions of validity and causality should be seen in this context.

The research design agreed upon is based on capturing the long-term developments within research and industry. Within the overall developments, we address specific issues, using multiple indicators, data, and methodologies.

The first issue is the choice of focusing upon the specific programs and projects that were financed by STU, Nutek and VINNOVA. The choice was made in consultation with experts. For Innovative food, we accessed all the specific project applications and reports, and could therefore focus upon the project level. For Medical technology, we had lists of programs and projects, but this was a much longer list, further back in time, and with less detailed information on each project. We decided to focus upon the larger picture of research environments and interactions with industry.

Some selection bias was introduced, in that we did not examine projects that were rejected. One pragmatic reason was that one could have relatively easily found the rejected projects through archive studies, but only in

Innovative food. The medtech project applications were in archives, and extensive resources would have had to be devoted. For this report, the aim was to analyze the more systemic effects, and the task already complex. Therefore, we chose to focus upon financed programs and projects. Moreover, the major research groups and companies were financed.

The second issue is whether and how the Innovative food case corresponds to our interpretation of an analysis of chain-linked effects. It is worthwhile to point out difficulties that may limit the effect analysis in relation to these programs, as compared to VINNOVA's definitions found in Chapter 1. Many of the projects are still fairly recent in time with some ending as late as in 2008 and where final reports have not yet been made. Provided this time-period of the programs it may still be too early to see some effects such as, for example, patents and products. In VINNOVA's own terminology therefore, the analysis becomes more one of effect evaluation than one of effect analysis (VA 2007:14). The positive side to the recent ending of the programs is that people interviewed tend to have a good remembrance of the projects.

Moreover, the two programs are fairly small scale in the sense that there are relatively many projects, but with relatively small amounts of funding provided each project. This holds especially for the first program, whereas the second program also funded some larger projects. However, this holds reasonably true for the Medical technology area as well.

A related issue is the additional financers of research, which is explicitly addressed in Chapter 4. As a result of the study reported here, we have discovered that most projects do not start nor end with the funding granted them within these two VINNOVA programs. Many projects have a prior history within earlier programs funded by VINNOVA or other funders, and also proceed after the formal closure of the specific projects of interest here. Each project that VINNOVA finances, then, is often part of a research group's larger research theme, where the funded project interacts more or less with other projects. This follows quite naturally because, as one interviewee put it, "you rarely apply for money for something which you don't know at all or have been into before".

Many projects therefore build on prior projects, and the constellations of many projects often go back a long time. The resulting consequence is that it sometimes becomes difficult to distinguish the effects of the funded project from those of the larger researcher theme. Conversely, "negative" results in a specific funded VINNOVA-project may not seem to be an important result in isolation, but may still have important effects for the larger research theme.

With these limitations in mind, this report has sought to analyze the effects of the two food-related VINNOVA programs so far by utilizing primarily two different sources; the evaluation assessments in projects' final reports and interviews. For projects initiated 2000 or later, the final reports include assessments of the results made by the project leader according to result categories specified by VINNOVA. In many instances the project officer at VINNOVA has supplemented the assessments with comments on the projects results. The pre-specified result categories in these assessments are as follows: Scientific publications, Scientific conferences, Other publications, Master theses, PhD positions and dissertations, New research network, New company network, New research group or program, New scientific method or theory, New practical method, Technology transfer, Prototype, Product development, Products, Patents, New technology or equipment, Seminars or demonstrations for practitioners, New firm or commercialization, and New center. Since some of the categories are partly overlapping, this report has used a condensed version of these categories to structure and analyze the results. For projects that lack these assessments, it is still possible to discern results from the final reports.

The third issue is whether one can assume that the public policy initiatives led to – or caused – the effects upon research and industry. The broad approach was to examine the developments, and place them in relation to the public policy initiatives studied here. Thereby, we also recognize and address that there are many external variables affecting these developments, and that those variables are outside the control of policy agencies. We chose to try to examine some dimensions (specifically, publications and patents) through statistical analysis, to at least show relationships.

This discussion of causality is related to the second issue, that many other sources of financing were available to the research groups. Although one can think of short-term project evaluations as a one-to-one causality from public policy initiative to output results, the multiple sources of funding need to be considered in discussion of long-term effects.

Therefore, we have chosen to develop an analytical framework and research design which enable us to point out how these complex relationships may be chain-linked together.

4 Swedish public policy initiatives in innovative food and medical technology and overview

This chapter focuses upon the public policy initiatives in Innovative food and Medical technology, as well as overviews of the two sub-sectors.

Section 4.1 presents basic information about the ten programs, and the time period in which they ran. In addition to the public policy initiatives studied here, STU/Nutek/VINNOVA has during the same period had other efforts to stimulate research grants, especially for Medical technology (i.e. other programs, competence centers and non-program grants). These are relevant from an effect point of view and will be considered in the following analysis.

Sections 4.2 and 4.3 give overviews of the two sub-sectors, in terms of some key historical and contemporary information with regard to industry and academic research. Section 4.4 introduces the additional financiers of research. These ten programs thus constitute the starting point for the effect analysis, but some external variables are described here and in the effect analysis in chapters 6 and 7.

4.1 Public policy initiatives

This analysis of public policy initiatives and broad developments in research and industry takes its starting point in two programs in Innovative food and eight programs in Medical technology, as agreed upon with VINNOVA. Figure 4.1 shows which these programs are and their duration, running from 1987 to 2006.

Figure 4.1. The ten programs in focus for the effect analysis

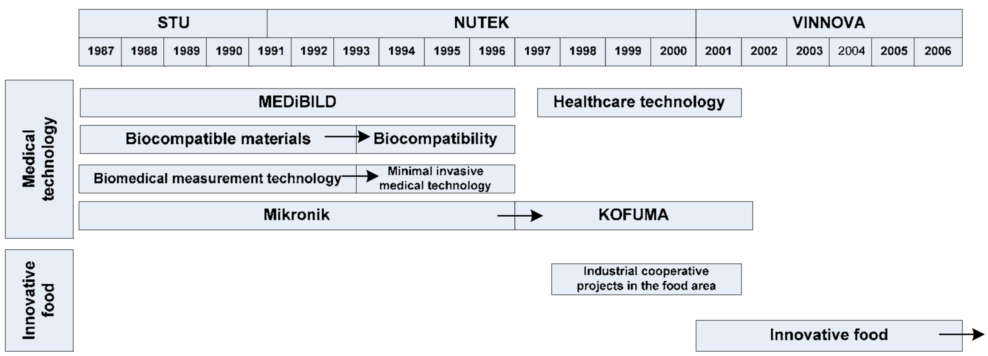

Figure 4.1 also shows a continuation of programs over a longer period of time. This is indicated with arrows in the figure, when new programs basically targeted the same technical areas.

The two programs in Innovative food run 1998 to 2005, and are called, respectively, Industrial cooperative projects in the food area and Innovative food. VINNOVA's program on Innovative food can to some extent be seen as a continuation of the Nutek program Industrial cooperative projects in the food area. We have chosen to call the general area for Innovative food, as discussed in the Definitions in Chapter 1.

The eight programs in Medical technology are MEDiBILD[21], Healthcare technology, Biocompatible materials, Biocompatability, Biomedical measurement technology, Minimal invasive medical technology, Mikronik and KOFUMA[22]. It should be noted that two of the early medtech programs started by STU (i.e. Biocompatible materials and Biomedical measurement technology) were later on substituted by new Nutek-programs within the same technical fields (Biocompatibility and Minimal invasive medical technology respectively). The STU program Mikronik and the follow-up Nutek program KOFUMA were broad technology development programs where medicine was one of several application fields.

Furthermore, after having terminated in 1996 the three programs MEDIBILD, Biocompatibility and Minimal invasive medical technology, Nutek's support of research in these areas continued in the form of a new program called Healthcare technology. It was a broad program giving support to projects in four areas: Diagnostics and therapy, Aids (for disabled), Biocompatible materials and Telemedicine. It means that to some extent the new program was also a continuation of another STU/Nutek program: Communication technology aids for disabled (1987-93).

Some information about the programs included in the two areas follows.

4.1.1 Innovative food

In Innovative food, the two programs which are subject to analysis started in 1998, and 2001 respectively. The two VINNOVA programs hosted 66 projects that received funding in either one or several stages within the two programs. Out of these 66 projects, there were 11 planning studies that did not result in any further funding within the two programs evaluated here. Thus, there were 55 larger projects, in the sense that they were run across several years and were reasonably independent and distinguishable.

[21] MEDiBILD is a program on Medical Imaging.
[22] KOFUMA stands for "new components and functional materials for tomorrow's industry".

Table 4.1. Key numbers for the focal Innovative food programs

	Duration	No of projects	Funding, total (MSEK)
Industrial cooperative projects in the food area	1998-2001	23	24,86
Innovative food	2001-2008	38	96,98
Projects in both programs	1998-2006	5	Included in above figures

In addition, SIK (the Swedish Institute for Food and Biotechnology) has received fixed funding from STU/Nutek/VINNOVA during the period.

Taken per program, 23 projects were part of the program Industrial cooperative projects in the food industry and 38 were part of the program Innovative food, and 5 projects in both. The funding awarded from VINNOVA varied among the projects. On average, the projects received MSEK 1.8 in funding, however, funding varied a lot, ranging from a mere 100 000 SEK to MSEK 8.3, as shown in Table 4.2.

Table 4.2. Number and characteristics of the projects

Project characteristics	
Number of projects	66
Industrial cooperative projects in the food area	23
Innovative food	38
Projects in both programs	5
Average funding	1857' SEK
Median	1230' SEK
Highest funding	8300' SEK
Lowest funding	100' SEK

This figure of 66 projects total, as categorized as 55 large projects and 11 planning projects, is based on our analysis of VINNOVA's project documentation. We excluded funding granted for projects specifically aimed for only purchasing equipment (which amount only to a few projects altogether), and so these have not been counted as projects. Projects awarded funding in several stages were counted as one large project, if the planning studies resulted in further funding in one or several stages. So, for example, projects where a research group first received funding for a planning study, and then received funding for the actual project proposal were counted as one project. When there are several projects in one or several stages, they are counted as separate projects. While some of these projects are related, and to some extent build on each other, they made up different project applications and have thus been counted as such.

4.1.2 Medical technology

In Medical technology, eight programs had at the outset been selected by VINNOVA as objects for the analysis. However, as explained in Chapter 3 we chose a somewhat different methodological approach for Medical technology from that in Innovative food. Instead of focusing on individual projects and their effects, we took a broader view with important medtech research environments as starting point for the analysis. Over the 20-year period that we have tried to cover in this study these environments have received funding of their medtech research not only through these eight programs. As will be elaborated in some more detail below they have received support from STU/Nutek/VINNOVA also through other efforts (other programs, centers etc). In addition, during certain periods of time other research financiers have supported research in the same sub-fields (such as, e.g., biocompatible materials). Thus, the long-term effects – for example in terms of environment building or commercialization of new knowledge – cannot be easily linked to individual project grants. Therefore, our analysis in the medtech field is broader than for Innovative food. Even if we cannot measure the effects on the project level, we mean that important lessons can be learnt regarding the long-term effects of needs-driven research efforts.

Table 4.3. Key numbers for the focal medtech programs

	Duration	No. of projects	Funding (MSEK)	Co-funding from industry[23]
MEDIBILD	1987-96	38	36.4	14.5
Biocompatible materials	1987- 93	25	38.4	0
Biocompatibility	1993- 96			
Biomedical measurement technology	1987-93	38	45.3	11.1
Minimal invasive medical technology	1993-96			
Mikronik	1987-96	n.a.	47.4	n.a.
KOFUMA	1997-2001	n.a.	31.2	n.a.
Healthcare technology	1997-2001[24]	76	39.6	n.a.[25]

[23] These figures are in cash contributions. Companies may also have done in kind contributions. In the case of Biomedical measurement technology and Minimal invasive medical technology the amount of such contributions have been estimated to one third of the public grants (Nutek, 1996, p. 11).
[24] The numbers given for this program are based on Nutek (2000) and pertain to the period 1997-2000.

Table 4.3 gives some key numbers for the focal medtech programs (duration, number of projects and STU/Nutek/VINNOVA funding and co-funding from industry).

We may recall that Mikronik and KOFUMA are broad technology development programs where medtech is one of several application fields. It has been estimated by VINNOVA officials that medtech accounts for approximately one third of the grants.

In Table 4.4 we summarize some key characteristics for the focal programs (research topics and objectives).[26]

Table 4.4. Key characteristics for the medtech programs

Program	Research topics	Objectives
MEDiBILD	PACS, Telemedicine, Decision support, Computer-aided image analysis	Support Swedish firms in the development of internationally competitive products and system solutions
Biocompatible materials	Methods for studying mechanisms for interaction between materials and living tissue	Establish an industrially relevant knowledge base
Biocompatability		- Establish networks; knowledge transfer to industry; training of industrially relevant researchers; develop and establish biomaterials-related activities in firms - Long term: develop products with high potential for exports
Biomedical measurement technology	Medical diagnostics and therapy (incl. e.g. flow and pressure measurements; electrical signal processing; gas analysis and regulation	- Develop new methods as a basis for new high-tech industries - Improve medical diagnostics in order to render healthcare more efficient
Minimal invasive medical technology		- Strengthen the competiveness of the medtech industry - Contribute to the development of new profitable products in new or existing firms - Provide industry with new technology and researchers with PhD degree
Mikronik	Micro- and nano-technology	- Stimulate cooperation between physicists, chemists, and biologists in order to make sub-micro structures
KOFUMA		- Create conditions for development of new types of products and systems - Establish new future-oriented firms - Secure the industry's capability to take advantage of future markets
Healthcare technology	Diagnostics and therapy Aids for disabled Biocompatible materials Telemedicine	- Support growth and renewal of industry - Create cooperation between healthcare, industry and academia - Support research leading to new medtech products - Develop, keep and use competence

[25] 76% of the projects have received co-funding (65% from companies) (Nutek, 2000, p. 19).
[26] The descriptions are based on written information provided by VINNOVA and evaluation reports (Nutek, 1996 and Nutek, 2000).

The degree of industrial involvement has varied among the programs. Table 4.3 shows that the co-funding from industry was relatively high for MEDiBILD, which was a very application-oriented program. In this case active participation was a requirement for grants – as well as commercial and clinical relevance. In total more than thirty companies have been linked to the program in some way or another (Nutek, 1996, p. 19). The companies have at some stage expressed interest in the research, but have not necessarily contributed in cash or engaged themselves in projects.

Also for the two programs Biomedical measurement technology and Minimal invasive medical technology there were high demands on industrial relevance and industry participation. These requirements, coming from the STU/Nutek officials and the steering group, were gradually increased over time, which had effects on the project characteristics (ibid., p. 17).

The programs Biocompatible materials and Biocompatibility were more research-oriented than those mentioned above. Co-funding from industry was not required and has not occurred in any project. However, from 1993 the steering group put more emphasis on the industrial relevance and gave priority to projects with active company participation (ibid. p. 26). It became an important goal to establish networks between researchers and companies and to develop products with export potential.

The program Healthcare technology aimed to support research that could lead to new medtech products. All projects should have clear industry relevance, and priority was given to projects where industrial co-funding could be achieved. In particular, collaboration with small companies was prioritized.

4.2 Innovative food overview

This section provides an overview of innovative food and the food industry in terms of the public policy initiatives, policy landscape, industry structure, and research. The public policy initiatives for research and innovation are focused upon particular objectives, but need to be understood within the broader policy, market and ownership structures of the food industry.

4.2.1 Public policy initiatives for research and innovation

The two research programs outlined above are part of a longer series of public policy initiatives within the food industry, albeit with few resources devoted to the area.

STU, the predecessor of VINNOVA and Nutek had run programs in the food area in the 1970s and early 1980s, but by 1986 efforts specifically targeted at the food area had decreased considerably. The food area was included in some other programs run by STU, for example, the DUPP-program, which had food as one of three application areas for research focused on IT and operations. The program ran for 9 years between 1986/7 and 1996, and proved important in interesting industry for collaborations with the university, according to a program director. Research related to the food area was included in some other VINNOVA-programs, but the situation of limited public policy funding for specific food programs largely remained until the late 1990s.

A main focus during this period of scarce resources was internationalization. Apart from a smaller project on small-scale food production in northern Sweden, the funding there was during this period mainly used for co-funding of international projects. This was partly the result of the limited resources, and partly the results of an aim to help researchers develop their international contacts. At the time, prior to the EU-membership, Swedish researchers had to pay to participate in EU-projects and Nutek/VINNOVA (and SJFR[27]) enabled participation in the different framework programs directed towards the food area (FLAIR) by providing funds for such costs of participation. In addition to the different EU framework programs, Nutek/VINNOVA also sponsored research groups' participation in EUREKA, COST and the NORDFOOD programs in which Sweden was very active. Most of the funding around 1994 (which still was not much), for example, went into NORDFOOD programs. Altogether, this resulted in about 14 projects with participation from industry, of which some co-operations later went into the cooperative program.

By the mid-1990s, however, the Ministry of Industry (*Näringsdepartementet*) began expressing interest in the food industry again, in part because of the so-called Björckska inquiry (SOU 1997a). This governmental inquiry pointed to the new competitive landscape of the Swedish food sector resulting from the EU-membership, as well as the lack of public efforts directed towards the area. The inquiry also strongly urged for a larger research program directed towards the food industry.

The rationale was related to national specificities and the need for a better market position. The new competitive situation of the EU market, coupled with some natural disadvantages such as high costs for raw material, made R&D of decisive importance to strengthen the food industry's international competitiveness, something that was also highlighted in the government bill on research (Proposition 1996/97:5). In particular, as the SOU 1997a report argued, such R&D efforts should develop those conditions that provide opportunities for competing with production from countries with lower costs

[27] Skogs- och Jordbrukets Forskningsråd (now Formas).

for raw material production, that is, efficient production, distribution and marketing. At the same time, the public support for food R&D was seen as significantly lower than in competitive countries that have produced for the international market. If something was not done, the report argued, a fate similar to that of the textile industry, which essentially disappeared in the 1970s, could well become a reality.

Thus, this governmental inquiry proposed a four-year program of in total MSEK 360, divided into four policy initiatives. This included an industrial co-operative program of MSEK/year 40; three framework programs aimed towards knowledge development of MSEK/year 25; a program aiming for knowledge exchange between actors of MSEK/year 20; and MSEK/year 5 in resources for in-depth studies of strategic issues for the food-related R&D system's development. Nutek was proposed to run the program. However, of the proposed funds of MSEK 360, only MSEK 20 to an industrial cooperative project was granted in the end.

The call for the program Industrial cooperative projects in the food industry (*Industriellt samverkansprojekt*) was announced in 1998 by Nutek (1998). The call was broad, reflecting to a large extent and addressing the areas recognized as important focus areas in the governmental inquiry introduced above, SOU 1997a (as well as in some previous inquires such as *Forskning för bättre mat* (SJFR 1986)). The stated purpose of the program is "to give companies and constellations of companies an increased opportunity to work on specific problems and at the same time develop contacts with the R&D-system. The R&D-system can, at the same time, develop its understanding of the problems that face companies. The aim is to bring together different actors from different parts of the food chain, from industry as well as from the research community, in order to achieve a better integration". More specifically, eligible projects could "treat widely disparate areas with significance for the food industry, for example, food security, process- and production techniques, quality, environment- and resource efficiency, product development and innovations, packaging systems, logistics and work environment" (Nutek 1998). The second call in the program was announced in 2000 and was similar to the first call. Altogether the program ran between 1998 and 2001.

With the building of the new governmental agency VINNOVA, a new program was also launched, called Innovative food. The name itself was more of a compromise between different stakeholders, as well as in line with the contemporary concepts such as smart food and intelligent food, and with somewhat less focus upon the whole food industry. The Innovative food program was partly a continuation of the program described above and partly a more specific effort directed towards functional foods with documented health effects.

The reason for narrowing down the focus in the second program was that the limited resources did not allow for a continued broad effort for the competitiveness of the industry, and diet and health could be motivated as vital to society. There were three calls for this second program, where the first call signaled an increased emphasis on diet and health, and where the second and third calls puts this as the focus.

According to the first call in Innovative food: “The overarching knowledge development of the program includes, for example, the development of methodology and/or systems in areas of product safety/security, traceability in the whole food chain, increased efficiency/rationalization and reduced environmental effects, innovation and product development, understanding of consumer preferences and enhanced consumer communications” (VINNOVA 2001).

As for the specific area of diet and health, the call states that important knowledge that the program aims to develop is, for example, development and usage of experimental models to ensure more links between diet and health, to develop methods for scientific evaluation of foods health effects, to identify biomarkers in humans which can be used to measure effects on health and/or sickness, to understand how links between diet and health can vary with individuals and thereby deepen the knowledge about how the individual genome affects physiological response

In the second and third call, announced in 2003 and 2004 respectively, the program narrowed in on the latter area. Naturally, this narrowing down of the scope of the program also had consequences for the projects granted funding as some areas previously eligible for funding were not included in these latter calls.

4.2.2 Public policy for food

Prior to 1990, vital parts of the Swedish food industry were, similarly to the food industry of many other countries, well protected and regulated. Such protection from international competition consisted of, for example, border protection in the form of import tolls, export subsidies, and rationalization subsidies. The major industries that were protected from international competition included abattoir-, cutting-up-, charcuterie-, dairy-, oil-, and fat industries, as well as milling and sugar industries. Altogether, these protected sectors made up about 80 percent of the turnover in the food industry. The parts of the food industry that accounted for the remaining turnover produced so-called free trade products that were subject to competition following an agreement made by EU and EFTA in 1973. The sectors that were subject to this competition included chocolate, pastry and bakery industries, beverage industry, and industries producing soups and sauces, fruit yoghurts, and ice cream. Other forms of protection included a system for food subsidies introduced in 1973, which meant that the food was partly paid through the state budget, that is, Swedish farmers were guaranteed an outlet for their products to a pre-negotiated price (SOU 1997a).

The structure of protection started to change in 1990 and in the years to follow the Swedish food industry underwent drastic regulative changes. In 1990 the government decided to deregulate the agricultural sector and impose a more market-oriented approach to the food industry at large. Accordingly, the government proposed that the earlier regulation that ensured Swedish farmers a pre-negotiated price would cease to exist after a transitional period, and that export subsidies would be removed. Other domestic protection such as tolls would remain in await of a coming GATT-agreement on lowered protections. But this new food policy never came to be fully implemented because at the same time as it came into being in 1991, Sweden applied for an EU-membership (SOU 1997a). While the proposed policy therefore never came to fully materialize, other shifts occurred.

The EU-membership in itself in 1995 meant a sea change in terms of regulation for the Swedish food industry. The membership opened the Swedish food sector to a market several times larger than the Swedish market, and the agricultural sector could compete on the world market under the same premises as the rest of the agricultural sector in the EU. At the same time, the competition on the domestic market increased from producers in other EU-countries, although some product areas retained national production quotas that put limits to the volume of production and market. (SOU 1997b).

While the EU-membership removed much of the protection within the European market, several rounds of negotiations on a fair and market-oriented system for world trade in GATT and WTO has still not resolved the issue of domestic protection on a worldwide basis (Li 2008). The aim of the negotiations has been to considerably lower tolls, and to deregulate export subsidies. The negotiations have, however, been fraught with set backs and crises, and by the turn of 2007/2008, the partners (in particular the US and EU) had still not agreed, especially not on how much the tolls were to be lowered and when it is to be done. However, border protection and export subsidies has with higher world market prices already been deregulated for some products and have in many cases a decreasing impact compared to when the WTO-negotiations started (Li 2008).

4.2.3 The Swedish food industry

The food industry is one of the largest industrial sectors in Sweden in terms of both turnover and employment, and it is also an industry that have experienced structural changes over past couple of decades.

In 2007 the food industry generated in total a turnover of about 150 billion SEK. The total food export during 2007 amounted to about 41 billion SEK, representing an export of about 20 percent of the production, which is somewhat higher than the EU food industry average. Closer to 70 percent of the food exports in 2007 went to the EU, while the remaining exports primarily goes to the US and Norway. Larger food companies with a considerable export volume are, for example, Vin&Sprit, Kraft Foods, Findus, AarhusKarlshamn, Santa Maria, Pågen, Cloetta Fazer, and Procordia Food, while midsized companies with a large export includes Aromatic, Gillebagarn, Frödinge, Löfbergs Lila, and Almondy. These are companies with a turnover from a couple of 100 million SEK to 1 billion SEK, and an export share of 20-80 percent (Li 2008).

The food industry employed about 56,000 persons in 2007. The sectors representing the largest shares of the food industry in terms of employment are the bakery industry and the abattoir- and charcuterie-industries with 14,000 and 12,000 employees respectively. The dairy and fruit- and vegetable conservation industries follow with about 6,000 and 4,300 employees respectively (Li 2008). Geographically, most employees are located in the County of Skåne (25% of the food industry's employees), followed by Region Västra Götaland (21%), and Stockholm County (16%). The industry is also important indirectly through the industry's close connections with other sectors of the economy such as agriculture, distribution and service. Including those sectors that have the strongest ties to the food industry, this extended definition of the food industry employed about 250 000 persons in 2007 (Li 2008).

The number of companies in the food industry as of 2007 was about 3,100. The lion's share of these companies is, however, made up of companies with no or only a few employees. About 1,300 companies of 3,100 companies were, for example, companies with no employees, and another 1,200 companies between 1-9 employees. There were around 500 companies that had between 10-49 employees. Several companies included in this latter category have been very successful in the last couple of years with examples including Almondy that have successfully exported frozen cakes (Li 2008). There are only about 140 companies that have more than 50 employees, and of these companies, 24 companies can be characterized as large companies with more than 500 employees.

While the small firms dominated in numbers, most employees work in larger firms. In total about 75 percent of the people employed in the food industry works in companies with more than 50 employees. The bakery industry is the sector that has the most companies, about 1400, although about 500 of these firms are firms without any employees. The abattoir- and charcuterie- industries have closer to 500 companies, while fruit- and vegetable conservation industries, fishing, and chocolate and confectionery industries have between 130 to 220 companies respectively, including companies with no employees.

Many food companies active in Sweden have participated in the two VINNOVA-sponsored food programs. We have therefore chosen to give the basic characteristics of firms which participated in the two innovative food programs, as found in Table 4.5. This table shows the number of projects within which they were involved, their size and ownership/parent company (as of 2008 or, in some instances, the latest year of available information).

Table 4.5. Food companies, by number of projects, size and parent company

Food company	Number of	Size	Parents
Arla	13	>500	Arla Foods
Orkla Foods	13	>500	Orkla
Cerealia	12	>500	Lantmännen
Skånemejerier	9	>500	Skånemejerier
Karlshamns AB	7	50-249	Raisio
Milko / NNP	5	>500	Milko ekonomisk förening
TetraPak	5	>500	Tetra Pak
AnalyCen AB	4	50-249	Lantmännen
Findus	4	>500	EQT / Food Vest
Källbergs Industri AB	4	50-249	Danaeg
Lantmännen	4	>500	Lantmännen
Lyckeby	4	50-249	Sveriges
Svensk Mjölk	4	10-49	Svensk Mjölk
BioGaia	3	10-49	BioGaia
CeBa	3	10-49	CeBa
Danisco	3	>500	Danisco AS
Kiviks Musterier	3	50-249	Kivik Holding
Kronfågel	3	>500	Lantmännen
LRF	3	-	Lantbrukarnas Riksförbund
Norrmejerier	3	250-	Norrmejerier ek. Förening
Probi AB	3	10-49	Probi
Semper	3	50-249	Hero
Svalöf Weibulls AB	3	50-249	Lantmännen
Dafgårds	2	>500	Gunnar Dafgård
Frigoscandia Equipment AB	2	250-	FMC Technologies
ICA	2	>500	ICA

Food company	Number of	Size	Parents
OLW Chips AB	2	50-249	Orkla
Wasabröd	2	250-	Guido M Barilla
ABB Automation Systems	1	>500	ABB
AgriSera AB	1	10-49	AgriSera
Anhydro AS	1	50-249	Anhydro AS
Arom Pak	1	0-9	Tetra Pak
Aromatic	1	50-249	Aromatic (Nico)
ASM Foods	1	50-249	Carletti
Biacore International AB	1	50-249	General Electric
Bioagri AB	1	10-49	Lantmännen
BTL-Schenker	1	>500	Deutsche Bahn
Chemel AB (IDEON)	1	0-9	Chemel
CloettaFazer	1	>500	Cloetta Fazer
De Laval International (Alfa	1	>500	Alfa Laval
Diffchamb	1	-	Raisio
Döhler Scandinavia	1	-	-
Festab	1	50-249	Domstein AS
Fresenius Kabi AB?	1	>500	Fresenius Kabi AG
Frödinge Mejeri AB	1	50-249	Rieber & Sons
IFP Research AB	1	10-49	Swerea AB
Infratest Burke AB	1	0-9	Taylor Nelson
Jaccon Classics	1	-	-
Kemikalia AB	1	10-49	CH Trading
KF	1	>500	KF
Kraft Freia Marabou Sweden AB	1	>500	Kraft Foods Inc
Lagafors Fabriks AB	1	10-49	Lagafors Industries
Leaf Sverige AB	1	250-	Leaf International
LignoTech Sweden AB	1	10-49	Orkla
Mälarchark	1	0-9	Mälarchark
MediPharm AB	1	10-49	Arla Foods
Muddus Hjortron AB	1	0-9	Muddus
Nordfalk (St Maria)	1	250-	Santa Maria
Nordic Sensor Technologies	1	10-49	Applied Sensor
Nutripharma	1	10-49	Nutripharma AS
ODAL	1	-	Lantmännen
Olligon	1	0-9	Lantmännen
Pågens	1	>500	Pågensgruppen
PartnerPac	1	10-49	ALNA Food
Perten Instruments AB	1	10-49	Larena AG
Pharmacia Diagnostics AB	1	>500	Pharmacia
Plant Science Sweden	1	10-49	BASF
Potatisspecialisten AB	1	0-9	
PPM AB	1	250-	FMC Technologies
Reppe	1	50-249	Lantmännen

Food company	Number of	Size	Parents
Samfood AB	1	>500	Atria
SCA Hygiene Products	1	>500	SCA
Scan Foods	1	>500	HKScan
Slakteriprodukter Helsingborg	1	50-249	HKScan
SMAK, Svensk matpotatiskontroll	1	10-49	Stiftelsen potatisbranschen
Solanum AB	1	10-49	Lantmännen
Spendrups	1	50-249	Spendrup
Svenska Malt AB	1	10-49	Viking Malt
Svenska Mc Donalds AB	1	>500	McDonalds
Swedish Match	1	250-	Swedish Match
Swedish Meats R&D	1	50-249	HKScan
Tärnö Säteri AB	1	0-9	Tärnö
Trensums AB	1	50-249	Nordicum
Ugglarps Slakteri AB	1	50-249	Ugglarps
Vattenfall	1	>500	Vattenfall
Viking Malt	1	10-49	Viking Malt
Whirlpool	1	250-	Whirlpool

4.2.4 Research in food areas

Secondary material about the food industry's research tend to stress two things; 1) research intensity in the industry has been low, and 2) the consequences for Sweden of increasing internationalization of ownership in the industry.

Regarding research intensity within the industry, the SOU report in 1997 noted the food industry has hitherto had little interest for higher education and have few employees with such an education. The technological resources, in the sense of educated personnel, in the food industry are concentrated to a few large companies. The report also made efforts to assess the level of industry research in the food industry, and found that the (primarily larger) companies interviewed devoted about 1-2 percent of their turnover to R&D (SOU 1997a). As for pure research, that is, not development, these large companies spent 21 man-years on this in 1995 (SOU 1997a). This can be compared with a figure from Nutek that 48 persons with research education were employed in food producing companies in 1993, with an additional 49 persons in companies producing equipment for the food industry, and 16 persons in food packaging companies (Nutek 1996a).

Since then, research efforts have increased somewhat. Between 1995 and 2005, for example, the R&D expenses in the food industry (SIC 15-16) increased by 79 percent (in current prices). In 2005 firms with more than 250 employees accounted for the majority of this R&D (70%). In terms of full-time equivalents for R&D (including all types of personnel and educational levels), there was an increase of 32 percent in the period 1995 to 2005. The total number of full-time equivalents in R&D amounted to 476 in 2005. However, according to SCB, only about 34 of these full-time equivalents consisted of people with research education (as based on SIC 15-16). This can be compared with the pharmaceutical industry (SIC 24.42) where postgraduates performed 1370 full-time equivalents of R&D (SCB 2006). The increase in R&D efforts there is, is in part due to some government programs where among others VINNOVA in spite of limited money, worked hard to invoke industry's interest for collaborations with universities. In part, the reasons for increased efforts stem from the increased competitive pressures in the industry. A strong productivity growth is necessary to meet this challenge, and research and technological development are important requirements to reach such growth. Significative of this are statements in both reports and from industry interest groups, calling for more use of universities, and more interaction between university and industry (Li 2004; Li 2008; SOU 1997a; Formas 2006).

The increasing foreign ownership of companies in the food industry has also affected research and research intensity within the industry. This in particular by raising fears for relocation of research units abroad, something which has already taken place when, for example, Nestlé moved their R&D company for northern Europe, Nordreco in Bjuv, to Switzerland upon the sales of Findus to the venture capitalist EQT (Formas 2006). EQT in turn added to this by laying off 160 out of 200 people working with R&D at Findus' facilities in Bjuv (Mål&Medel 2007).

In terms of research at universities and research institutes, Sweden is active in a number of areas. The research areas focused upon in publicly financed food research have remained fairly stable over time. The report SOU 1997a found that food research since long had been targeted at providing basic knowledge of food composition and the on the relationship between food and health as well as on other issues concerning the consumer. More specifically, a mapping of ongoing R&D in 1996 showed that the public efforts weighed towards diet/health and security as well as foods' basic chemistry. The split between the respective areas was roughly: food/health (31%), food physiology, chemistry and biology (24%), food security (14%) (SOU 1997a). The Formas report in 2006 to some extent confirmed this distribution of efforts in a mapping of food research. The report estimated that about 60 research groups conducted food-related research in the area of biology/medicine (including areas such as food science, nutrition, and microbiology), 15 groups pursued food-related research in the area of technology (including areas such as food technology, logistics, and packaging), and that another 15 groups conducted research in consumer sciences related to food (including toxicology and sensory related research) (Formas 2006).

As for the quality of research, the SOU 1997a report judged that Sweden had a strong position in, for example, environment, hygiene, ethics, security, nutrition research. The report also stated that the strong position of Swedish medicine research created favorable opportunities for profiling the Swedish food industry. Further, Sweden is also well positioned when it comes to raw material producers efforts on environmentally adapted and long-term sustainable production systems (SOU 1997a). The report also judged a number of areas as insufficiently addressed, including process, packaging, marketing and consumer knowledge, food/health (functional foods) as well as pointed out a need for more close-to-industry problem formulations and for a better coordination between different research areas. Whereas the Formas report does not judge the quality of research, the report identifies a number of areas as underfinanced or insufficiently addressed, including the areas of cost-health-nutrition, food safety, process technology, and research on food physiology, chemistry and biology (Formas 2006).

University research into the food area has been divided geographically into primarily three areas; Gothenburg, Lund, and Uppsala. In Gothenburg, research is shared between the University of Gothenburg (GU), Chalmers University of Technology (Chalmers, and SIK, with focus on Chalmers and SIK. At Chalmers, research is primarily conducted at the Division for Food Science (*Livsmedelsvetenskap*), while SIK organizes its activities around 4 main areas today. Apart from the activities in Gothenburg, SIK is also established in Lund and have smaller offices in Umeå, Uppsala and Linköping. The University of Gothenburg, finally, conducts food-oriented research primarily at the medical faculty.

In Lund research is conducted at departments at, or connected to, Lund University, Lund Institute of Technology, and the University Hospital MAS in Malmö (UMAS). Lund University and Lund Institute of Technology (LTH) primarily conducts research within Applied Nutrition and Food Chemistry, Food Technology and Applied Microbiology but also have economic and societal research with a focus on food (SOU 1997a; Formas 2006). Apart from Lund University and LTH, the Swedish University of Agricultural Sciences (SLU) also has research facilities in the Lund region as does SIK as mentioned above. Apart from these research facilities the Lund region also houses a number of other organizations related to the food industry such as Livsmedelskollegiet and IDEON AgroFood. In Uppsala, research is split between Uppsala University (UU) and SLU, which apart from the primary oriented R&D also have R&D focused on the next steps in the food chain. Uppsala houses research on, among other things, clinical nutrition and also focuses on raw material-oriented research in basic chemistry and biology, especially with regard to milk, cereals and meat where SLU's departments for food science and food hygiene are the largest actors. Pathogen organisms are another focus area. SLU has, since a parliamentary decision in 1994 a special responsibility for the connection between raw material production, and food processing, as well as for issues concerning food quality. SLU has defined four overarching programs for research within food: Production systems where production and environmental goals are equal; The production chain from earth to table; Quality in both production and product given new consumer preferences; Animal health and ethics. Apart from Uppsala university and SLU, Uppsala also houses the National Food Administration (*Livsmedelsverket)* which has food security as its primary focus, the major part on development of methods for food control.

Apart from these centers, there are also some other albeit often smaller competence centers and/or universities and higher education institutions that conduct food research or research on problem areas of interest or close to food research. These centers include Linköping University, Umeå University (UmU), Stockholm University, Karolinska Institutet, the Institute for Surface Chemistry (YKI) in Stockholm, University of Kalmar, and Örebro University (Formas 2006).

4.3 Medical technology overview

This section provides an overview of the medical technology sub-sector with focus on industry and academic research. First, we describe the main characteristics of the medtech industry and identify the largest companies. Second, we identify the major medtech research environments (and some smaller ones) at the Swedish universities and give some data about their present size and research focus.

By focusing on the current situation the purpose is to give a background for the subsequent effect analysis. The developments that have taken place over time, both within the industry and in academia, are related to the public research policy pursued by STU/Nutek/VINNOVA among others and will be described and discussed in Chapter 5 and Chapter 6.

In the preceding section there was a discussion on the Swedish public policy in the food area. The medical technology has not been subject to specific government policy initiatives in the same way as food (or pharmaceuticals for that matter). Apart from the general industry policy, the development conditions for the medtech sub-sector have been affected by sector-specific policies primarily in the fields of research and innovation, to be analyzed in subsequent chapters, and healthcare. Regarding the latter, there is no doubt that the large public investments in healthcare during the second half of the last century created favorable conditions for industrial development. Public efforts to build an advanced healthcare system provided the companies with opportunities to develop new products in collaboration with demanding and expanding customers in the domestic market. These products could then be exported to other countries. More lately, however, the developments in the healthcare sector have been less positive from the industry's point of view. For example, cost rationalizations and reorganizations within the healthcare system have made it more difficult for companies to establish fruitful collaboration and test new products. Furthermore, Sweden has lost position in clinical (close-to-the-patient) research, which is of particular importance to companies. These are current problems which have attracted a great deal of attention, and various measures to strengthen the clinical research and open up hospitals to increasing collaboration with industry are under way, as it seems.[28]

4.3.1 The medtech industry in Sweden

The medical technology industry can be characterized as heterogeneous and comprises a broad range of companies working with different sets of knowledge, technologies and products. See, for example, Table 4.6 for a list of product groups defined by the Global Medical Device Nomenclature. Furthermore, as pointed out by Sidén (2003, p. 18) the sub-industries that can be identified work under very different conditions of competition and in their degree of dependency on research. The size varies from "very large companies, traditionally based on electrical engineering and electronics producing heavy, big ticket, complex systems" to "small to very small firms in specific areas of surgical instruments, rehabilitation aids, etc produced in e.g. mechanical workshops and other materials-processing settings" (ibid. p. 18-19).

[28] See Arvidsson et al (2007) for a discussion on the role of the healthcare system in supporting the development of the biomedical industry in Sweden. The report argues for policy changes in order to facilitate for industry to establish effective collaboration with hospitals and other healthcare providers.

Table 4.6. Product groups

Code 01 Term:	Active implantable devices
Code 02 Term:	Anaesthetic and respiratory devices
Code 03 Term:	Dental devices
Code 04 Term:	Electro mechanical medical devices
Code 05 Term:	Hospital hardware
Code 06 Term:	In vitro diagnostic devices
Code 07 Term:	Nonactive implantable devices
Code 08 Term:	Ophthalmic and optical devices
Code 09 Term:	Reusable instruments
Code 10 Term:	Single use devices
Code 11 Term:	Technical aids for disabled persons
Code 12 Term:	Diagnostic and therapeutic devices

Source: Sidén (2003, p. 17)

In VINNOVA's recent cluster study on companies in biotechnology, pharmaceuticals and medical technology, the last-mentioned sector includes over 300 firms operating in the following business segments: Biotech medical technology, Diagnostics, Healthcare equipment, Active and non-active implantable devices, Anaesthetic/Respiratory equipment, Dental devices, Electromechanical and imaging equipment, Ophthalmic devices, Surgical instruments and supplies for electromechanical and imaging applications, Medical disposables, CRO Medtech, and IT and training (VINNOVA 2007c). Based on this study, Table 4.7, shows the names of the largest Swedish companies in each of these business segments (in terms of number of employees in Sweden) and the total number of firms identified.

Table 4.7. Medical technology companies in Sweden

Business segment	Firms with more than 250 employees	Firms with 51-250 employees	No. of firms
Biotech medical technology	Q-Med Octapharma	Vitrolife	26
Diagnostics	HemoCue Phadia	EuroDiagnostica Sangtec Molecular Diagn. Biomet Cementing Techn.	37
Healthcare equipment		Liko Textil Arjo[29]	21
Active and non-active implantable devices	Nobel Biocare Astra Tech St. Jude Medical	Cochlear Nordic Elos Medical Atos Medical	23
Anaesthetic/Respiratory equipment		Maquet Critical Care[30] Breas Medical	16
Dental devices			27
Electromechanical and imaging equipment	Gambro	Boule Medical Arcoma Getinge GEMS PET Systems Radi Medical Systems[31] Elekta Sectra	81
Ophthalmic devices		Advanced Medical Optics	4
Surgical instruments and supplies for electro-mechanical and imaging applications			16
Medical disposables	Mölnlycke Health Care PaperPak Sweden[32] Becton Dickinson Cederroth International Fresenius Kabi Promech Lab	AKLA Millipore Medical Rubber	36
CRO Medtech	Kronans Droghandel		2
IT and training		Cambio Healthcare Systems Ims Medical Radar	26

Source: VINNOVA (2007c)

Despite the large number of firms, the medtech industry in Sweden is dominated by a relatively small number of internationally operating companies, the largest ones being: Astra Tech, Becton Dickinson, Elekta, Fresenius Kabi, Gambro, Getinge Group (incl. Maquet Critical Care and ArjoHuntleigh), HemoCue, Mölnlycke Health Care, Nobel Biocare,

[29] This company belongs to the Getinge Group. The current name is ArjoHuntleigh.
[30] This company belongs to the Getinge Group.
[31] This company was in December 2008 acquired by St. Jude Medical for USD 250 million.
[32] The company's current name is Attends Healthcare.

Octapharma, PhaDia, Q-Med and St. Jude Medical. Table 4.8 gives some key data for these firms in 2007. We have added one more firm that is not included in VINNOVA's study but in our view should be regarded as a medtech company, namely SCA Incontinence Care. At the same time, it can be noted that Fresenius Kabi produces products (nutrition solutions) which are of pharmaceutical character (but not classified as drugs by the regulatory authorities). This company does not view itself as belonging to the medtech industry. The same goes for Octapharma (a spin-off from Pharmacia making plasma products). Some of the companies in Table 4.8, Becton Dickinson, Fresenius Kabi, HemoCue, Octapharma and St. Jude Medical, are subsidiaries of multinational firms with headquarters outside of Sweden.

Table 4.8. Key data for the largest medtech companies in Sweden (approx. numbers for 2007)

Name of company	Total turnover (BSEK)	Total number of employees	Number of employees in Sweden	Main product areas
Astra Tech	3.0	2,100	900	Dental implants Single-use products
Becton Dickinson[33]	---	---	470	Infusion therapy
Elekta	4.5	2,000	200	Radio surgery and radiation therapy
Fresenius Kabi[34]	---	---	850	Infusion therapy and clinical nutrition
Gambro	n.a.[35]	8,000	1,000	Renal care products
Getinge Group	16.5	10,400	1,300	Medical systems Infection control Aids for elderly and disabled people
HemoCue[36]	0.5	n.a.	250	Near patient diagnostics
Mölnlycke Health Care	3.6	5,500	300	Surgical and wound care
Nobel Biocare	7.0	2,200	470	Restorative aesthetic dentistry
Octapharma[37]	---	---	500	Plasma products
PhaDia	2.3	1,300	450	Allergy diagnostics
Q-Med	1.3	700	500	Medical implants
SCA Incontinence Care	12.1	n.a.	300	Incontinence care
St. Jude Medical[38]	--	---	700	Pacemakers

Source: Annual Reports and/or homepages

33 Becton Dickinson is a global medtech company with headquarters in the US. It employs some 28,000 people worldwide and in 2007 had revenues amounting to MUSD 6,400.
34 Fresenius Kabi is a subsidiary of the German Fresenius Group with more than 65,000 employees worldwide.
35 In 2005, Gambro had a turnover of approximately BSEK 15.6 (Action MedTech, 2007, p. 16).
36 HemoCue is since February 2007 a subsidiary of Quest Diagnostics Inc in the US.
37 Octapharma, which is a family-owned company with headquarters in Switzerland, took over Biovitrum's plasma business in 2002.
38 St. Jude Medical is a global medtech company with headquarters in the US. It employs some 12,000 people worldwide, and in 2007 had revenues amounting to MUSD 3,800.

According to VINNOVA's cluster study (ibid.) the medtech sector in 2006 employed 12,280 people in 326 companies. The industry was dominated by three business segments, namely, electromechanical and imaging equipment, active and non-active implantable devices, and medical disposables, which jointly employ almost 60 percent of the total number of employees in the sector.

As pointed out by VINNOVA these numbers do not include companies within the field of disability aids (e.g., rollators and wheelchairs, prostheses or hearing aids that are not bone-anchored and orthopaedic devices). But VINNOVA has identified 74 such companies employing approximately 2,180 people. If these firms are included it means that the medtech sector consists of at least 400 firms with 14,510 employees.[39]

As we have seen, VINNOVA measured the size of the medtech industry in terms of its employment in Sweden. If we instead look at the turnover, Action MedTech (2007, p. 15-16) has calculated that in 2005/2006 the Swedish medtech industry achieved sales amounting to SEK 60 billion in total, that is, including foreign operations. Five companies accounted for 75 percent of revenues (Gambro, Getinge, Mölnlycke Health Care, Nobel Biocare and Elekta). According to Focus Medtech Agenda (2005, p. 8) the Swedish part of the industry (i.e. excluding foreign operations) achieved a turnover of SEK 20 billion in 2003. This difference in numbers reflects the high degree of internationalization of the large Swedish medtech companies.

The medtech industry as characterized above can be said to represent "traditional medical technology", which is commonly the basis for classification of firms. However, it is important to note that due to the scientific and technological development the traditional medical technology, at least in some product areas, is increasingly being combined with modern bioscience (e.g., molecular and cell biology and immunology) as well as with micro- and nano-technology. This means that there is no clear boundary between the medtech industry and the biotech industry.[40] For example, there are companies developing tools for biotechnology research where there are also possible applications in healthcare (more or less actively pursued by the companies). Examples of such companies are GE Healthcare (previously Amersham Pharmacia Biotech, and including the recently acquired Biacore), and Biotage. These firms are commonly not classified as medtech. Nonetheless, it is not unusual for medtech researchers at universities to have collaboration with such firms (which are thus

[39] According to the same study, the entire life science industry in Sweden (including sales and marketing companies) consisted of some 850 firms and had 41,700 employees in 2006.
[40] This is one of the reasons why the broader concept of life science industry is more frequently used.

interested in commercializing findings from the medtech research). It is also worth mentioning that medical technologies and devices developed primarily for healthcare purposes are sometimes used as research tools by pharmaceutical companies. For instance, AstraZeneca is involved in several collaborations with medtech research environments in Sweden.

It should be noted, however, that the more traditional medtech industry, which still dominates the sector in Sweden, in many respects differs from the pharmaceutical industry and other life science sub-sectors having primarily chemistry and biology as their technological base. Today, the medtech industry receives most of its revenues from high-tech but relatively mature products. Many market segments are characterized by tough price competition and large-scale economies. The R&D expenditures of the established firms tend to be high by general industry standards (typically 4-6% of turnover) but considerably lower than in the pharmaceutical industry.[41] Although many products historically have their roots in academic research product development is today primarily driven by market needs (rather than technology push). Besides the established firms there are, for example in Sweden, a large number of small R&D-based firms, many of which are spin-offs from the universities. These firms are of course driven by the scientific and technological development and play an important role for the gradual and long-term renewal of the business. However, in terms of sales and employment they account for a small part of the industry.

Diagnostic versus therapeutic medtech equipment

In the field of medtech equipment the Swedish industry is comparatively stronger in therapeutic devices than in diagnostic devices. There are several internationally successful companies in the former business, such as Elekta, Gambro, Getinge and St. Jude Medical. In radiation therapy a cluster of firms has emerged in the Stockholm-Uppsala region.[42]

In the 1980s and 90s, Siemens-Elema was one of the largest manufacturers of medical devices in Sweden. Two of its four divisions (X-ray and Electrocardiography) disappeared when Siemens winded up its medtech operations in Sweden. One of our interviewees, who has a long experience from the medtech industry, says that this meant a death blow to the diagnostic-oriented equipment business in Sweden, since Siemens was the dominant player.

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[41] Some medtech companies spend more on R&D (see, e.g., ActionMedtech, 2007, p. 30). Elekta, for example, spent in 2006 7.2% as share of sales. Generally, leading Swedish companies are not among the highest spenders if we look at the global industry (ibid.).
[42] Besides Elekta, this cluster comprises the following small firms: C-RAD, IBA Dosimetry, Nucletron Scandinavia, Oncolog and Skandinova. Micropos Medical is another company active in the field, but it is located in Gothenburg.

Globally, the diagnostic market is much larger than the therapeutic one, but both profitability and growth rate are lower. The market is characterized by fierce competition, low margins, scale advantages and dominance by large multinationals (such as Siemens, Philips and General Electric). The same interviewee means that the therapeutic market is more attractive from a Swedish perspective. Besides higher margins and higher growth potential, another advantage is that the large multinational companies tend to avoid this market, since they are afraid of the risk to get sued by patients. This risk is lower for diagnostic devices. In Sweden, he says, there are people coming from for example Siemens-Elema or Scanditronix who know these risks and how to handle them. He believes that Sweden as a nation has a good chance to build up an expanding business in the therapeutic field.

4.3.2 The medtech research in Sweden

Generally, research in medical technology is characterized by being strongly *application-oriented*. The findings – in the form of new or improved methods and devices – are to be applied in healthcare and contribute to more effective diagnosis or treatment or better cost-efficiency. From this follows that there is (or should be) a close connection between the academic research and industrial product development. Intellectually, there tends to be a short distance between scientific breakthroughs and practical application. This does not hinder, however, that the time it takes to transform a research-based idea or invention into an industrial innovation is quite long.

Another important trait of medical technology is its *inter-disciplinarity*. Research of relevance for the development of medical devices is carried out by a broad range of research departments and centers representing different scientific disciplines. This is something that has gradually increased over the past couple of decades – not least as a result of the rapid advances in fields such as modern biotechnology, nanotechnology, microelectronics, and information and communication technology. In all these disciplines there are many potential applications to medical technology. Their realization may require inter-linking with knowledge from the more traditional medtech research fields (such as electrical engineering and biomaterials).

An inter-disciplinary approach is also needed in order to link the technical research to clinical needs. This can be done through collaboration between technical researchers and clinicians working at hospitals. The latter bring knowledge about user needs and applications as well as access to patients and patient materials (e.g. databases and biobanks), which are needed in order to test the methods and devices under development.

Like other parts of the life sciences, the medtech sector is characterized by *frequent formation of new companies* – often in the form of university spin-offs. This shows that, despite the high degree of maturity characterizing many of the core products sold by the large firms, there is an ongoing research-driven renewal of the industry. And the university spin-offs play an important role in this gradual transformation process. The formation of new companies is thus an important phenomenon that we will have reason to come back to later on.

The main purpose of this section is to present the most important medtech research environments in Sweden as of today. For the main university regions (Stocholm/Uppsala, Lund/Malmö, Gothenburg, Linköping, and Umeå/Luleå, we identify the largest research units and – depending on what data that we have managed to collect – give information about their research focus and size (in terms of number of researchers, including seniors as well as PhD students). The result is summarized in Tables 4.9- 4.14. We also include some research units that are currently not so big, but can be regarded as important nodes in the sectoral innovation system. Some of them may have been bigger in the past or, the other way around, can be expected to have growth potential.

The information provided in this section is limited to the current situation (2008). Later on, we will give a short description of the historical development. Changes in the medtech research landscape that have taken place over the past twenty years are partly an effect of the policy pursued by STU/Nutek/VINNOVA and other research financiers.

Table 4.9 presents key research environments in the Stockholm/Uppsala region. At the Karolinska Institutet (KI), two main research groups with specific focus on medtech have been identified. It is the Division of Medical Engineering located at the Huddinge campus and the Research Center for Radiation Therapy (approx. corresponding to the Division of Medical Radiation Physics) located at the Solna campus. The former has its roots in KI’s pioneering start up of medtech research in the 1950s and 60s, but today it is a small unit. However, by being physically and partly organizationally integrated with KTH’s School of Technology and Health it is part of a larger research environment. The research is carried out in close collaboration with this school. The Research Center for Radiation Therapy is one of the competence centers funded by Nutek and VINNOVA from 1996 to 2006. The VINNOVA-funding has ceased but the center still exists.

Table 4.9. Key research environments in the Stockholm/Uppsala region

University/organization	Dept./Division/Center	Research focus	Number of researchers
Karolinska Institutet (KI)	Dept. of Laboratory Medicine, Div. of Medical Engineering	Technical methods in cardiology	3
	Dept. of Oncology and Pathology, Research Center for Radiation Therapy	Radiation therapy	20
Royal Institute of Technology (KTH)	Dept. of Applied Physics, Div. Biomedical and X-Ray Physics	X-ray science and technology	25[43]
	Dept. of Physics, Div. of Medical Imaging	X-ray imaging	7
	Dept. of Signals, Systems and Sensors.	Microsystems technology	15
	School of Technology and Health	Medical technology broadly	20[44]
Uppsala University and the Swedish University of Agricultural Sciences	Center for Image Analysis	Image analysis and visualization	17-18[45]
Uppsala University, Faculty of Medicine	Dept. for oncology, radiology and clinical immunology, Unit for clinical immunology, Complement and Biomaterials Group	Blood cascade system	n.a.

Needless to say, there is at KI (Sweden's largest institution for education and research in medicine) a great deal of other medical research which is of relevance to the development and application of medical technology. Not least, this includes clinical research using different types of medtech products. KI also carries out a large amount of basic life-scientific research (in fields such as molecular and cell biology, genetics and immunology), which generates knowledge of relevance to medical technology.

At the Royal Institute of Technology (KTH), there are within the Department of Applied Physics several groups, in total comprising some 50 people, involved in medtech- or bio-related research. The largest one is the Division of Biomedical and X-Ray Physics ("Biox") with some 25 people. The research carried out at this division is to a large extent directed at or of relevance to medtech applications (some research, though, is more basic or

[43] In total, some 50 researchers within the whole department.
[44] Not counting some 11 researchers working on neuronics and 4 in ergonomics.
[45] These are people working on medical applications. In total, the Center has more than 30 researchers.

directed at electronics manufacturing). Other bio/medicine-related divisions at the department are Biomolecular Physics (13 people), Cell Physics (14 people), and Nanostructural Physics (11 people). Within the Department of Physics there is another medtech research group focusing on high-resolution X-ray imaging, with 7 people. Within the Department of Signals, Systems and Sensors there is a fairly large group working on microsystems technology with medical applications (some 15 people).

Another major research unit is KTH's School of Technology and Health, which is located at two campuses in the southern part of Stockholm. All medtech research within this school, as already mentioned, is co-located and integrated with KI's Division for Medical Engineering. The research profile is broad. Besides the medtech research, in a more narrow sense, there are other related research activities carried out in the same building (e.g. neuronic engineering and ergonomics).

Interestingly, it seems that there are no medtech research groups of significant size at Stockholm University, one of the largest institutions of higher education in Sweden. This is probably a consequence of the fact that there are in Stockholm separate universities specializing in medicine (KI) and engineering (KTH).

Uppsala University has a large Faculty of Medicine, which is carrying out internationally leading research in many fields. There is also a Faculty of Science and Technology. Uppsala is not so strong in "traditional medical technology" (compared with e.g. Stockholm, Lund, Linköping and Gothenburg). However, there is a major research center for image analysis (run jointly with the Swedish University of Agricultural Sciences), for which healthcare and medicine is an important application field. Within the related Department of Information Technology there is a small research groups working on analysis of human movement. Within the Department of Engineering Sciences there is another IT-group working on medicine-related research in the fields of pattern recognition and decision systems. On the hardware side, there is since long micromechanics research focusing on medical applications (e.g. sensors for pressure measurement). Within the Faculty of Medicine, there is a biomaterials group.[46]

Besides those units mentioned above, there are a number of other research groups which have received financial support from STU/Nutek/VINNOVA and/or from the other major financiers of medtech research in Sweden. The

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[46] There is also within the Faculty of Medicine extensive biotechnology-related research some of which may lie on the borderline between biotechnology and medical technology (e.g. research on molecular tools).

following ones were covered by the international evaluation of Swedish research in biomedical engineering (Swedish Research Council, 2006):

At KI:

- Magnetic Resonance Spectroscopy and Imaging Group
- Design of positron camera systems optimized for animal studies and oncology
- Section of Pharmacological Neurochemistry
- Brain Research

At KTH:

- Biomedical Functional Polymers
- SANS
- Hearing Technology
- Materials Chemistry

At Uppsala University:

- Polymer chemistry
- Digital X-ray imaging (DIXI)

Acreo Sensors Group

Within Lund Institute of Technology (i.e. the Faculty of Engineering at Lund University) there are three units carrying out a substantial amount of medtech research (see Table 4.10). The Division of Electrical Measurements is the largest one (and with a long history in the field that we will come back to later, in Chapter 5). There are three research groups, each with a significant size. At the Department of Electrical and Information Technology there is a research group with main focus on signal processing. Both these units are now involved in the creation of new, inter-disciplinary centers together with the Medical Faculty (Proteomics and nanobiotech application lab and Center for integrative ECG respectively). The third unit is the Medical Laser Physics Group, which is part of Lund Laser Center. The Medical Faculty has its own Biomedical Engineering Group, which is collaborating closely with the Department of Electrical measurements.

Table 4.10. Key research environments in the Lund/Malmö region

University/organization	Dept./Division/Center	Research focus	Number of researchers (approx)
Lund University, Faculty of Engineering (Lund Institute of Technology)	Dept. of Electrical Measurements, Div. of Electrical Measurements	Ultrasound Nano-biotechnology and Lab-on-a-chip Smarthand	20
	Dept. of Electrical and Information Technology	Signal processing Circuit design Radio systems	14
	Lund Laser Center, Div. of Atomic Physics, Medical Laser Physics Group	Biomedical optics	7
Lund University, Faculty of Medicine	Dept. of Clinical Sciences Lund, Biomedical Engineering Group	Ultrasound Medical imaging	4

Besides those units mentioned above, there are a number of other research groups which have received financial support from STU/Nutek/VINNOVA and/or from the other major financiers of medtech research in Sweden. The following ones were covered by the international evaluation of Swedish research in biomedical engineering (ibid.):

At Lund Institute of Technology:

- Bio analysis (Dept. of Chemistry, Division of Applied Biochemistry)

At Lund University, Medical or Science Faculty:

- Biosensors Group (Dept of Chemistry, Div of Analytical Chemistry)
- Unit of neural interfaces (Dept. of Experimental Medical Sciences)
- Fluid Mechanics
- Zoological Cell Biology/Nerve Regeneration
- Dept. of Orthopedics, Clinical Sciences
- Dept. of Hand Surgery
- Chemical Radiology/CMIV
- MR Physics Group

In Gothenburg, major medtech research units exist both at Chalmers and the University of Gothenburg (see Table 4.11). The newly established Division of Biomedical Engineering at Chalmers (within the Dept. of Signals and Systems) consists of four research groups and has its roots in the previous Department of Applied Electronics. As will be described in Chapter 5, this department was one of the pioneers in medtech research in Sweden. The Division of Biological Physics and the Division of Biopolymer Technology are two other important research environments at Chalmers. Both are doing research in the field of biomaterials, broadly defined, but with focus on different materials and applications.[47] [48]

Table 4.11. Key research environments in the Gothenburg region

University/organization	Dept./Division/Center	Research focus	Number of researchers (approx)
University of Gothenburg, Sahlgrenska Academy	Institute of Clinical Sciences, Dept. of Biomaterials	Biomaterials/Handicap research Cell biology	40
Chalmers University of Technology	Dept. of Signals and Systems, Div. of Biomedical Engineering	Bio effects Electromagnetics Signals and systems Imaging	20
	Dept. of Applied Physics, Div. of Biological Physics	Biosensors/biochips Nano-biotechnology Tissue engineering Vesicles and bilayers	20
	Dept. of Chemical and Biological Engineering, Div. Biopolymer Technology	Plant Polysaccharides Tissue engineering Superabsorbing polymers	15
University College of Borås	School of Engineering, Biomedical Engineering Group	Signal processing and analysis of medical and physiological signals	7
SP Technical Research Institute of Sweden	Dept. of Materials Science and Chemistry, Biomaterials and Diagnostics Program Area	Biocompatible materials New analytical methods	6

The Sahlgrenska Academy at the University of Gothenburg has a long history in the field of biomaterials, where there are today two larger research groups. Local collaboration with the Department of Applied Physics at Chalmers has existed ever since the 1980s. Since 2007 the Department of Biomaterials has hosted BIOMATCELL, which is a VINNOVA-funded VinnExcellence Center.

[47] In the Gothenburg region, there is an ongoing process aiming to create a platform for triple helix collaboration in medical technology – called Medtech West. An inventory of medtech-related research in the region, carried out as part of this process, revealed that there are many such activities going on within different parts of Chalmers.
[48] There are at Chalmers other research groups focusing more on biotechnology, but with possible applications in medicine. One example is the Division of Physical Chemistry, which is exploring methods to address problems of biological and biomedical relevance.

Medtech research at the University College of Borås has been built up by recruiting a professor from Chalmers' Department of Applied Electronics. The research focuses on signal processing and analysis of medical/physiological signals with specialization in development of technology for measurement and monitoring.

SP Technical Research Institute of Sweden is a state-owned group with headquarters and main facilities in Borås. Biomaterials and diagnostics is one of five program areas within the Department of Material Sciences and Chemistry. Projects in this area are mainly focused on biocompatible materials and the development of new analytical methods for biological systems with potential applications in, for example, early disease diagnostics.

Besides those units mentioned above, there are a number of other research groups which have received financial support from STU/Nutek/VINNOVA and/or from the other major financiers of medtech research in Sweden. The following ones at the University of Gothenburg were covered by the international evaluation of Swedish research in biomedical engineering (ibid.):

- Adaptive optics group
- Joint Replacement and Radiostereometry Unit
- ANNIMAB
- Anatomy and Cell Biology
- Vascular Engineering Center

At Linköping Institute of Technology there are several important research environments, as we can see in Table 4.12. The Department of Biomedical Engineering, founded in 1972, has for many years been one of the largest medtech research units in Sweden, with up to 50 researchers employed a few years ago. In recent years, due to the ending of a large VINNOVA grant for the NIMED competence center the department has reduced its workforce somewhat.

Table 4.12. Key research environments in Linköping

University/organization	Dept./Division/Center	Research focus	Number of researchers
Linköping University, Faculty of Engineering (Linköping Institute of Technology)	Dept. of Biomedical Engineering	Biomed. instrumentation Physiological measurements Medical informatics	35
	Dept. of Physics, Chemistry and Biology, Scientific Branch of Applied Physics (incl. parts of S-SENCE competence center)	Applied physics Applied optics Biomaterials Biomolecular and organic electronics Biotechnology Molecular physics and sensor science	35[49]
	Dept. of Systems Technology, Computer Vision Laboratory	Medical image analysis, Computer tomography	n.a.

Applied Physics, a scientific branch within the Department for Physics, Chemistry and Biology, is another major research unit. Half of the researchers (some 35 people) are working on the interface between physics, chemistry, biology and medicine. However, it should be noted that all applications that these researchers work with are not medtech in a true sense, but may be concerned with other fields of life science (e.g. tools for biotech research). A third important unit is the Computer Vision Laboratory at the Department of Systems Technology. Medical Image Analysis and Computer Tomography are two of several research directions.

Besides these university departments, the Center for Medical Image Science and Visualization (CMIV) is an important organizational entity. It is a multidisciplinary research center initiated in 2001 by Linköping University, Östergötland County Council and Sectra AB. The organization of CMIV comprises researchers from both the medical and the engineering faculties (including, e.g., the Department of Biomedical Engineering, Division of Medical Informatics). A core group, consisting of about 15 researchers, is co-located at the University Hospital. Some 70 researchers, mainly from different clinics, also belong to the center.

Besides those units mentioned above, there are a number of other research groups which have received financial support from STU/Nutek/VINNOVA

[49] This figure includes biotech research which is not directed at healthcare applications.

and/or from the other major financiers of medtech research in Sweden. The following ones at the Linköping University were covered by the international evaluation of Swedish research in biomedical engineering (ibid.):

- COMEX
- Technical Audiology
- Experimental Orthopedics
- MR-unit
- Clinical physiology (Dept of Medicine and Care)

The Center for Biomedical Engineering and Physics (CMTF) was established at Umeå University in 2000 as a network platform for medtech research projects carried out at different departments at the university and the university hospital. Since 2007, the Center is run jointly together with Luleå University of Technology. Currently, in total more than 100 researchers, including people outside of Umeå and Luleå, are involved in projects linked to the Center (Table 4.13).

Table 4.13. Key research environments in Umeå/Luleå

University/organization	Dept./Division/Center	Research focus	Number of researchers
Umeå University and Luleå University of Technology	Center for Biomedical Engineering and Physics (CMTF)	Biomedical engineering	Approx 40[50]

In recent years medtech research has been established also at several of the younger universities, such as Halmstad University, Mälardalen University (Västerås) and Örebro University (see Table 4.14).

Table 4.14. Research environments in other regions

University/organization	Dept./Division/Center	Research focus	Number of researchers
Halmstad University	Biological and Environmental Systems	Biomechanics and biomedicine	n.a.
Mälardalen University	Div. of Intelligence Sensor Systems, Biomedical Engineering research group	Sensor systems for measurements of physiological parameters	12
Örebro University	School of Health and Medical Science	E.g. biomaterials	n.a.

[50] This figure is the approximate full-time equivalents (man-years) for the 70-80 researchers involved from Umeå and Luleå. These researchers belong to 15-20 different departments at the two universities and work together in different constellations in 17 projects. This figure is not directly comparable with the figures given in other tables for individual departments. But it is a measure of the size of the combined medtech research environment in Umeå and Luleå.

It should be noted that besides the larger research environments specializing in medical technology, there is at Swedish universities a great deal of other research activities that are of relevance to the development of medtech products. This includes pure technical research within various engineering disciplines as well as pre-clinical and clinical research carried out at medical faculties. In other words, the above tables do not give a complete picture of the medtech research landscape in Sweden. The international evaluation of Swedish research in biomedical engineering (ibid.), that we have already referred to, covered in total 60 research groups which had received grants from the Swedish Research Council, Nutek/VINNOVA or the Foundation for Strategic Research (during the period 1997-2006). But there are others that were not included in the evaluation. The listing of research projects within STU/Nutek's research programs ran from 1987 to 1996 show that in those days there were many receivers of grants who came from other environments than those mentioned above (Nutek, 1997).

4.4 Additional funders of research

Given the broad and long-term approach the analysis has to take into consideration other programs and project financing schemes supporting the two fields. This includes especially research funding from the public policy initiatives studied here from STU/Nutek/VINNOVA (e.g. the competence centers) as well as from other organizations such as research councils and research foundations. One important reason for briefly introducing these external variables here is that in practice it may be difficult to distinguish effects resulting from different grants. For example, it is not uncommon that research carried out by a department in a certain scientific or technical area receives complementary funding from several sources – in parallel or consecutively.

4.4.1 Funders of food research

There are several organizations that publicly fund food research and development. Some of the funding provided by these organizations has been exclusively directly towards the food industry, however, funding has also been awarded food-related projects within programs not specifically directed at the food industry.

Focusing on funding specifically intended for food-related research, the major funders are VINNOVA, Formas (and their respective predecessors Nutek and SJFR), the Swedish Research Council (*Vetenskapsrådet*), and the research foundations.

VINNOVA (and Nutek) has supported food research through several different efforts, where the major effort has consisted of the Innovative

Food programs. Other efforts include support of SIK (MSEK 8 and MSEK 9 in 2002 and 2003 respectively), and support of food related research through programs such as VinnVäxt, VinnExcellence Centers, and Efficient Product Development (Effektiv produktframtagning – VINNOVA 2006b). In collaboration with SSF, VINNOVA has granted MSEK 1.5 to food-related research through the program VINST in 2003 (Formas 2006). Earlier efforts in related areas include a R&D program within the packaging area that Nutek handled on a national level. The program was coordinated by SIK and to more than half funded by about 20 packaging companies and 15 food companies (SOU 1997a).

Formas provides support to food research for yearly calls. In 2002 and 2003, the amount of funding for new and ongoing projects was about MSEK 15 and MSEK 10 respectively. The report by Formas (2006) estimated that these levels were about the same as the funding levels for its predecessor SJFR. In addition, Formas also provides support for occasional food-related projects in other areas. SJFR and Stiftelsen för Marknadstekniskt Centrum (MTC) also financed the program "Kunskapsplattform för livsmedelsbranschen" (K-LIV) (SOU 1997a).

Regarding the research foundations, the Foundation for Strategic Research (SSF) financed a program and a research school for future technologies LiFT from 1997 to 2004. The program was coordinated by SIK. Upon program completion, though, the research school has continued under the direction of Chalmers, SLU, and Lund University in close collaboration with the Swedish Food Federation (*Livsmedelsföretagen*) (LiFT homepage)[51]. MISTRA has financed via MAT21 a program focused on primary production (SOU 1997a). The program ran between 1997 and 2004. Upon completion, however, MISTRA agreed to provide additional funding for the period 2005 to 2008 (Mat21 homepage)[52].

To a lesser extent there has been and is also funding from other actors such as the Swedish Research Council and its predecessors Medicinska forskningsrådet (MFR), Teknikvetenskapliga forskningsrådet (TFR), and Naturvetenskapliga forskningsrådet (NFR). Also Nordisk Industrifond has provided funding, for example, via the program NORDFOOD.

A Swedish work group that consists of university and industry researchers connected to the European Technology Platform Food for Life has made an estimation of the amount of funding directed towards the food industry from different actors (NRA 2007). The results are summarized in Table 4.15.

[51] www.chalmers.se/chem/SV/amnesomraden/livsmedelsvetenskap/lift/forskarskolan-lift
[52] www-mat21.slu.se

Table 4.15. Funding results to food industry

Public funder	Funding 2006
Research councils and public foundations	MSEK 60
Faculty funding and institute support	MSEK 40
EU-funding	MSEK 75
Nordic programs	MSEK 10
Total	**MSEK 185**

According to the group, FORMAS, VINNOVA and other Swedish foundations put about MSEK 60 a year into food industry research over the period 2004-2006. In addition, public funding of about MSEK 40 in the form of, for example, faculty funds went into the food sector for the year 2006. The report also considered funding from the EU, Nordic Innovation Center (NICe) and Nordforsk, the largest funders of Swedish food research outside the Swedish public funding system. The yearly contribution to Swedish research groups from the 6th EU-framework program was estimated to MSEK 75 a year the last couple of years, and the contribution from NICe and Nordforsk was estimated to MSEK 10 a year. An estimation of the amount of funding to Swedish food research in 2006 would thus amount to MSEK 185 (see Table 4.15). Funding from the two VINNOVA-programs directed towards the food area amounted to about MSEK 122 over a period of 10 years. Based on a yearly average then, the VINNOVA-funding would amount to about 6.6 percent of total public funding towards the food area in 2006.

The same report also made an estimation of the food industry's funding of research. According to the report, Swedish food industry's R&D efforts at their own facilities could be estimated to about MSEK 400, or about 0.3 percent of total industry turnover, for 2005. The figures were based on SCB's company statistics. The raw material and food producing companies also fund research via foundations such as Stiftelsen Cerealia R&D, Stiftelsen Lantbruksforskning. These foundations make a yearly contribution to R&D projects at Swedish universities and institutes of about MSEK 120, including funding to agriculturally oriented research. The food industry also fund contract research at the industry research institutes of about MSEK 60 a year, and participate as a co-financer in research projects and research programs at Swedish universities and institutes with an estimated amount of MSEK 40 a year.

In total this amounts to about MSEK 620 spent on R&D by industry in the year 2005, partly including agriculturally oriented research (see table 4.16).

Table 4.16. Money spent by companies for food research (NRA 2007)

Activities funded	Funding 2005
R&D efforts within firms	MSEK 400
Contract research at institutes	MSEK 60
Co-financing of research projects and programs	MSEK 40
R&D efforts via “private” foundations	MSEK 120
Total	**MSEK 620**

4.4.2 Funders of medtech research

During the 20-year period that we cover in this study medtech research has been supported by STU/Nutek/VINNOVA through other efforts than the eight focal programs described in Section 4.1. Among various research programs one that is of particular relevance for medical technology is ‘Communication technology aids for disabled’. This program was run from 1987 to 1993. It was later on substituted by the program ‘IT for disabled and elderly’ run jointly by Nutek, KFB and Hjälpmedelsinstitutet. Other programs that were started in the 2000s and therefore were not included among the targeted programs for the present study are ‘IT for home care (2003-) and BioNanoIT (2002-2005).

A later research program specifically targeting medical technology is Biomedical Engineering for Improved Health (2006-). This program was run in collaboration between VINNOVA, the Swedish Research Council (*Vetenskapsrådet*) and the Foundation for Strategic Research (*Stiftelsen för strategisk forskning*). However, since it is relatively recent this program is not targeted in the present study. This program has in turn been followed by a new VINNOVA program called Innovations for Future Health (2008-13). Two other ongoing VINNOVA programs are VINNVÅRD (2007-11) and SAMBIO (2006-10).

Although this study focuses on the effects of academic research, it is worth mentioning that during the period there have also been some programs more directed at product development. This includes the Nutek program PUFFA (1993-), which was devoted at commercializing medtech inventions. Two more general programs run by Nutek are Research and Technology Based Product Development and SNITS (1994-). The receivers of these grants are companies.

Besides the program grants, substantial funding of medtech research has come through *non-program project grants*. For certain departments this kind of external funding has been the dominant one, since their research topics did not fit the objectives of existing programs. For other departments such grants have been a welcome complement to the program funding.

It can be added that some of the research environments covered by our study have received research grants administered by other units and officials than those responsible for medical technology (or life science). This is especially the case for IT-related projects. It also includes support of Swedish participation in EU projects.

An important policy initiative taken by Nutek in 1996 was to support the building of strong research environments through its *competence center* program. The funding was long-term (ten years) and required co-funding and active participation from industry. Two of the competence centers were totally dedicated to medical technology, namely, NIMED (Non invasive medical measurement technology) at Linköping University and the Research Center for Radiation Therapy at the Karolinska Institutet. Given that these centers accounted for a substantial share of Nutek/VINNOVA's funding of medtech research during the period 1996-2006 we decided to include both centers in our study. There were some other competence centers for which healthcare was one of several application areas. One example is S-SENCE (Swedish Sensor Center) at Linköping University. About 10 percent of the research dealt with biosensors for use in healthcare. Also within SUMMIT, a center for research on surface and microstructure technology there were some projects related to medicine.

In VINNOVA's more recent program for *VinnExcellence centers*, the following centers carry out research in the medtech field: BIOMATCELL (University of Gothenburg), SUMO (Chalmers), and CHASE (Chalmers, partly medtech). Since they have just started their activities (2007), these centers are not covered by our effect analysis. It can also be mentioned that VINNOVA is supporting medtech research and commercialization through its ongoing *VinnVäxt program*: Uppsala BIO, Biomedical Development in Western Sweden (Gothenburg) and The New Tools of Life (Linköping).

This study focuses on effects of STU/Nutek/VINNOVA's efforts directed at medical technology since the late 1980s. It should not be forgotten, however, that medtech research has been supported also by other financiers. For many research environments, grants from such financiers have periodically been a valuable complement to the STU/Nutek/VINNOVA funding. In many cases, it is the same research topics that have been funded by several financiers. In reality, some effects may be a combined outcome of efforts made by two or more financiers. Therefore, in our effect analysis we have to take these financiers in consideration.

Needless to say, the Swedish Research Council (created in 2001) and its predecessors, the Medical Research Council and the Technical Research Council, have been important financiers of academic research in Sweden, and this includes medical technology, especially during the last ten years.

Among the research foundations, the foundation for Strategic Research (SSF) has been quite active in the medtech field. This includes, for example, the following efforts:

- Program Biocompatible materials (1995/96-)
- Sub-area Physiological measurement technology (within the program Forum Scientum) (1997-)
- Biomaterials consortium (1997-2000)
- Directed project support (medical technology is one of six targeted areas) (1997-)
- Frame grants in medical technology (1998-)

The Foundation for Knowledge and Competence Development (*KK-stiftelsen*) has supported medtech research through the following programs.

- IT within healthcare
- IT and education for disabled

The foundation LFTP (*Landstingens Fond för Teknikupphandling och Produktutveckling*) was a financier which has supported applied R&D projects in the healthcare area.

Lastly, funding from the EU through its framework programs and other initiatives has emerged as an increasingly important source of research funding for the medtech research environments.

5 Effects: From the perspective of academic research

5.1 Introduction

This chapter focuses upon the effects, from the perspective of academic research, on the two sub-sectors of innovative food and medical technology. Academic research can consist of many things, but we are particularly interested in how these sub-sectors develop, over time. Therefore, we are particularly interested in the competencies of the actors; in the linkages amongst actors; in the flows of information, material, and people; and in changes in the selection mechanisms, which affect the overall co-evolutionary pattern of the sectoral system of innovation.

The perspective of academic research in innovative food focuses mainly upon the project level. These programs and projects are much closer in time, and we have collected and analyzed material about all projects. One aspect is the detailed analysis of actors involved in projects, and relationships amongst them. This provides some insight into the main research environments, which together with an implicit understanding of the new knowledge involved enables us to examine academic results. We also examine education.

The perspective of academic research in medical technology focuses primarily upon the research environment, and their developments over time. These programs and projects started much longer ago in time, and therefore we can track the developments and provide an overall picture. As the research environment in our effect chain model (see Figure 2.1) has arrows running to many other steps, this focus enables us to discuss many related issues.

5.2 Innovative food

The academic research carried out in innovative food has been introduced in Chapter 4 ‘Public policy initiatives and overviews’. The two research programs were Industrial cooperative projects in the food industry and Innovative food. Both can be seen as primarily academic research, which were driven by the needs of industry. Hence, the interaction between academic research and industrial R&D should be kept in mind as an important characteristic of these needs-driven projects.

Fifty-six projects of the 66 projects analyzed in innovative food provide more or less detailed information, which includes all the larger projects and a few of the planning reports.[53] The number of times that specific academic results were reported follows in Table 5.1.

Table 5.1. Categories of outputs reported by 56 innovative food projects

Category	Number of projects reporting as result
Scientific publications	45
Conference/Other publications	
Master thesis	32
PhD student involvement	
New scientific method and/or theory development	15

A few methodological notes are in order first. We have primarily utilized three sources; the initial project application; the evaluation assessments in projects' final reports and interviews with some project leaders. Moreover, for projects initiated 2000 or later, the final reports include assessments of the results made by the project leader according to result categories specified by VINNOVA. In many instances the project officer at VINNOVA has supplemented the assessments with comments on the projects results.[54].

Hence, three main sources for determining research results are the self-evaluation assessments, final reports, and project officers' comments. In addition, interviews have been conducted with project officers and project leaders of different projects. Eleven such interviews were made, covering project leaders in charge of altogether 11 projects (and participating in some

[53] Of the 66 projects, the final reports include self-evaluated assessments for 41 of the projects, while less detailed reports of results exists for 15 of the projects. These 15 are older projects, or projects that have yet not written the final report. In the remaining ten projects with fewer details, it has been difficult to find any conclusive reported results for various reasons. There are thus reported results from 56 of the projects, four of which are planning projects.

[54] The pre-specified result categories in these assessments are as follows: Scientific publications, scientific conferences, Other publications, Master theses, PhD positions and dissertations, New research network, New company network, New research group or program, New scientific method or theory, New practical method, Technology transfer, Prototype, Product development, Products, Patents, New technology or equipment, Seminars or demonstrations for practitioners, New firm or commercialization, and New center. Since some of the categories are partly overlapping, this report has used a condensed version of these categories to structure and analyze the results. For projects that lack these assessments, it is still possible to discern results from the final reports, with additional information coming from interviews

additional projects) and firms representatives participating in a total of 14 projects.[55]

In the following text, the perspective of academic research in innovative food therefore goes through these topics: Actors involved in the projects including the main research environments; Academic results in terms of publications and conferences; Education and training in terms of PhD and Master theses; Academic results and interactions with companies in terms of new scientific methods and theories; and Relationships between grants, publications and patents.

5.2.1 Actors involved in projects

This section discusses the actors involved in the projects, including first the universities, colleges and research institutes and individual project leaders and then the companies.

Universities, colleges and research institutes

In terms of the universities, colleges and research institutes involved, the projects are almost exclusively located in the three geographical regions of Gothenburg, Uppsala and Lund. These correspond to the location of the main universities in the three main Swedish metropolitan areas of, respectively, Gothenburg, Stockholm-Uppsala and Malmö-Lund. Categorizing projects according to the host organization of the project leader, 48 of the projects were headed by project leaders from the universities or institutes in these regions.

In terms of the academic institutions receiving the majority of funding, Table 5.2 details the results.

The academic institutions located in Gothenburg and receiving the most money are: Chalmers and SIK; the academic institutions in or near Stockholm-Uppsala are KI, SLU and UU; and the academic institutions in Malmö-Lund are LU/LTH as well as the local offices of SIK and SLU.

Hence these represent the six main research environments of relevance for innovative food. With one exception, they have also worked in the field for many years, as outlined in Chapter 4. Note there is one entrant to being financed by VINNOVA, namely Karolinska Institutet (KI) in Stockholm. Although KI is not entirely new to the food area, it is a new actor to be funded by VINNOVA in this area, something that VINNOVA actively sought to encourage. The other five are incumbent research environments,

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[55] The interviews were conducted either face-to-face or by phone and lasted between 0.5 to 2 hours.

in the sense that they have specific areas of specialization and already had competencies before the program began as identified in, for example, SOU 1997a.

Table 5.2. Research environments for innovative food, by origin of project leader, number of projects and total funding from VINNOVA

Origin of project leader	Number of projects	Total funding from VINNOVA
Companies	2	1 551 854
Chalmers University of Technology (Chalmers)	4	13 098 000
University of Gothenburg (GU)	1	300 000
Karolinska Institutet (KI)	2	8 600 000
Royal Institute of Technology (KTH)	1	300 000
Lund University/LTH	17	33 472 497
SIK[1]	18	31 023 555
SLU	11	11 639 000
Umeå University	3	2 870 000
Uppsala University[2] (UU)	7	17 398 200
Institute for Surface Chemistry (YKI)	3	1 797 000
National Food Administration	1	531 150
Total[3]	**70**	**122 581 256**

1) SIK includes both offices in Gothenburg and Lund; the remaining three offices in Linköping, Uppsala and Umeå have not headed any projects.
2) One of the projects in Uppsala was actually initiated by industry, but still came to have UU as running the project.
3) Some projects have been co-headed by two universities. Splitting these projects on the respective universities the total number of projects become 70 instead of 66.

This first classification started by the research environments, but in fact, there are extensive network linkages across the academic partners. There is often more than one university, university department, or institute, connected to each project. Thus, in 44 of the projects this was the case, although the extent of involvement varied. Moreover, eight of the projects reported involvement of international universities. However, the number of international collaborations is probably higher as many projects formed part of, or ran alongside, other larger projects, such as EU-projects (as outlined in Chapter 4).

Taking all national collaborations into account, the research environments which participated in projects becomes slightly different. Table 5.3 specifies the number of projects that each academic partner was project leader for, as well as the total number of projects in which they participated (including projects that they were project leader for).

Table 5.3. Research environments for innovative food, by origin of project leader and total number of projects in which they participated

University/Institute	Project leader	Project participation
Chalmers	4	7
University of Gothenburg	1	6
KI	2	5
KTH	1	2
Linköping University	0	2
Lund University/LTH	17	22
UMAS	0	2
SIK	18	21
SLU	11	19
Umeå University	3	5
Uppsala University	7	11
YKI	3	3
Total	**66**	**105**

Three research environments are outstanding, both in terms of being project leader and in participation in projects. They are LU/LTH in Lund, SIK in Gothenburg and Lund and SLU near Stockholm-Uppsala. These three have each participated in approximately 20 financed projects, which indicate a major concentration of competencies (and of resource flows, as indicated in Tables 5.2 earlier).

Another interesting aspect is the existence of linkages amongst these academic partners. Many of the collaborations between universities and institutes are between actors located within the same region. Thus, for example, all projects that University of Gothenburg (GU) has participated in as a collaborating partner are with either SIK or Chalmers, which are both located in Gothenburg. Similarly, Chalmers and SIK have been collaborating partners on projects. Uppsala University often collaborates with colleagues at SLU, and to the extent that KI has been involved as a collaborative partner such collaborations has solely extended to Uppsala University (UU). Whereas Lund University has been engaged in collaborations with both SIK and SLU, these collaborations are primarily with the local office of SIK and SLU-Alnarp, and thus also primarily regional.

We have identified a few cases of collaborative projects where the partners come from different regions in Sweden. Umeå has had some collaboration with Uppsala. In Linköping it is the group S-Sence that has been involved in one project with SIK and one with Lund University. The assessment that we have is that these linkages were forged by specific individuals, often ones whom had changed jobs. For example, Chalmers and Uppsala University (UU) collaborated, and the project leader at Chalmers had a prior history at UU. We do not know if this is correct for all cases. Still, in one sense then, labor mobility can stimulate linkages in the SSI.

Industrial participation and quasi-public organizations participation in projects

Most of the projects had at least one industrial partner, and usually a number of industrial partners. Because we have detailed project information, it is interesting to go through and identify the industrial actors, the types of companies, and their involvement. We would therefore expect to find effects of the two-way arrows between academic research and industrial R&D in later parts of this chain-linked effect.

In the 66 projects there were 58 projects that involved a number of companies, institutes and other organizations. For eight of the projects, no external collaborative partners could be found either because lack of information, or because the projects were planning projects with no participation from external stakeholders. Two of the projects lacked any company involvement for other reasons (although these projects hosted reference groups consisting partly of industry professionals). One of these projects concerned the building of an Internet webpage for the food industry, and the other was a project evaluating consumers' attitude to and knowledge of functional foods, a study where direct company involvement seemed inappropriate. Hence, about 88 percent of the projects involved an industrial partner.

The number of industrial partners, government agencies and other organizations is much larger, however. Each project may have several partners, and each partner may be active in more than one project.

We examined all companies and organizations that have signed agreements of participation, as well as some companies stated by the project leaders as contributors to the projects. Seen from this perspective, there were 206 instances of involvement from companies and other external organizations.

Out of these, the vast majorities, 187 instances consisted of firms involved in one or several projects. These 187 instances of participation were accounted for by about 87 different companies and subsidiaries. Counting only the company groups to which the subsidiaries belonged as of the project start date (several companies were bought or merged within the timeframe of the projects), there were all in all 71 company groups involved in the projects. The detailed table of companies is presented in Chapter 4. In other words, a large number of industrial actors active in the Swedish food industry and market have been involved – one way or another – with these programs.

The other 19 collaborations involved other organizations such as, for example, the National Food Administration, the National Veterinary Institute (SVA), Packforsk and Matforsk (Norway). Most of these other organizations have a quasi-public or public role in developing, enforcing and sometimes leading research about issues of regulation, safety and further developments in the agro-food industry.

On average, each project has 3.17 organizations per project. The highest number of firms involved in a project exceeded 15. Comparing the different major research environments, the average involvement of firms across projects is similar with one exception, namely SIK. SIK on average involved more firms (about one firm more per project); something which is perhaps not surprising provided their role as a research institute. Naturally, the role and extent of participation of each company varied considerably from company to company, as well as from project to project. Still, the number of companies and organizations involved provides an idea about the level of industry participation.

The linkages and intensity of linkages across several actors is also visible. Some of the 100 different companies identified above only participated in one project, but several firms participated in a number of different projects.

Out of the 100 organizations that participated, 87 were firms and 13 were other organizations. Table 5.4 shows the distribution of participation, by company and by other organization. Thus, for example, 59 participating firms were only involved in 1 project, as well as 10 of the other organizations. At the other extreme, two firms were involved in 13 projects each.

Table 5.4. Participation in projects, by company and other organization

Number of projects involved in	Number of companies	Number of other organization	Total
1	59	10	69
2	5	1	6
3	10	1	11
4	6	1	7
5	2	0	2
7	1	0	1
9	1	0	1
12	1	0	1
13	2	0	2

As shown in Table 5.4 the majority of these companies were involved only in one project, while about one third of the companies were involved in two or more projects. There are no general patterns regarding collaboration between firms and research environments, although it is possible to discern some ongoing collaborations. Karlshamns and SIK have, for example, collaborated on several projects, as has SIK and Arla and other dairy companies. These repeat collaborations suggest a certain increase in intensity of the linkages. Small research intensive companies such as Probi and Ceba also tend to work with the same universities and even the same university departments for the projects they participate in. However, for larger companies such as Cerealia and Orkla that are involved in many projects, collaborations extend to all of the major research environments.

A few companies have been particularly frequent in project participation, and also with several different research groups. For example, aggregating subsidiaries to company groups, Lantmännen is involved in about 1/3 of all projects, and Arla and Orkla are involved in 1/4 and 1/5 of all projects respectively.

The companies involved in the projects are predominantly companies that produce for end customers, such as Arla, Findus and Orkla. However, the program includes companies from all stages of the value chain and several projects also represent companies from different stages of the value chain within one and the same project. Sometimes, the project requires that companies from different stages of the value chain are included, for example, to be able to develop a new product such as consistency optimized for food for the elderly. Other projects could involve competing companies that produce similar products to end customers, i.e. direct competitors. These would often be on issues of relevance to all, i.e., that go beyond products that they directly compete upon. To take one illustration of such a project, several of the major dairy producers in Sweden were involved in a project concerning issues of hygiene in production.

As for the size of the industrial partners, most of the companies are fairly large, including companies such as Arla, Orkla, and Tetra Pak. Chapter 4 provides detailed information about the size of the companies (as of 2008 or latest available date). Table 5.5 categorizes the industrial partner by size of company at the time of the project.

Hence, Table 5.5 demonstrates that industrial partners of all size categories participated. This is a good indication of the heterogeneous nature of actors involved.

Table 5.5. Innovative food projects, by size of company and number of projects involved

Size of the company	Number of projects
0-9	8
10-49	19
50-249	21
250-499	8
>500	26
No information	5
	87

An interesting question is what companies and industrial R&D contributed to the academic research. Many of these companies were actively involved in the projects, with one illustration being that they contributed actively with specially designed products and biological materials. Carrying out academic research on dairy hygiene for example, may require testing on production sites at the companies. As for the smaller companies involved in the projects, some of these were small companies that only provided raw materials such as berries into the projects. Other small firms were the research intensive small firms, which actively worked on the projects and sometimes worked as intermediaries between other actors in the SSI. The latter could be exemplified with BioGaia, CeBa, and Probi that are all present in several projects. A common denominator for these latter firms is that they are university spin-offs with good connections to academia, and often also to other larger firms. Hence, even though we here focus upon academic research, it is clear that in some cases, the industrial partners and their R&D made the collaborative project possible, and also contributed to the research environment and academic results.

5.2.2 Education and training

We now turn to education and training, which is a step related to both academic research and the environment discussed above. We primarily examine education and training from the perspective of academic research, and do so by focusing on PhD theses and Master theses. The sources are the self-reported assessments as well as more subjective illustrations from the interviews. However, these individuals also represent a key type of flow of information and knowledge between actors in the SSIs. Therefore, we have also gathered more in-depth information on one research school, LiFT, in terms of where the students get jobs, including linkages to the industrial partners.[56]

About 60 percent of the projects reported the project had influenced graduate students in terms of leading to one or more master theses, and/or involving projects with PhD students. The actual figures are a bit hard to assess. On the one hand, the actual numbers may be higher still, since several projects were not asked to explicitly report on master theses and PhDs. On the other hand, PhD students in technical subjects are generally financed by grants, and we can expect that their financing also came from additional financiers. Given that the figures could easily go up (if all included) or down (if only the percentage financed by these projects are included), we feel it is reasonable to assume that at least about 60 percent did lead to effects on education and training in terms of Master and PhD students.

Master theses in Sweden are commonly done with companies, especially in technical subjects, but they can also be conducted solely within the research environment. About half of the programs report one or more master theses, being conducted within the framework of the two programs studied here. These theses can be important to different actors, and to linkages between them.

One illustration that we have shows that the Master thesis can lead to the initial probing of a new idea or area. Such a Master project can probe an area of interest to both academic and industrial partners, and then lead on to new projects. The illustration comes from a project dealing with fermentation in grain.[57] The idea behind the project was conceived of about fifteen years ago and hence before the current project (in Innovative Food) was started. This idea formed the basis for a Master thesis many years later, and the academic results of this Master thesis were deemed interesting enough to pursue further. This in turn led to a patent application and the founding of a firm, Olligon, in 2001. The two Master students were employed by the firm, and some aspects of the ideas formed the basis for a project within the VINNOVA program. Additional projects studied here also indicate that working on Master thesis is a way to signal interest in continuing as PhD students in subsequent projects. In some cases, it is possible to track through names of participants in project reports, where we can see how Master students in early projects participate as PhD-students in

[56] Hence, this aspect is not visible in Table 5.1 and our discussion of academic research. It is very interesting, however, as a bridge to the discussion about the perspective of industry, found in the next section.
[57] P20105 – *Nutritionella effekter av nya livsmedel från svampförädlade spannmål*. The project is further discussed in relation to product development.

later projects. This long-term continuation of projects and the hiring and training of researchers is thus one important mechanism behind the cumulative development of actors' competencies and of creating and intensifying linkages in the innovation system.

PhD students were involved in about half of the 56 projects (45%) for which we have information. However, many fewer projects report that the project funding was actually the cause for hiring a new PhD, or that the project funded a whole PhD. One reason for this (as indicated above) is that PhD students in these subjects are often employees of the universities, and hence require significant sources of funding for long periods of time (4 to 6 years on average). Hence, one could hardly expect that the VINNOVA project funded a whole PhD project, also given the relatively small scale of most projects.

Some projects can be found that report on a dissertation as a project result, and where the project likely provided funding for the larger part of those dissertations. In one case, for example, a company initiated a project in collaboration with a university partner. This student worked for the company prior to embarking on her doctoral studies. More often, though, PhD students reoccur across several projects suggesting that specific projects form parts of research environments', as well as individual students', larger research themes.

There is little general information reported in the projects about what happens to PhD-students after dissertation. We have examined one project, the LiFT-program, which has tracked many of their PhD's occupations and positions after they obtained their PhD degree[58]. LiFT was started in the late 1990s, and after program completion in 2004 it has continued as a research school under the direction of three universities and in close collaboration with the Swedish Food Federation. The list includes a total of 58 doctoral or licentiate defenses. For eleven persons no information was available and they are therefore not on the following table (which is based on information from September 2008).

LiFT PhD students – as counted from defenses from 2001 through 2008 – have been employed in the following places (see Table 5.6).

Table 5.6. LiFT PhD students later employment (at time of reporting)

Company	University, research institute	Regulatory, branch and other organization
27	11	9

[58] The information was kindly provided by the program director of LiFT.

Table 5.6 thus indicates that the PhD students have been employed in many parts of society. The companies involved are quite diverse. Twenty-one of the companies may be described as more food-related, including, food companies such as Swedish Oat Fiber and Atria Lithells, equipment and packaging producers such as Tetra Pak and Ecolean Development, and analysis companies such as Lantmännen Analycen. The remaining six companies are pharmaceutical or medtech companies such as AstraZeneca and Mölnlycke Health Care. About 25 percent continued to work in academia after PhD, primarily in the Gothenburg and Lund regions. The final category relates to more or less food-related organizations, ranging from Uppsala Livsmedelscentrum and SVA to the Swedish Patent and Registration Office (PRV).

The interviews also provide additional information. The university researchers that have supervised many PhD-students state that most of them have remained in the food industry, either within academia, firms, or government institutes or agencies. However, for those who remain in academia it usually takes a 5-10 years before they manage to create their own platform. In the meantime, their research unit, or the university they belong to, must be willing to finance them and this is increasingly difficult with reductions in fixed based financing, although the creation of new, large centers counterweight this to some extent. That there are few positions within academia, and more so in institutes, for new PhDs, contributes to the problem.

While PhDs do move on to industry, some industry representatives also point to difficulties for PhDs to be hired to continue their line of research within the firms. Representatives of two different firms say that for their company to actually hire a PhD-student after dissertation to continue on the research project, the results of the project need to be very, very interesting even if the company was involved in the PhD-project. There is simply no room within the company to hire someone to continue experiment. If they are to hire a PhD on the basis of his/her results, these results must clearly point to commercially interesting applications. Both interviewees view this as a disadvantage and would like to see some form of post doc position that could be jointly financed by firms and the state to overcome it.

5.2.3 Publications and conferences

The majority of the projects report one or several papers published in scientific journals, and/or that conference papers, reports or book chapters have been published on the basis of results from the projects. 11 of the 56 projects that report on results, report no publications or conference presentations at all. In at least three of these projects, scientific publications are a likely future result as the projects are still very recent or even ongoing.

As for the other projects these were either planning studies, or projects that were of a more practical nature. An example of the latter kind of projects is a project aimed to construct an Internet webpage for the Food industry.

The interviews also show that at least some of the papers resulting from the projects have been published in top ranked journals. One of the projects, for example, tested a well-established hypothesis regarding the effects of whole grain on health in a large-scale study on humans.[59] The results could, however, not confirm the hypothesis. The "negative" results surprised the researchers, and also earned them a publication in one of the top ranked journals in the field.

Apart from the purely academic merits and knowledge diffusion, the publications are sometimes also important for the legitimacy and publicity they can provide companies. Research documentation may be necessary to legitimize claims and to gain publicity needed in order to be able to sell products. We expect this to be particularly true for nutritional foods, given the expected health benefits. Moreover, if results are published, they may well draw attention. In a project aimed to form the basis of a new product line for consistency optimized food for elderly,[60] research was related to international expansion. The research documentation provided the whole company unit for special foods with a firmer scientific base which was important for sales on export markets.

Another aspect from a company point of view is publications, and hence publicity, may help generate value already early in the project. As one firm representative put it, "while new products are always a goal, this often takes a long time to realize, however, the information that the projects generates is something that could be used on a much earlier stage to create value". That is, to, for example, create legitimacy and publicity as well as to inform consumers about what the company is doing.

Naturally, conflicts may also exist between the publication of results and the commercialization of results. If we look a bit closer on one project[61], one patent is registered. LTH owns the patent, and has offered it to the companies. However, it is difficult and costly for the company to pursue further commercialization, particularly if the information has already been put in the public domain through publications. However, the main reason is

[59] P25083 – Positive health effects of whole grains food (Positiva hälsoeffekter av livsmedel rika på fullkorn).
[60] P20510 – Konsistensoptimering och sensorisk design för hälsa och välbefinnande hos äldre.
[61] P20071 – Exopolysackarider producerade av mjölsyrabakterier: pre- och probiotisk funktionalitet och nyttjande som förtjockningsmedel i livsmede

that many aspects have to be developed, before a new product is placed on the market.

5.2.4 New scientific method and/or theoretical development

About one fourth (27%) of these projects report on what is categorized as new scientific method and/or theory as project results. In the vast majority of cases, this refers to new scientific methods. The magnitude of these scientific results is naturally difficult to establish, but the interviews still suggest how the results have increased scientific knowledge and point to some of the effects of these results.

One illustrative case shows how research helps explore new areas, but may take a long time to lead to commercialization. One project aimed to investigate a certain substance (exopolysaccharide) produced by lactic acid bacteria, and the pre- and probiotic functionality of these bacteria as well as their effect on health. Not much scientific work had been conducted on the substance prior to the project, and there was not much known regarding the substance' effects on health nor about how it was produced, that is, the biosynthesis and how it could be manipulated. Through the project they developed an understanding of how the substance could be used and also managed to develop ways to stimulate the production. The new methods to stimulate production were important as natural production of the substance is far too small to generate the amount needed in order to make controlled tests for the substance' effects on health. The project thus contributed to a new understanding of how lactic acid bacteria produce the substance and how this production can be stimulated. The research department involved in the project has not continued to study the effects on health, but the small research intensive company that was primarily involved in the project has. Depending on the results from that study, the substance and the project could lead to new functional food products.

The project mentioned above that was concerned with health effects of whole grain has also led to the development of new methods.[62] In an earlier project, researchers found out that they could use metabolites of a substance as a biomarker that they could use to assess how much whole grain someone has consumed from blood samples. This method was then validated within the VINNOVA-financed projects. The discovery and validation of this new method for measuring intake of whole grain is important as it facilitates and increases the validity of studies that relate intake of whole grain to, for example, health. Prior to the discovery of the biomarker, they instead had to

[62] P25083 – Positive health effects of whole grains food (Positiva hälsoeffekter av livsmedel rika på fullkorn)

tightly control that the test persons consumed the amount of whole grain prescribed for them.

The quote from one dairy company is interesting, as it helps explain why these results – which are not immediately applicable as a product – can still be important to the companies.[63] These results are sometimes "basic requirements to move on, the basic research conducted is a prerequisite for the project. For our part, as a firm, we have to choose parts of these basic research results and try to apply them. The advantage for us in this case is that the technology applied makes it possible to screen for different new applications relatively quickly". Hence, this quote indicates that the collaborative, basic research is needed, but they focus upon one part, to solve a particular problem. New methods (technologies) can help them do so faster, and are therefore valuable, which is further discussed under the later section on new practical method and/or technology/equipment.

The impact of new scientific methods and/or theoretical developments on further research is often difficult to quantify in monetary term. The "pay off" in terms of a host of potential new projects, products and/or processes that emanate from these findings is often far in the future. Still, these illustrative cases indicate how the results in terms of new methods help both the academic research and industrial R&D to do additional research and solve specific problems.

5.3 Medical technology

We will start by giving a short historical background to the medical technology research in Sweden. In the following section, the development of research funding in the medtech field will be briefly commented, also as a background. This issue will be further elaborated in the third section, which focuses on the effects of the research financing on research environments, in terms of their development over time. This is, as we see it, a key subject from an effect analysis point of view. Subsequent sections will deal with the university-industry interaction, first with a focus on collaboration with established firms and then with a focus on the formation of start-up companies.

5.3.1 Medtech research in Sweden: history in short

Academic research in medical technology (or biomedical engineering that we use synonymously) is a relatively young discipline in Sweden dating back to the 1940s/50s, when more focused research began to emerge in

[63] P25075 – Maintained health with functional food (Bibehållen hälsa med funktionella livsmedel)

some places. Today, as we saw in Chapter 4 medtech research, broadly defined, is carried out at many universities and departments/centers.

In this section, the history of medtech (or biomedical engineering) research in Sweden will be described shortly as a background to the current situation (as described in Chapter 4) and, more importantly, to the effect analysis.

From an international perspective, medical technology as a research field began to appear in the 1940s. There were for example clinical physiologists or other physicians within the faculties of medicine who were interested in technology and began to develop new techniques and instruments, which they needed primarily for their own medical research (rather than for treatment or diagnosis of patients). At the same time, technical research dealing specifically with the development of new methods, apparatuses and other types of products to be used in healthcare began to appear at some universities of technology. Commonly, research groups with such a focus emerged within departments of electrical engineering (where medical technology became one of several application fields – typically one of the smaller). Sweden, which already in those days had an internationally well-reputed medical research and where large resources were invested in the creation of an advanced and publicly funded healthcare system, became at an early stage one of the leading countries in Europe also in medtech research. In the beginning of the 1950s, three pioneering research groups began to develop, namely, at the Karolinska Institutet (KI), Lund University and Chalmers University of Technology.

Before describing these developments, it is worth mentioning that Sweden as one of the first countries in the world established in 1956 a Society for Medical Engineering and Medical Physics (*Svensk förening för Medicinsk Teknik och Fysik*, MTF). In 1967, it arranged the World Congress in Biomedical Engineering, which is seen as an early milestone in the development of medical technology in Sweden.[64]

At KI, Sweden's largest medical school, the initiative to start up medtech research was taken by Bertil Jacobson, a physician and clinical physiologist who had a strong interest in technology and in developing new products for healthcare. In the early 1960s, thanks to his efforts in this field he got a personal professorship in medical technology and built up a small research group (4-5 people). However, the main focus was on product development, rather than building up an expanding research group and establishing a post graduate program. Among other accomplishments, Bertil Jacobson came up

[64] MTF has today about 1,000 members, most of whom work with clinical engineering at hospitals. The main tasks of the clinical engineers are procurement, service and maintenance of medtech equipment, but they may also take part in R&D projects.

with a number of X-ray inventions made in collaboration with radiologists.[65] The group was later on moved from the main campus in Solna to the new campus in Huddinge, in the southern part of the Stockholm region. After Bertil Jacobson's retirement in 1992 Håkan Elmqvist took over as professor and head of the current Division of Medical Engineering (a position he had until he retired in 2008). Interestingly, he came from Siemens in Germany where he had had a senior management position in the medical business. Despite being a pioneer within Swedish medtech research, the division has remained relatively small over the years and has produced only a limited number of PhDs. However, a close collaboration has been established with KTH's School of Technology and Health, and since early 2000s they form a joint research environment in the southern part of Stockholm.

In parallel to the activities at KI, Lund Institute of Technology (i.e. the Faculty of Engineering within Lund University) emerged as another Swedish pioneer in medtech research. The key figure here was physics professor Hellmuth Hertz, who is behind several breakthrough discoveries and inventions, especially regarding ink-jet technology and medical applications of ultrasound. Starting in the early 1950s, and in close collaboration with clinical researchers in Lund, he developed methods to use ultrasound for medical diagnostics – methods that have been widely used worldwide and contributed to build a new branch of industry. Attempts to get the technology commercialized by Swedish industry failed, due to lack of interest from the firms concerned. So unfortunately, the industrial effects of this pioneering research did not benefit Sweden, but were instead materialized in other countries. In 1963, the Department of Electrical Measurements was established, and Hellmuth Hertz began to build up a strong research group in the area. After his retirement in 1986, the environment-building work was continued by his successor Professor Kjell Lindström – with good help from a small group of senior researchers who had chosen to stay at the department after having completed their PhD. As a complement to the ultrasound research, which has remained a core activity, the department has since then expanded into other research fields, in particular microsystems engineering, nano-biotechnology (incl. lab-on-a-chip), proteomics, and neural interfaces. Within the current Division of Electrical Measurements there are some 20 researchers working in the medical field.

Also in the 1950s, Chalmers University of Technology began to build up research in applied electronics with a focus on medical applications. It all

[65] An important contribution of Bertil Jacobson was a text book on biomedical engineering that has become widely used in Sweden, and still is many years after the first edition. The book has been translated into English and is used also abroad.

started with Professor Henry Wallman, an American mathematician from MIT who had been recruited by Chalmers. For personal reasons he became interested in medical technology and started pioneering research on X-ray television. He also began to build up a research group and broadened the research to cover other technologies and applications. Signal processing at an early stage became a core area. The second half of the 1970s and the first half of the 1980s can be characterized as a flourishing time from a medtech point of view. The Department of Applied Electronics had two full professors (Robert Magnusson and Torsten Olsson) and practically all research was focused on bioengineering. A tradition of close collaboration with clinicians at the nearby Sahlgrenska University Hospital was established.

Despite internationally well-recognized research and interesting results produced by the Chalmers researchers commercialization was rare. It was difficult to get established medtech firms to take over the knowledge and inventions and bring them to the market. It was against that background that Chalmers established the foundation Medicin & Teknik in 1985. The main idea was to further develop and prepare commercially interesting projects for exploitation by established firms or start-up companies. Besides a number of successful consulting projects for firms, the main outcome of Medicin & Teknik's activities is the founding in 1991 of a company called Svenska Telemedicin System. It was six years later acquired by Ortivus Medical and is the origin for one of this company's present core businesses. There are a few other companies which over the years have spun off from the department, with or without support from Medicin & Teknik.

Linköping Institute of Technology (i.e. the Faculty of Engineering within Linköping University) is home of one of the largest medtech research and educational environment in Sweden, that is, the Department of Biomedical Engineering with at present some 35 researchers (incl. PhD students). This department was established in 1972 in connection to the founding of Linköping Institute of Technology. In the preceding planning process, and based upon an idea put forward by an industry representative, it had been decided that biomedical engineering should become a core activity of the new Institute. Such an investment in creating a large academic unit specializing in medical technology was at the time perceived to be in line with international trends. Professor Bertil Jacobson from KI, who had been engaged as councilor, had come up with a unique proposal – today described by many as brilliant – to locate the department to the university hospital, instead of to the main campus where the other technical departments had their facilities. With hindsight, this choice became very important for the development of the department, since it enabled the medtech researchers to have daily contacts with the physicians at the hospital. Thus, from the very beginning the research was carried out in proximity to the clinical environment, which facilitated cooperation with clinicians and testing of new methods and products under real-world conditions. The fact that Åke Öberg, the first professor of the department, also became head of the clinical engineering department at the university hospital also contributed to make Linköping a pioneer in integrating technology and medicine. Even in an international perspective this kind of strong linkage between technical research and practical healthcare was rare.

Linköping Institute of Technology soon became Sweden's largest educator of clinical engineers to be employed by the healthcare sector and the industry as well. The expanding research at the department, initially funded mainly through General University Funds[66] also resulted in a large number of PhD theses (in total 65 up till today). Later on in this chapter we will describe in more detail how this department has evolved over time.

From the late 1970s and onwards, a large number of other research environments with different fields of specialization have emerged in different parts of the country. At Lund Institute of Technology, for example, medtech-oriented research groups of considerable size have been established also within the Department of Electrical and Information Technology and at Lund Laser Center. In addition, a separate Biomedical Engineering Group has been formed within the Faculty of Medicine. In Linköping, technical research focusing on medical applications has been established, *inter alia*, within the Department of Physics, Chemistry and Biology and the Department of Systems Technology. At Umeå University, which has a strong research tradition in medicine and biosciences, a Center for Biomedical Engineering and Physics was established in 2000. This center is now, since a couple of years, run jointly with Luleå University of Technology. In Gothenburg, strong research groups working on biomaterials have been built both at Chalmers and the University of Gothenburg. The latter has in fact a long tradition in this field thanks to Professor Per-Ingvar Brånemark's pioneering research on osseointegration of titanium implants (starting already in the 1950s).

Besides the emergence of new medtech-oriented research groups at the older universities, some of the younger ones have more recently entered the field, typically by recruiting key persons from other universities. This includes Luleå University of Technology, University College of Borås, Mälardalen University and Örebro University.

[66] This is what in Swedish is usually called ”fakultetsmedel” (the latest government bill on research and innovation, from Fall 2008, uses the expression "Direkta anslag till lärosäten"). This is research money granted to the universities by the government as ”block funding", as opposed to direct funding of specific projects.

As will be further discussed below, during the 1980s and 90s STU and its successor Nutek (from 1991) became the dominant external financiers of medtech research in Sweden. Through its medtech and other relevant programs STU/Nutek helped many existing research environments to expand as well as to build up new research groups (some of which had not worked much on biomedical engineering before).

From the beginning, leading professors mainly from the large medtech research environments had a dominant influence on STU/Nutek's medtech programs. But in 1993, Nutek decided to take in company representatives in the steering groups. An effect of the increasing influence from industry was that the research projects in many cases became more interdisciplinary. As described by a previous Nutek project officer the companies often made other priorities than the academics. This led to the bringing in of researchers who did not come from the traditional medtech environments. These "non-traditional" medtech researchers added new competencies, technologies and perspectives that sometimes could be used to strengthen existing projects run within the classical research environments.

Another initiative taken by Nutek in 1993 was to organize annual medtech conferences. They substituted previous separate meetings arranged by each program. These national conferences were broadened also by inviting companies and by dealing with EU projects. A further broadening took place after a few years when the conferences also included the new Nutek-funded competence centers and researchers who received grants from the Foundation for Strategic Research. These conferences were highly appreciated both by academics and company representatives. They became an important meeting place and enabled new contacts to be established both among researchers and between academia and industry. These medtech conferences were run until around 2000. After the formation of VINNOVA no such meeting activities directed specifically at medical technology have taken place.

It is beyond the purpose of this study to describe in detail how the medtech research landscape in Sweden has evolved over time. But this short historical account, and the examples given, will hopefully help the reader to get a feeling for the historical context in which the effect analysis has been carried out. How the present situation looks like was presented in Chapter 4. We saw there that the field of medtech research is increasingly more difficult to define and delimit. The reason is the increasing convergence of different technologies, meaning for example that traditional medical technologies are often combined with modern biotechnology as well as with micro and nano technologies. This means that an increasing number of research groups claim to be active in the field, and by consequence compete for grants dedicated to medical technology/biomedical engineering.

It seems that the broadening of the medtech discipline, spurred by scientific and technological developments as well as STU/Nutek/VINNOVA's actions, has not been appreciated by all researchers representing the classical medical technology. It has meant increasing competition for research grants. Others are more positive and emphasize the need for renewal of the medtech research.

5.3.2 Funding of medtech research in Sweden: a short note on the development over time

Until the mid-1990s the financing situation for Swedish academic researchers was relatively stable, with substantial General University Funds for research coming from the government via the university. That gave good prerequisites for long-term planning of the research. However, from 1995, and during the following years, the system for public financing of university research was changed. The researchers could no longer count on the same amounts of General University Funds as before. Instead, they became increasingly dependent on external grants, resulting *inter alia* in greater uncertainties and more time spent on writing applications. The new research foundations and the EU became important sources of research money, along with the research councils and Nutek.

For the medtech researchers, this system change coincided with the ending of three Nutek programs dedicated to medical technology: MEDiBILD, Biocompatibility, and Minimal invasive medical technology (see Chapter 4). During the 1980s and 90s, STU and Nutek had become important financiers of research for many medtech research groups around the country. In 1996, these programs were substituted by a new broad program called Healthcare Technology. Another new program was the competence centers, where Nutek granted long-term funding of selected centers for the purpose of building strong research environments.

As will be described in the next section, these changes in funding conditions during the second half of the 1990s have had effects on several medtech research environments – either in a positive or a negative way.

While many medtech researchers highly appreciate the policy towards medical technology pursued by STU and Nutek in the 1980s and 90s, many of them are critical of VINNOVA, which came into being in 2001. VINNOVA has designated medical technology as a priority area, within the field of life science. However, the more medtech-oriented programs have been relatively small and quite broad, which in practice means that it has been difficult to obtain grants. Through the Swedish Society for Medical Engineering and Medical Physics VINNOVA as well as the Foundation for Strategic Research have been approached with the purpose of initiating a discussion regarding future funding of medtech research in Sweden. The recent call for a new program called Innovations for Better Health is perceived as a signal that VINNOVA has listened to the criticism.

5.3.3 Development of research environments

Today, a clearly stated policy objective of VINNOVA is to support the creation of strong and sustainable “research and innovation environments”. Also in the past, if we go back to STU and Nutek, this was at least implicitly an important goal with the research programs and the competence centers. Under all circumstances, the long-term effects of the research funding on the development of the research environments is, as we see it, a key issue from a policy point of view. What can we learn from the past experience? In this section, we will exemplify and discuss how some key medtech research environments in Sweden have developed over time, and how this development has been affected by STU/Nutek/VINNOVA’s policy and by other factors.

Building of strong research environments[67] is first of all about creating a “critical mass” and capabilities that enable the performance of research at a high international level. Given the applied nature of most medtech research and the mission of STU/Nutek/VINNOVA to support industrial development, the research environments should also benefit firms in various ways. The most important benefit for existing firms, generally, is probably their effects on the quality of education. The possibility for firms to recruit competent and well-trained engineers and R&D personnel – at the basic, graduate and post-graduate levels – has positive effects on the firms’ competitiveness. But strong research environments may also have more direct effects on the industrial development. In particular, the capabilities built up thanks to the research grants may enable the academic scientists to generate new knowledge and inventions that can be exploited by companies. Other possible advantages are the possibilities for firms to use these environments for carrying out contract research or purchasing consulting services. The firms may also benefit from drawing on the academic researchers’ own networks within the international research community. Needless to say, strong research environments may also constitute a

[67] With research environment we mean an academic organizational unit (department, division, center or research group) which is specialized in some part of medical technology. To be characterized as an environment most staff of the unit should normally be located in one place. But it is possible to conceive of a unit with several locations, provided that the work is closely integrated. A current example is the Center for Biomedical Engineering and Physics, which is now a joint research facility for Umeå University and Luleå University of Technology.

breeding ground for formation of new companies. We will elaborate more on these different effects in the next chapter.

As shown by our effect model (see Figure 3 in Chapter 2) a research environment can be described in terms of skilled staff, facilities, organization & management, and not to forget networks of different kinds. Thus, besides building up internal resources and capabilities within the unit or units concerned, the establishment of cooperative relationships with various types of external actors – academic as well as industrial – is a crucial part of the process.

First, collaboration among academics is a well-established feature of the scientific community. In the case of medical technology, researchers may need to link up with other academic researchers for a variety of reasons, such as sharing of resources, exchanging data and, not least, gaining access to complementary competencies. Thus, it is impossible to build a strong research environment without having an external network within the scientific community. Needless to say, what kind of relationships that are needed depends on situation-specific circumstances. Of particular importance to medtech researchers, which was pointed out already in the historical section above, is collaboration with clinical researchers. They have not only access to patients and testing facilities but also clinical knowledge that can be an essential input to the research process. They can, for example, bring detailed knowledge about the needs and information on the users' requirements on the new methods and products to be developed.

Second, putting the research results into practical use in healthcare on a larger scale normally requires industrial product development and commercialization. Normally, the transfer of knowledge to industry cannot be done on arm's length distance, but necessitates some form of collaboration with firms. Thus, if a research environment has commercialization ambitions efforts must be made in order to create appropriate networks with industry. Once built, the network constitutes an important asset and a key feature of the research environment. An alternative to collaborating with existing firms is of course to start up new companies ("university spin-offs").

To begin with, we will describe below two cases showing how new research environments have come into being and how they have evolved over time with support of different financiers. The first case is the Department of Biomedical Engineering in Linköping. The second case deals with biomaterials research in Gothenburg, an environment which comprises groups both at Chalmers and the University of Gothenburg. In the subsequent discussion on the role of STU/Nutek/VINNOVA illustrating examples from other environments will be added.

<u>Case</u>: Department of Biomedical Engineering, Linköping Institute of Technology

As we saw in our short description of the early history of medtech research in Sweden this department called IMT (Institutionen för medicinsk teknik) was established in 1972 when Linköping got an Institute of Technology with biomedical engineering as one of its core areas. Åke Öberg (coming from Uppsala University) became the first professor and head of department. A year later, Ove Wigertz from Karolinska Institutet and the Royal Institute of Technology got the second professorship with specialization in medical informatics.

Åke Öberg's vision was to create a bridge between engineering and medicine. He abandoned his own research field and initiated new research projects together with local clinicians (in line with the idea of locating the department in the hospital area). He also made several study trips abroad (e.g. to the USA and Japan) to find out what was going on in the world and get an input to the planning process. One important outcome of this was that biomedical optics, and laser Doppler flowmetry in particular, became a key research area, and it has ever since remained a core activity within the department. Much of the research carried out by Åke Öberg and his group came to be focused on measurements of various physiological parameters. Besides the bio-optical methods the group has worked also with ultrasound and bio-acoustics. Today Physiological Measurements is one of IMT's three research areas and a division within the department.

Gert Nilsson was the first PhD student of Åke Öberg. He received his doctorate in 1977 but remained at IMT until 1982, when he started to work for Gambro. He explains that in the early days the researchers did not pay much attention to innovation. But in his thesis work Gert Nilsson had developed a method for measuring water evaporation. He was contacted by ServoMed, a small technology-based company founded by a well-known entrepreneur and businessman active in the life sciences. The latter wanted to buy the rights to the invention and commercialize it. Despite the early access to the method, ServoMed did not succeed to defend its market position and later became outcompeted by foreign firms.[68] An important

[68] The technology in itself has become a commercial success. It has become one of the standard methods in dermatology for studying the barrier function of the skin and is marketed by 3-4 companies, none of which is Swedish.

effect of the event, however, was that it made the researchers aware of commercialization possibilities and interested in innovation.

Another early company contact was Synectics Medical in Stockholm. The background was that Per Ask, the second PhD graduate from the department, had at the time his research interest on diagnostic methods on the gastro-intestinal tract. After having earned his PhD in 1978 he started a project to develop a new pH-probe for the gastro-intestinal tract. This was done in cooperation with clinicians at the Ear, Nose and Throat Department within the Faculty of Medicine and with Gunnar Edwall at the Royal Institute of Technology. When having developed the new probe in 1980 the researchers were contacted by Synectics, which at that time was a small distributor of medtech products in the Swedish market. A fruitful collaboration was established which resulted in the successful commercialization of a new diagnostic system for measuring pH and pressure that was used in gastro-intestinal applications. This system became the core product of Synectics and helped the company to grow rapidly. In 1994, when Synectics had reached a turnover of approximately SEK 180 million, it was introduced on the stock market. Two years later it was sold to the large American medtech corporation Medtronic and became integrated in its neurology business area. After a couple of years, all of Synectics' activities in Sweden had been moved to the USA.

Ever since the early 1970s much of the research has been devoted to laser Doppler flowmetry, where IMT has obtained a world-leading position.[69] In 1980, a new company called Perimed was spun-off in order to commercialize a method for measuring blood circulation in the skin. Despite many years of development the method has not got clinical applications, but remained a research tool. But Perimed has gradually managed to build up a profitable business and it is today one of the leading suppliers of such instruments in the world market. In 2007 it had 52 employees and a turnover amounting to MSEK45.[70]

[69] Laser Doppler flowmetry is a non-invasive method to measure the microcirculary blood flow based on the fact that light impinging any moving scattering object undergoes a very small frequency shift.

[70] Åke Öberg maintains that the success of one company like Perimed is enough to pay back to society all the public research money granted to IMT over the years.

In 1987, Gert Nilsson came back to IMT after five years with Gambro and got a new professorship in Medical Instruments Technology. Biomedical Instrumentation became the third research area and division within IMT (beside Physiological Measurements and Medical Informatics). The research focus has gradually been broadened to cover different bio-optical methods and different application areas, in particular skin, neuro and cardiovascular.

It can be added that later on, in the late 1990s and early 2000s, Biomedical Modelling and Simulation emerged as a fourth research area within IMT. However, it is currently "sleeping", since the professor has moved to another department within the university.

During the start-up period the department got very good financial support from the university. The annual grants for research correspond to approximately SEK 16 million in today's money value. The money was used to start recruiting PhD students and other personnel and buying equipment. The department also developed courses in biomedical engineering and Linköping Institute of Technology soon became Sweden's largest educator of clinical engineers.

Already at an early stage, and despite the strong support from the university, STU (and later on Nutek) became the backbone in the research financing. In fact, IMT was involved in designing the medtech programs started by STU in 1987. STU/Nutek became the dominant source of research financing and enabled the department to expand, mainly by recruiting a large number of PhD students. From 1977 to 2008 IMT has awarded 65 doctoral degrees and many of these students have received funding from STU/Nutek/VINNOVA.

In the 1970s and early 1980s, as mentioned above, IMT became involved in several commercialization processes together with small or newly started companies (ServoMed, Synectics, Perimed and Fältelektronik). Contacts were taken with several of the large medtech companies, such as Gambro and Siemens-Elema, but these discussions did not result in any substantial research collaboration. It turned out to be difficult to penetrate the long decision-making hierarchies in these companies. Often the new product ideas did not fit in and many promising inventions ended up on the shelf and nothing happened. These experiences led Åke Öberg to conclude that commercialization of research results should primarily take place by starting and/or collaborating with small companies.

It can be noted that the department in those days had good finances and therefore did not need to get money from industry. The availability of "free resources" made it possible for the researchers to make pre-studies and test new wild ideas. Åke Öberg says that this was extremely valuable and stimulated new thinking. He compares with today's situation where grants have to be applied for all projects. It means that the researchers must know in advance if a certain idea is practicable.

In 1996, when the STU/Nutek programs ended, IMT was lucky to become host of a competence center NIMED (Non-Invasive Medical Measurements). This meant significantly increased research resources, a situation that lasted for ten years (1996-2006). The annual budget was on average SEK 16 million – roughly one third each from Nutek/VINNOVA, Linköping University and industry. The companies made contributions both in cash (approx. 40%) and in kind. 80-90 percent of the budget went to IMT and the rest to a couple of other units within the technical faculty. There were a large number of participating clinicians from the medical faculty, but they were not funded by NIMED. Over the ten-year period NIMED accounted for approximately 40 percent of IMT's research funding. Other projects were funded, for example, by the EU, the Swedish Research Council and the KK Foundation.

The NIMED grants were used by IMT both to finance new PhD students and to offer newly graduated PhDs to stay at the department as research fellows. Some of them have now become full professors with their own research groups.

The overall goal of NIMED was to carry out internationally competitive research and postgraduate training in active collaboration with industry. Thus, the idea was to collaborate with existing firms. Over the whole ten-year period 18 companies have been involved in so-called applied projects, each one with one participating company.[71] About half of the companies were large (or belonged to large corporate groups) and the other half consisted of small or medium-sized firms. While some companies remained as industrial partners during

[71] NIMED has also carried out "technology focus projects" with a character of basic science.

the whole period others participated only during one or several of the four stages.

An interesting effect of NIMED from a research environment development point of view is that the center seems to have had to some extent a conserving effect. In terms of research focus NIMED was quite broad. By inviting existing medtech firms to start collaborative projects it is not surprising that many of the selected projects built on existing strength areas, such as for example laser Doppler and other bio-optical technologies. For natural reasons the companies often wanted to take advantage of the unique competencies of IMT, which had been created through many years of previous research and had led to impressing academic results. At the same time, at least some people at IMT felt the need for a major renewal by entering new research fields (e.g. by incorporating modern biotechnology just to mention one option). To some extent the research at IMT has been broadened thanks to NIMED by moving into new application fields (typically triggered by the interests of industrial partners) and by introducing new technologies (e.g. thanks to new recruitments). However, this set up did not allow big technological leaps to be taken.

A tentative conclusion from this observation is that a center like NIMED may not be the best way to initiate a more radical change of research direction (if that is desirable). It should be recalled, however, that IMT in parallel to NIMED carried out other research. For example, in several of the divisions IMT has started up new projects related to home or distributed healthcare, where there is a great need for new technologies and products. This is now considered a key area for IMT as a whole. It illustrates how the department is now expanding its research within a field that lies outside its traditional core.

The involvement of firms in collaborative projects through NIMED resulted in the establishment of many new company relationships that did not exist before. Some projects were not so successful and the companies left NIMED after some years. In other cases the project developed well and produced results that were useful to the industrial partner. In a few cases the collaboration has continued after the termination of VINNOVA’s funding in 2006. However, it seems that generally it has been difficult to keep the collaboration alive when there is no longer any public funding available. Thus, with a few exceptions the industrial partners have not been willing to take over the full responsibility for the continued financing of the research.

In other words, the network effects have been mixed. Obviously, it does not go without saying that center-related collaborations lead to long-term relationships with industrial partners – unless there is continued public support for collaborative projects. Now when NIMED has been finished there is some disappointment within IMT that the effects on industry have not been greater and that closer company relationships have not been established to a larger extent.

As a continuation of NIMED, IMT has established the Center for Biomedical Data Processing (CBDP) together with seven partners. Three of them are companies that participated in NIMED (Atos Medical, Elekta and Perimed), and they are now co-funding together with the university continued research. The scope of NIMED-CBDP is wider than for NIMED and involves some other companies and healthcare organizations that did not take part in NIMED. The new center has received some grants from the university for 2007-2009, which has turned out to be very useful in the discussions with companies regarding future collaborations.

By definition the industrial collaboration within NIMED was directed at existing firms. This means that for the researchers who worked on applied NIMED projects the possibility to get engaged in start-up activities were limited (according to the agreements the industrial partners owned the rights to all intellectual properties from the project). The strong focus on the established firms also meant a weakening of the entrepreneurial climate. One of the professors says that the interest among PhD students in starting companies decreased during the NIMED period. However, the situation has changed now when NIMED has been finished, and during the last 3-4 years several new companies have spun off from IMT. Two of them are Ldiamon and LB Index both of which are based on results from NIMED projects. In both cases the participating large firm was not interested in commercializing the product idea and the researchers behind the invention therefore chose to start up their own company to bring the product to the market. There are some other recent spin-off companies that are not directly linked to NIMED, but have their roots in the long-standing research tradition of IMT. One example is Bio-Optico started in 2005 by Åke Öberg together with three other researchers representing different academic disciplines. The company is developing an optical method for measuring cartilage thickness in joints. WheelsBridge started by Gert Nilsson is another example of a spin-off company based on the department's long research tradition in biomedical optics. The company is now commercializing a new technology for tissue characterization.

In commenting the NIMED focus on collaboration with the established industry one of the professors says that the competence center model has clear advantages. To start up a new medtech company and take a new idea all the way to the market is a long and cumbersome process. One advantage with the large firms is that they have established marketing channels. And moreover many of these companies have a need to renew their core business. The dilemma, however, is that the market potential of the new product must be high, often several hundred million Swedish crowns, in order to make it worthwhile for the large firm to go in.

Thanks to the favorable financing situation through NIMED, IMT grew in size from the mid-1990s and reached a peak in terms of staff number around 2005/06. At that point in time the department had some 50 researchers, including PhD students. The ending of the NIMED funding could not, in the short run, be compensated by other external research grants or contributions from companies. The department therefore started to shrink, mainly by not replacing PhD students when they graduated. The staff number is today down at the level of 35 (the majority of which are seniors). Medical Informatics has now become the largest division, accounting for more than half of the department's staff. The head of the department says that this division managed the financial tightening better than other groups since it was not part of the classic medtech research track in NIMED.

While some of the NIMED researchers have succeeded in getting new financing others are still struggling. One of the professors has chosen to be on part-time leave and has moved his research to one of the new spin-off companies.

<u>Case</u>: Biomaterials research in Gothenburg

Gothenburg is today a world-leading center within biomaterials research. The tradition goes back to Professor Per-Ingvar Brånemark's pioneering research on osseointegration in the 1960s and 70s. He was from the beginning working at the

University of Gothenburg's Department of Anatomy. Later on a Department for Biomaterials was founded.

In 1979 a fruitful meeting took place between Professor Brånemark and Bengt Kasemo, then associate professor in chemical physics at Chalmers University of Technology. Bengt Kasemo had done some work on titanium surfaces. As a result of this meeting he and his group became involved in Per-Ingvar Brånemark's research on titanium-based dental implants. This research in 1981 led to the foundation of the company Nobelpharma (today Nobel Biocare)[72] for commercialization of Per-Ingvar Brånemark's invention.

During the early 1980s a fruitful collaboration developed between the two research groups. For example, for some time Per-Ingvar Brånemark financed one of Bengt Kasemo's PhD students, who worked on surface preparation and characterization. After a couple of years this person became an industry PhD student financed by Nobelpharma.

In the same period Bengt Kasemo and his co-workers received grants from STU's framework program for Physics and Chemistry of Surfaces. A smaller part of the research funded by this program concerned biomaterials. Besides Per-Ingvar Brånemark, Bengt Kasemo also developed fruitful collaboration with Professor Ingemar Lundström at the Department of Applied Physics in Linköping.

STU had an evolutionary view on the biomaterials research meaning that the last 1-2 years of the above-mentioned program were used to design, together with the leading researchers, a new program on Biocompatible materials. This was run from 1987 to 1993, when it was substituted by a new program called Biocompatibility (1993-1996). The grants from the STU program made it possible to expand the biomaterials-oriented research and the group gradually increased in size.

One initiative from STU that was highly appreciated was to bring all the biomaterials researchers together at seminars and annual meetings. These events had a stimulating effect on the collaboration among different groups.

[72] Nobelpharma was a new wholly-owned subsidiary of Bofors (later on Nobel Industrier). Thus, it was not a true university spin-off even though the company was founded for the purpose of commercializing academic research results.

In the end of the 1980s, a government enquiry of materials research in Sweden resulted in a proposal to start up a number of ten-year materials consortia (a type of centers of excellence according to today's terminology). Responding on a call from STU, Bengt Kasemo and Ingemar Lundström jointly proposed a consortium for biomaterials. It ultimately became one of twelve materials consortia selected and supported by STU. It started in 1990. As testified by Bengt Kasemo, this initiative from STU proved to have crucial importance for the long-term building of a strong biomaterials research group at Chalmers (Chemical Physics) – and in Linköping as well. The grants were quite large (SEK 3 million in a first round followed by more grants later on) and made it possible to expand the group, which towards the end of the decade had grown to some 15-20 people.

At Chalmers, the Biomaterials Consortium was in the beginning run in parallel to research projects financed by STU/Nutek's biocompatibility program. However, since Chemical Physics had such a good funding from the former it did not apply for more money from the latter. But the two consecutive biocompatibility programs were instead important sources of funding for the biomaterials research at the University of Gothenburg, where the key individuals were Per-Ingvar Brånemark, Tomas Albrektsson and Peter Thomsen. This group also grew in size thanks to the grants from STU and Nutek.

Despite being funded through different programs a close collaboration emerged between the three groups (two in Gothenburg and one in Linköping). The researchers also collaborated with Nobelpharma, which for example financed one of Bengt Kasemo's PhD students.

In the mid-1990s, when the Biomaterials Consortium had come approximately halfway, Nutek and three research councils (Medical, Science and Technical science) developed a plan to make a joint investment in biomaterials research in Sweden. Bengt Kasemo, together with a group of other leading biomaterials researchers, was assigned the task to map the ongoing research and come up with a proposal for such a program. However, for various reasons these plans came to nothing. But at the same point in time the Foundation for Strategic Research (SSF) had been established. SSF liked the ideas put forward by the professors and invited them to come up with a program proposal. Following the change of government in Sweden, a deal was made which meant that SSF took over from Nutek the responsibility for financing the materials consortia.

As before, the two universities in Gothenburg became a strong node in the new SSF-funded biomaterials program (which started in 1997 and was run until 2000). It also funded other biomaterials groups, for example, in Linköping, Lund, Uppsala and at SP in Borås.

In parallel, SSF funded a Gradual School in Material Sciences, where the biomaterials part was managed jointly by Chalmers and the University of Gothenburg. This school proved to have positive effects on the collaboration among the biomaterials researchers in Sweden (including both PhD students and seniors engaged as teachers). For example, it fostered an interdisciplinary approach where technology, biology, medicine and odontology were integrated. The researchers from different disciplines learned to understand each other's language.

Bengt Kasemo concludes that these research efforts made by STU, Nutek and SSF have been large-scale and have had a great impact on the biomaterials research environment in Gothenburg – as well as in many other places in Sweden. In can be noted, though, that SSF's program to a large extent was a continuation of research that had already been started up by Nutek.

For Chalmers, the platform that had been created thanks to support from these financiers later on enabled Chemical Physics (now called Biological Physics) to successfully apply for EU grants. Since 2003, the group has participated in several projects. In one of them, called Nanocue with seven partners two of which were Swedish (Chalmers and KI), Bengt Kasemo was the coordinator. The latest EU project is on nano-bio-pharmaceuticals and means that the group is diversifying into a new field for biomaterial applications.

In connection to Bengt Kasemo's recent retirement the Division of Chemical Physics has been divided into two divisions, one of which is Biological Physics and totally dedicated to bio-related research. The creation of this unit is an effect of the previous, long-term investments in biomaterials research.

Bengt Kasemo points out that building a strong research environment with a critical mass presupposes cross-fertilization between good academic research, graduate schools (PhD education) and industry collaboration with established and spin-off companies.

As to the industry collaboration, the long-standing relationship with Nobelpharma/Nobel Biocare has been important for the Chalmers group. The company has financed three industry PhD students. They have spent 80 percent of their time on research at Chalmers and worked 20 percent for the company (e.g. with development of quality control methods). Interestingly, none of them remained at Nobel Biocare. But instead the company has employed several other PhD graduates from the biomaterials group at the University of Gothenburg.

Towards the end of the 1990s Chalmers' collaboration with Nobelpharma/Nobel Biocare was winded up. Dental implants had become an established product and the material issues were of less interest from an academic point of view. The Chalmers group therefore began to reorient its research into new directions such as biosensors, tissue engineering and drug screening. This research is largely based on nanotechnology, for which much of the basic knowledge development has taken place within the biomaterials programs. Important grants had also been obtained from the Mikronik program, where Bengt Kasemo had been instrumental in designing the program (bio/medicine became one of four targeted application fields).

Also in the mid/late 1990s some of the biomaterials researchers at Chalmers moved to SP in Borås. SP also took over the collaboration with Nobelpharma/Nobel Biocare, which periodically was quite intensive. One key example is Nobel Biocare's TIUnite surface which is today applied on most dental implants manufactured by the company. The project started as a jointly financed collaboration between SP and Nobelpharma/Nobel Biocare in 1996 and lasted for 2-3 years. The project was based on knowledge from Chalmers that had been brought to SP through recruitment. The development and characterization of the new surface took place at SP after which clinical testing was carried out together with Nobelpharma/Nobel Biocare's clinical partners. After having developed and validated a semi-industrial manufacturing process at SP the technology was transferred to Nobelpharma/Nobel Biocare's factory. But before that, when the project had approached a commercialization stage, Nobelpharma/Nobel Biocare had taken over full responsibility for the financing. At the end this project had a great impact on the company's product development, and it is a good illustration of how knowledge created in an academic setting can be used as an input to industrial product development.

Q-Sense is a spin-off company founded by Bengt Kasemo and three colleagues. The surface analysis instrument successfully commercialized by Q-Sense is a direct outcome of the research funded by STU and Nutek. Since its foundation in 1996 the company has maintained close contact with the research group. For example, one PhD student moved over to the company after graduation.

In parallel to the developments at Chalmers, the biomaterials research environment at the University of Gothenburg also expanded thanks to support from STU/Nutek/VINNOVA. In 1994, when Per-Ingvar Brånemark retired, and was succeeded by Peter Thomsen, the professorship was changed from anatomy to biomaterials. The group participated in SSF's materials consortium, but belonging to a medical faculty they felt that they were not in the center of the research program, since the clinical anchoring was weak.

In 2001, Peter Thomsen's group was organizationally merged with Tomas Albrektsson's group, focusing on handicap research, in a new department called Biomaterial Science. Tomas Albreksson had been a key member of the team that developed oral implants based on osseointegration, first commercialized by Nobelpharma/Nobel Biocare, as already mentioned.

When the SSF program ended in the early 2000s, it became difficult to get new funding for this type of research and it was not possible to maintain the same level of activity as before. "There was no money to apply for – neither from VINNOVA nor from SSF, for example", Peter Thomsen says. For a period of 4-5 years the two research groups survived thanks to some EU grants and support from industry. Both groups became dependent on bilateral contract research projects carried out for Nobel Biocare and Astra Tech.

These collaborations were thus very important for the department and the knowledge generated by the research was in different ways transferred to the companies. For example, several PhD graduates were recruited and brought specific research results as well as more general scientific competencies.

Despite these positive outcomes, both for the department and for the companies, Peter Thomsen was not fully satisfied with the situation. The researchers had become too dependent on the companies and tended to serve as “suppliers of data”. In this respect there are more positive experiences from collaboration with two other companies: Artimplant (a spin-off from Chalmers) and Mölnlycke Health Care. Both companies were searching for new biological knowledge in an open-minded way, and working together with them was stimulating for the researchers and led to renewal of the research orientation, that is, a reorientation away from titanium implants to other materials and other concepts (like degradable implants).

For the Department of Biomaterials, the financing situation improved substantially from the mid-2000s. First, biomaterials and cell therapy became a focus area within the ten-year Vinnväxt project Biomedical Development in Western Sweden. This has enabled the establishment of a separate Institute for Biomaterials and Cell Therapy (IBCT), where the department is participating in interdisciplinary multilateral research projects together with several regional companies (including e.g. Nobel Biocare and Mölnlycke Health Care). These projects are applied in nature and focuses on the development of new innovative methods that industry needs in its product development. Second, since 2007 VINNOVA is funding BIOMATCELL, a VinnExcellence Center based in Gothenburg. The center is hosted by the Sahlgrenska Academy at the University of Gothenburg, but involves researchers also from Chalmers, SP and Uppsala University. Although BIOMATCELL is exploring new frontlines of research – combining biomaterials with cell therapy – the center’s activities to a large extent draw on capabilities that were built up over the years with support from STU/Nutek/VINNOVA and SSF among others. There are seven industrial partners in BIOMATCELL, including large as well as small companies coming from different parts of Sweden. The involvement of these firms in the research is expected to have positive effects on the research environment, quantitatively and qualitatively, and contribute to strengthen Gothenburg’s position as an international leader in biomaterials research.

Peter Thomsen explains that by combining biomaterials and stem cell research BIOMATCELL applies a unique approach to tissue engineering, which is different from the path commonly followed abroad, for example, in the USA (there are hundreds of start-up companies in the field but few of them have managed to reach the market).Tissue engineering is a field where Sweden has not spent large resources in the past. But he means that the BIOMATCELL approach will give Sweden an opportunity to become a key player internationally in regenerative medicine (which has recently been designated by the government as a strategic research area). This would not have been possible without the strong biomaterials research tradition that has been built over a long period of time, and which is now combined with other ongoing research and development processes in the regional and national environment.

In parallel to this reorientation of the research, in the direction towards regenerative medicine, the collaboration with the dental implants companies Nobel Biocare and Astra Tech continue. The former is involved in IBCT and the latter is involved in academic research activities. For instance, Astra Tech's R&D Director (a previous PhD graduate) has an adjunct professorship at the department.

Thanks to the VinnExcellence and Vinnväxt programs VINNOVA has thus become a key financier of the biomaterials research at the University of Gothenburg. Other grants come from EU's Framework Program 7, the Swedish Research Council and Region Västra Götaland. VINNOVA's support of the "researcher school" BIOSUM is also considered to be important for the development of the research environment. The school is run together with SuMo, another VinnExcellence center hosted by Chalmers, and is expected to increase interactions between the two universities.

During recent years the interface with industry has been substantially broadened. Besides the Vinnväxt and VinnExcellence collaborations, contacts have been established with a large number of European firms, mainly small ones, through EU projects. One example is a small London-based orthopedic company which is developing new better surfaces for its implants. The department gives the company advice on different materials-related matters and carries out small assignments.

These two cases illustrate how STU and Nutek became key sources of research funding during the 1980s and 1990s. It is true that Biomedical Engineering in Linköping had strong financial support from the university during the early years, but the external grants especially from STU and

Nutek increased in importance and enabled an expansion of the research volume that would otherwise not have been possible. Receiving long-term funding for the NIMED competence center had crucial importance for the development during the second half of the 1990s and the first half of the 2000s. In the case of biomaterials it is obvious that STU and Nutek, together with the Foundation for Strategic Research, were instrumental in creating several strong research environments, in particular in Gothenburg. More recently, VINNOVA has become an important financier for at least one of the key groups. This is definitely an outcome of the previous support. Besides successful publications in academic journals, the research groups have made important contributions to the technological and commercial development of two successful companies – Astra Tech and Nobel Biocare.

If we consider the alternative funding opportunities that existed during the period in question, it is unlikely that the same developments, scientifically as well as industrially, would have taken place in Gothenburg and in Linköping without the support of STU and Nutek.

These cases are not unique. Among today's key research environments (see Chapter 4) there are many which for a fairly long period of time were dependent on STU/Nutek grants – in order to build up research groups specializing in medical technology. One example from Lund Institute of Technology is Electrical Measurements, which was one of the pioneering research environments. The programs Biomedical measurement technology followed by Minimal invasive medical technology were instrumental for several research groups. Furthermore, in the early 1990s, grants from the Mikronik program (and later on the follow up program KOFUMA) enabled the department to expand in the field of microtechnology, for example, development of nerve chips, which is the basis for one of the present four key research areas (Smart Hand). Grants from the same programs also helped the department to build up extensive research in the field of Lab-on-a-chip, another of today's strength areas. When the Nutek-funding ceased around 2000, the Swedish Research Council instead became the main financier of this research. The grants from VINNOVA have remained small, which is regretted though an increasing trend is seen in the past few years. But instead the department has succeeded to get other external funding for its research, primarily from the Swedish Research Council, the Foundation for Strategic Research and the EU. Electrical and Information Technology and Lund Laser Center are two other environments for which STU and Nutek played a crucial role. Among other large research environments, as of today, it is obvious that that the following ones can be mentioned as examples of environments that historically have been dependent on STU/Nutek-grants for building up the position they have today: the Center for Image Analysis in Uppsala, KI's Research Center for Radiation Therapy (competence center from 1996), and Applied Physics in Linköping.

To a large extent the STU/Nutek funding has come through various programs, and later on, through the competence centers. But there are also some units for which the programs did not fit well. Instead they have got funding through non-program project grants (e.g., Electrical and Information Technology in Lund) or from other (non-medtech) parts of STU/Nutek (e.g. Lund Laser Center, which has received money dedicated to electronics research).

Periods of financing problem and decline

In 1996 three of Nutek's medtech programs ended at the same time: MEDiBILD, Biocompatibility and Minimal invasive medical technology. This meant that several research units and individual groups lost an important source of financing which had been available for ten years. There was a new program, Healthcare technology, but it did not fill the gap. First, in terms of money it was not big enough (compared to the combined size of the preceding programs). Second, it was a very broad program which attracted applications also from other research groups, and hence increased the competition for grants.

In parallel to the ending of the above mentioned programs, Nutek launched its competence center program (running from 1996 to 2006). Two of the selected centers, NIMED in Linköping and the Research Center for Radiation Therapy at Karolinska Institutet (KI), were fully dedicated to medical technology. For the Department of Biomedical Engineering in Linköping, which hosted NIMED, this meant substantially increased resources and an opportunity to continue expanding the research. At the end of the ten-year period during which the center-funding lasted the department reached a peak with some 50 researchers employed. Also at KI, the center grants from Nutek enabled a significant expansion of the research efforts.

Other environments, which did not get a competence center, have in many cases suffered from the decreasing Nutek-funding of medtech research, and unless they have managed to get other funding have been forced to reduce the volume and the staff (usually by not substituting PhD students when they graduated). The financing situation did not improve, from the researchers' perspective, after the reorganization of the governmental policy units and the creation of VINNOVA in 2001. The researchers have noticed that medical technology (treated as a part of the broader field life science) has been presented as a priority area, but in reality relatively little money has gone to that field. After the international evaluation of medtech research in 2006 a new program (Biomedical Engineering for Improved Health) was started up jointly by VINNOVA, the Swedish Research Council and the

Foundation for Strategic Research. But again, the researchers have experienced this program to be too small and too broad, from a medtech point of view. There is a widespread opinion that there were many good projects that did not receive any money.

In other words, during the latter part of the 1990s and early 2000s there were several research environments that experienced periods of financing problems which in some cases forced them to shrink the volume. However, it seems that in most cases these problems have been temporary. Often after a few years, the researchers have managed to find some other source of funding. For the medtech research generally, the Swedish Research Council, the Foundation for Strategic Research and the EU emerged as important financiers. Let us give one example to illustrate how it could look like.

Case: Center for Image Analysis, Uppsala University and the Swedish University of Agricultural Sciences

> This center was established in 1988 based on research on computerized imaging that had been supported by STU already in the 1970s (and had resulted in several spin-off companies from Linköping and Uppsala). Approximately half of the researchers worked on medical applications.
>
> From the beginning, Nutek became an important financier through its MEDiBILD program (as an important complement to the base funding from the two parent universities). When this external funding ended, the situation could be saved thanks to grants from the Foundation for Strategic Research (VISIT program) for the period 1997-2002. But when these grants had been finished the center got problems to finance the continued research and was forced to reduce its staff. The period of decline lasted for a few years during which strong efforts were made to apply for new money – with mixed results. From 2005 the center has received new grants from the Swedish Research Council, which since then has become the dominant financier and enabled the center to recover and start growing again (today some 18 of the center's 30 researchers are dedicated to medtech).
>
> Due to the Swedish Research Council becoming the dominant financier the research has gradually become more basic in nature. Attempts to get funding from VINNOVA have failed (until very recently, when three smaller projects have been started up). At present, the center has grants also from research foundations and the EU.

The case illustrates a pattern that appears to be relatively common. Many medtech research environments had become dependent on STU/Nutek. It can be concluded that STU/Nutek has in fact successfully contributed to build up new research environments. But when these environments (or individual research groups) due to policy changes could no longer rely on financing from Nutek/VINNOVA, to the same extent as in the past, they often got into troubles. However, it seems that most of these environments/groups, sometimes after a few years of shrinking research volume, have succeeded to find new sources of funding and have started to grow again by recruiting new people. The financing picture is more diversified today than it was 10-15 years ago. Many of the research groups that used to be highly dependent on STU/Nutek now have grants from a number of different external sources. In a long-term perspective, this must be perceived as a positive effect of the policy, since these groups have now become less vulnerable to policy changes implemented by single financiers.

In the case of the two competence centers, NIMED and KI's Research Center for Radiation Therapy, the host departments which received most of the money had a favorable situation for ten years. As intended the grants enabled them to expand. But even if this type of funding is long-term it does not last forever. In both cases it has not been possible, so far one should say, to fully replace the center grants. This has resulted in decreasing research volume. In Linköping, the number of research staff at the Department of Biomedical Engineering has gone from around 50 to 35. At KI, there were as a maximum up to 37 researchers involved in the center (including 30 PhD students). Today, the center employs some 20 people (10 of which are PhD students).

In many cases the observed fluctuation of research volume has been related mainly to the changing opportunities for external funding from different sources. But as the following case on the electrical engineering oriented medtech research at Chalmers illustrates, there are other factors contributing to explain why research environments may experience shorter or longer periods of decline.

Case: Department of Applied Electronics, Chalmers

> With regard to the volume of medtech research, this department had its peak time already in the late 1970s and the first half of the 1980s, with two full professorships and in total more than 30 people involved in biomedical engineering. Besides the general university funds, the research funding came from several external sources with STU/Nutek being the individually most important one. Other important financiers were the Technical Research Council and EU's framework programs. During one

period substantial research grants were obtained from Televerket (support of telemedicine research).

From the late 1980s and onwards, however, the amount of medtech research at the department began to decrease. First one of the professors and later on the other retired and none of them were substituted by persons working in the field of biomedical engineering. Gradually, the department's research came to focus more on signal processing in general and on other (non-medical) applications. Some people left, but a small group of researchers dedicated to bioengineering remained. In the early 2000s, there were only about ten people active in the area. But around the same point in time the downward trend was broken and since then the medtech-oriented research has experienced a revival, meaning that the number of people and the research volume have gradually increased. This development has been driven by a small group of dedicated individuals, who have managed to get support both from Chalmers and from the local environment (including key collaborators at the Sahlgrenska University Hospital and the Sahlgrenska Academy). Thus, the medtech research is now expanding again and a Master program in biomedical engineering has been established as a core activity. At present, there are four research groups, each one headed by a professor, which are focusing on different fields. In total, the Department of Signals and Systems as it is now called has some 20 researchers within its Division of Biomedical Engineering. Increasing collaboration with other researchers both within Chalmers and in the region is seen as a means to further strengthen the research environment and continue to grow.

It seems that in this case the variation in research volume can to a large extent be explained by internal factors such as leadership and priorities within the university – rather than availability of external funding (although it cannot be excluded that the reduction of Nutek's and VINNOVA's efforts in the field of medical technology during the second half of the 1990s and early 2000s have contributed to the decline).

We have thus seen that research environments have been negatively affected, as perceived by the researchers, by policy changes – that is, in terms of research funds allocated to medical technology. The research environments have been forced to shrink their costume, unless they have been able to compensate the loss by finding alternative sources. A risk is that the continuity of the research, and thereby also the sustainability of the environment, may suffer. But it seems that as a rule the research groups that have encountered this type of problem have been able to survive – and sometimes to start growing again – by finding other sources of financing, such as the Swedish Research Council, EU programs or one of the research foundations. An effect of this is of course that the research direction may change. If Nutek/VINNOVA funding is substituted by grants from the Swedish Research Council, for example, the research may become more basic, instead of applied (see e.g. the Uppsala case above). Whether such reorientation of the research is a bad or a good thing is difficult for us to judge. A possible positive effect is that the research environments are forced to reconsider their research focus and renew themselves.

Development without support of STU/Nutek/VINNOVA

It is true that STU/Nutek/VINNOVA has historically been a major source of funding of medtech research in Sweden and enabled a number of academic units to build up strong and sustainable research environments. But there are also examples of environments that have succeeded to build up extensive research in medical technology without the support of STU/Nutek/VINNOVA. Let us give one example illustrating how one environment by finding alternative means of financing has managed to grow steadily over a 15-year period and now has reached a critical mass.

Case: Center for Biomedical Engineering and Physics in Umeå and Luleå

> Medtech research at Umeå University began to develop in the early 1990s with local support from the university (e.g. through Uminova). In 2000, CMTF (Centrum för medicinsk teknik och fysik) was formed as a network platform for collaboration among different researchers working on various medtech-oriented projects. From 2000 to 2007, eleven projects were carried out involving some 70 researchers from some fifteen departments.
>
> On many occasions over the years, CMTF has applied for research grants from VINNOVA, but the results have been meager. Instead, CMTF has managed to raise money from other sources. One of the most important ones were EU's Structural Funds (Mål 1 and Mål 2), which for the period 2000-2007, accounted for more than one third of the total financing, amounting to SEK 61 million (including some grants from the 6th Framework Program). Other important financiers were the Swedish Research Council, the Västerbotten County Council, and Umeå University. As we saw in Chapter 4, CMTF has now grown to become a major research environment with currently more than 100 people involved in 17 projects covering a broad spectrum of medical technologies. The Director of the center

says that it has now reached a critical mass enabling it to compete for major research grants.[73]

Not least given the support from EU's Structural Funds, a large share of CMTF's activities has been directed towards interacting with the surrounding society (Mål 1: "R&D for long-term development of industry" and Mål 2: "Innovative environments"). A clear goal has therefore been to commercialize the research results in the form of new industrial products. This is done both through collaboration with existing firms and by starting up new firms.

A more recent example is KTH's and KI's combined research environment which is now being created in the southern part of Stockholm – adjacent to the Karolinska University Hospital in Huddinge. The rapid growth of this environment since the early 2000s has been possible thanks to financial support from the two universities and the Stockholm County Council.

In the following two sections we will elaborate on two specific aspects of particular importance to environment-building in the medtech field, namely, (1) the establishment of linkages between technical research and clinical needs and (2) the creation of networks with industry.

Linkage between technical research and clinical needs

It is well known that successful development of new medtech methods and products requires a close linkage to clinical needs and the involvement of users.[74] This means that for research units at technical universities it is important to establish collaboration with clinicians. The following short examples illustrate how a number of units have done this.

Case: Department of Applied Electronics, Chalmers

As mentioned in the historical section above, this department at a very early stage established a tradition of close collaboration with clinicians at the Sahlgrenska University Hospital. Collaborative work has taken place between individuals both at the level of seniors and among doctoral students. For example, it became common that one doctoral student at Chalmers and one at the Medical Faculty worked together as a pair and wrote their respective theses on the same problem but from different angles. Over the years a large number of such "pair dissertations" have

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[73] When Nutek granted money for the creation of competence centers in 1996 Umeå did not yet have a critical mass and could therefore not compete with the established medtech research environments.

[74] See, e.g., Roberts et al (1981), IVA (1987), Laage-Hellman (1990), and Shaw (1991).

been carried out. This tradition of close clinical collaboration still prevails, and has been spread to other places through people who have moved. One example is the University College of Borås, which has recruited a professor from Chalmers. He has continued to work closely with the same partners at the Sahlgrenska University Hospital, where he and his colleagues spend much time. "our entire research takes place there", he comments.

Traditionally, the collaboration with the clinicians has been rather ad hoc and based on individual relationships. Now, there are plans to create a formal structure for the collaboration (this is done within the regional initiative Medtech West). One of the ideas is to set up joint professorships between Chalmers and the Sahlgrenska Academy. By creating a formal but open platform the collaboration will be less dependent on individuals, it is argued.

Case: Department of Electrical and Information Technology, Lund Institute of Technology

At this department there is a research group (presently consisting of some 14 people) which develops methods for retrieving information from medical signals, especially heart-related ones (e.g. analysis of cardiac arrhythmia). Ever since the group was established in the mid-1970s it has had close and fruitful collaboration with the Medical Faculty at Lund University. Recently, this long-standing cooperation has been formalized by establishing a Center for Integrative ECG, which involves several departments at the technical and medical faculties. It is expected that this new (virtual) center will contribute to strengthen the already existing inter-disciplinary research approach.

Case: Department of Biomedical Engineering, Linköping Institute of Technology

Also this department has a long-standing history of working closely together with clinicians at the university hospital. In fact, as we have seen, already when this department was founded in 1972 it was physically located to the hospital area, in order to facilitate collaboration with the clinical side. This is today regarded as a far-seeing decision, which has had a great impact on the quality of research. It can be added that one of the professors (Åke Öberg) for a long period of time (26 years) had a parallel position as head of the Clinical Engineering

Department at the university hospital. This gave a valuable clinical perspective and deeper knowledge about what kind of problems and challenges that the healthcare was facing.

Furthermore, this is one of the departments involved in a multidisciplinary research center at Linköping University called Center for Medical Image Science and Visualization (CMIV). One of the ideas is to integrate researchers from the medical and engineering faculties. There is a core group of fifteen researchers from both faculties and they are co-located to a building situated in the middle of the hospital area. There are some 70 associated members of the center, most of whom are clinicians.

These cases, which are not unique, illustrate how technical researchers have established fruitful cooperation with local clinicians, not seldom at an early stage of the environment-building process. In many cases, STU and Nutek have been central financiers of the research, at least up till around 2000. It is obvious, however, that this collaborative approach has been driven mainly by the researchers themselves, who have realized the need to link up with clinicians. It is not a response to demands coming from the financiers. Nonetheless, the involvement of clinicians in the medtech research has in different ways been pushed by STU and Nutek. For example, in the early 1990s representatives of the clinical side were given increasing influence over the distribution of research grants, through membership in the steering groups of the medtech programs.

It is interesting also to note that companies that participate in academic research projects attribute great importance to close links with the clinical side. One example is the Research Center for Radiation Therapy. The center is located close to Radiumhemmet at the Karolinska Hospital. Initially, the director of the center was head of radiation physics at Radiumhemmet, which gave a strong and natural connection to the healthcare – very much appreciated by the companies. But when the director after a few years resigned from that position, the clinical anchoring of the research became weaker. The industry representatives on the board were critical of this and pushed for closer links to clinical environments, but unfortunately with unsatisfactory results. The lack of sufficiently strong clinical links has been criticized also by the external evaluators of the center (which otherwise are very positive to the performance of this competence center).

In the International Evaluation of Swedish Research in Biomedical Engineering (Swedish Research Council, 2006), the panel complained that many of the research groups did not have sufficient interaction with clinicians. It observed that “there were even a number of investigators who seemingly had no interest in or did not understand biological questions or clinical problems, only an interest in the technology being developed in their individual laboratories" (ibid. p. 19). One must agree with the evaluators that the lack of clinical links is a serious deficiency, given the applied nature of most medtech research. However, to judge from our interview data, exemplified above, most of the larger research environments are well aware of this need and have also built up collaborative relationships with clinicians – often locally but sometimes also with more distant partners. As illustrated, this is not a recent phenomenon. But at the same time we can observe that in several places steps have now been taken to make the collaboration even more effective by creating formal structures. This is done, for example, by establishing new centers for translational research. We have already mentioned CMIV in Linköping. In Lund, the Department of Electrical Measurements is now involved in the creation of a new applications laboratory at the university's Biomedical Center (BMC). Some of the department's researchers have already moved into new facilities at BMC where they work closely together with colleagues from the Medical Faculty. As one professor put it, this means that "we are becoming a technology-node right in the heart of the medical environment in Lund". This is seen as a strategic step in the department's efforts to grow in research areas where the technology can be applied in clinical situations.

We can thus conclude that at least the larger medtech research environments have over a long period of time devoted considerable efforts to building networks with clinicians. These existing networks are valuable and contribute to increase the research capability of these environments. The networks have been built in the context of ongoing research, which often but not always have been funded by STU/Nutek/VINNOVA. However, one cannot say that the clinical networks are a direct effect of the financiers' policy and acting. But indirectly, by supporting research projects where technical and clinical researchers work together they have contributed to the network-building process. To judge from the criticism put forward by the international evaluation panel, there are certain research groups, or maybe entire research environments, which need to interact better with the clinical side. There is thus a need for VINNOVA and other financiers to secure that appropriate clinical linkages exist in all project they support. By doing so, they can contribute not only to make the individual projects better but also to strengthen the long-term development of the research environments.

Networking with industry

Another important aspect of the development of research environments is the building of networks with industry. Here we must conclude that there is a great deal of variation among research environments (and sometimes among divisions or research groups within an environment). They have for various reasons chosen, more or less consciously, different "strategies" for industry collaboration (these "strategies" are often implicit in nature, but they may in some cases be explicit). Furthermore, for an individual research group or an environment the pattern of interaction with industry may change over time. This variability can be explained by what type of research is carried out at a certain point in time and from where the funding is coming (e.g., VINNOVA vs. the Swedish Research Council). The Linköping case above illustrates how the extent of industry collaboration increased when the Department of Biomedical Engineering got a competence center.

Given that the research carried out at a certain unit has commercial potential (rather than being purely basic, which is relatively rare) it is important to build up networks with external actors, which can facilitate knowledge transfer and commercialization. Establishment of direct relationships with companies (large or small) is one possible element in the network-building effort.[75]

With regard to networking it is obvious that the financier can have an impact on how the researchers interact with industry. By demanding, as a pre-condition for receiving a grant, that industry is involved the financier influences how the research project is carried out. In addition to that, there may also be effects on the long-term network-building and the development of the research environment as such.

It is very clear that STU, Nutek and VINNOVA through their different research efforts have influenced the networks that tie medtech research environments to industry. The competence centers are extreme examples, since active industry participation and commitments from firms were a prerequisite for support. But also in other programs there has been a more or less explicit demand or push for industry cooperation. In this respect STU/Nutek/VINNOVA differs from, for example, the Swedish Research Council (and its predecessors), which does not require industry involvement.[76]

We have in our study collected information about two competence centers, namely, NIMED (Linköping) and the Research Center for Radiation Therapy (KI). In both cases a number of established firms have been involved. In Table 5.7 we list those that have formally participated as industrial partners. Some of these companies have been more active, while

[75] Another complementary approach is to build up relationships with various types of intermediary organizations which can assist the researchers when they have results to be commercialized. The universities' own technology transfer offices are one example.
[76] Since its role is to support basic research and the allocation of funds is based on pure scientific criteria, i.e., without consideration of commercial potential.

others have been more passive. In NIMED the following partners have been particularly active, resulting in fruitful collaboration at the project level: Althin Medical/Baxter, Atos Medical, Elekta, Gambro and Flodafors. In the case of KI, Elekta, Nucletron and Scanditronix/IBA were the most active ones among the established firms. In addition, two spin-off companies from the center (C-RAD and RaySearch) have also been very active.

Table 5.7. Industrial partners in the two competence centers

	NIMED	Research Center for Radiation Therapy[77]
Large firms	Althin Medical/Baxter Amersham Health AS (Norway) AstraZeneca Bruker SA (France) Elekta Gambro GE VingMed (Norway) Nycomed Imaging AS (Norway) Siemens-Elema	Elekta Nucletron
Small firms	Atos Medical Flodafors LEGO Lisca Development (acquired by Perimed) Lund Instruments Mamea Imaging (acquired by Sectra) Mezona Instruments Optovent OptoQ Perimed	Applied Medical Imaging Comair C-RAD CTI PET Systems (acquired by Siemens) Eurona Helax (acquired by Nucletron) Latronix PencilBeam Technologies (acquired by C-RAD) Precitron (merged with Helax) RaySearch Laboratories ScandiNova Systems Scanditronix (acquired by IBA) SenseGraphics Studsvik Medical

In several of these cases, the joint research projects within the competence centers have led to the establishment of a lasting relationship and continued collaboration. However, the experiences from both Linköping and KI show that it is generally difficult to keep the collaboration alive once the public funding has ended. This illustrates that even a 10-year funding of a competence center does not automatically lead to the establishment of long-term networks with industry.

Also in the case of the "normal" research programs STU/Nutek/VINNOVA has contributed to the network-building by demanding or stimulating collaboration with companies. As shown by Nutek (1996c), which is an

[77] Besides those companies mentioned there are some others that were involved as industrial partners but have not participated actively in research projects.

evaluation of STU/Nutek's medtech efforts 1987-1996, a relatively large number of firms have been involved in each program. Although the calculations are very uncertain the study concludes that there have been considerable effects on the firms in terms of sales and employment. It is unclear to what extent these project-based collaborations have led to the establishment of long-term relationships between the research units and the established firms. As we will come back to later on, our own data indicates that such long-term collaborative relationships seem to be relatively rare in the medtech field. But there are a few exceptions. For example, Nobel Biocare has had long-standing collaboration with biomaterial researchers both at Chalmers and the University of Gothenburg (Medical Faculty). The latter now has a long-lasting collaboration with Astra Tech. Biacore has ever since it was founded in 1985 had a close collaboration with Applied Physics in Linköping (from where a key technology was sourced) and is since 1995 a partner of the competence center S-SENCE. And as mentioned above some of the companies that participated in the two competence centers have continued to collaborate with their academic partners after the public funding of the center has ceased.

In contrast to the established firms, the university spin-offs more often tend to maintain close collaborative relationships with the research environments from which they have originated. This is natural since they are often dependent on the continued research on the technologies they are commercializing. In addition, it is common that the university researchers are involved in the company in the form of shareholders, board members, advisors, or consultants. Perimed, which spun out from Biomedical Engineering in Linköping, is one example of a company that over a long period of time has continued to collaborate with the parent department. For instance, it was an active participant in NIMED. It has also acquired another spin-off from the department (Lisca), which had developed a complementary product. The department today constitutes an important research resource for Perimed.

The spin-off companies have often chosen to locate themselves in the vicinity of the university (e.g. in a science park) and this has of course facilitated close contacts with the parent. Thus, these companies have in many cases become natural nodes in the research environment's external network.

Concluding comment

During the 1980s and 90s STU and Nutek, together with other financiers, played a key role for the development of several research environments specializing in medical technology. Here we find for example the following units which still exist and belong to the group of larger medtech research environments in Sweden.

At Linköping Institute of Technology: Biomedical Engineering, Applied Physics, Computer Vision Technology

At Lund Institute of Technology: Electrical Measurements, Electrical and Information Technology, Lund Laser Center

At Chalmers University of Technology: Applied Electronics/Biomedical Engineering, Applied Physics

At the University of Gothenburg: Biomaterials

At Uppsala University: Image Analysis

Besides these larger units there are a considerable number of smaller research groups that have emerged at different universities around the country.

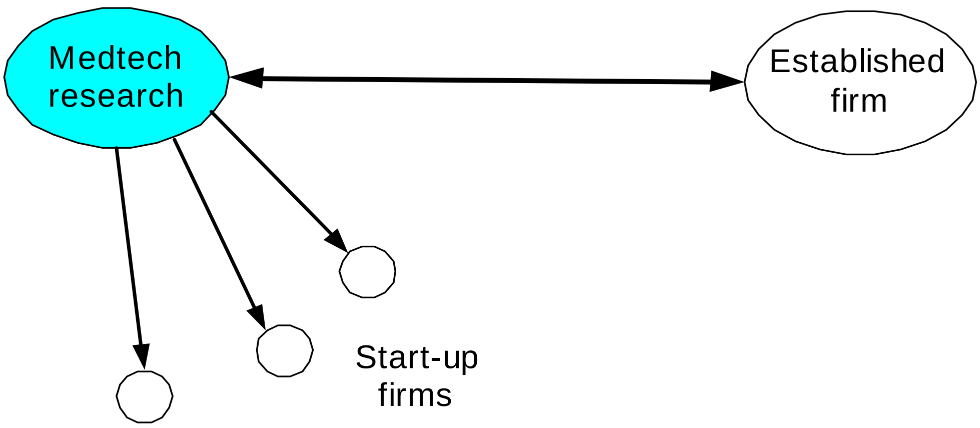
Up until the mid-1990s, the General University Funds ("*fakultetsmedel*") for most of these units provided basic financing of the research, but yet the external grants from STU/Nutek were crucial for the environment-building process. Except for those environments that got competence centers (from 1996), the importance of Nutek and later on VINNOVA decreased from the mid-1990s. However, basically all of these environments have, sometimes after a shorter or longer period of decline, survived by finding other sources of research funds (research councils, research foundations, EU, etc.). This has enabled them to maintain size or even continue to grow. Clearly, the academic results and the research capabilities created thanks to the grants from STU and Nutek, over a long period of time, have had decisive importance for the ability to obtain grants from others. In a historical perspective, it can therefore be argued that the policy pursued by STU/Nutek/VINNOVA has been quite successful, at least from an environment-building point of view. They have helped to create research environments that are sustainable and which are currently not too dependent on VINNOVA-funding.

However, it seems that at least in some cases the changing financing situation has led to a reorientation of the research in the direction of making it more basic. Even if the research carried out has been academically excellent, this change may have affected the practical applicability of the results. Given the needs for new technologies to meet the challenges of healthcare, it is important that the applications-oriented medtech research also receives strong support – in order to develop knowledge, inventions and solutions that can be transferred to and commercialized by existing or new companies. Here, VINNOVA with its mission to support needs-driven research undoubtedly has a central role to play. It is also true that in recent years VINNOVA has awarded long-term grants to certain medtech research environments, for example, through its Vinnväxt and VinnExcellence Centers programs. VINNOVA has recently launched a new program, Innovations for Future Health. This is an initiative appreciated by many medtech researchers, even though it is too early to see where the grants will go.

5.3.4 Research collaboration with established firms

From the academic researchers' point of view, we can distinguish two main routes for commercializing research results (see Figure 5.1). One is collaboration with existing firms, which can be large or small. The other route is the formation of new start-up companies, so-called university spin-offs.

Figure 5.1. The two routes for commercializing research results



In tables 5.8-5.12 we give for each of the research environments that we have looked closer at in this study the names of established companies with which these environments have collaborated and the names of start-up companies spun off since the late 1980s (i.e. around 1987/88). Regarding the former, it must be admitted that the listing is not complete. We have in first place tried to identify the most central partners during the 20-year period. Thus, there may be other firms with which joint R&D activities have taken place, but these collaborations have not been considered particularly important. There may also have been industrial connections that our interviewees are not aware of, since they have been handled by colleagues. Also regarding the start-up companies there are some firms, for example created for consulting or patent-holding purposes, that are not included in the tables.

Table 5.8. Firm involvement for investigated research environments in the Stockholm and Uppsala region (since late 1980s)

Unit	Research collaboration with established firms	Start of new company
Medical Engineering, KI and Technology and Health, KTH	GE Health Care (Norway) Radi Medical Systems St. Jude Medical	Adolesco Cathprint Gripping Heart MIPS Nanexa Medical Repair Technologies RT Technology SciBase
Research Center for Radiation Therapy, KI[78]	Elekta Latronix Nucletron Scandinavia Scanditronix/IBA	C-RAD[79] RayClinic RaySearch[80]
Biomedical and X-Ray Physics, KTH[81]	Silex + a number of foreign firms (mainly contract research and non-medical applications)	CardioVas Inc. (US) Excillum[82] Hearing Armour Inc. (US)
Center for Image Analysis (Uppsala)	Amersham Biosciences IMTEC[83] Sidec Technology Uppsala Imanet Virinova	Applied Medical Imaging Diascan Rainfall

[78] There are a number of other firms that have been formally involved in the center, but their activity level has been low and in several cases they have chosen to leave the center.
[79] C-RAD is a group consisting of three companies all of which have spun off from the competence center: C-RAD Imaging, C-RAD Positioning and C-RAD Innovation (previously PencilBeam Technologies.).
[80] RaySearch is based on research carried out before the start of the competence center, but the company was founded when the center had been put in place.
[81] Mamea Imaging (now owned by Sectra) is a spin-off from KTH's Department of Physics. The founder of this company was also involved in the start-up of C-RAD.
[82] This company is commercializing a new hard x-ray source, currently for non-medical applications. At a later stage, according to the business plan, medical applications will also be targeted.
[83] IMTEC was an early spin-off company established in 1980 based on STU-funded research on computerized imaging at the universities of Uppsala and Linköping. IMTEC went bankrupt in 1993 after which some of its assets and staff were taken over by Sectra in Linköping (a competitor in the radiology field).

Table 5.9. Firm involvement for investigated research environments in Lund (since late 1980s)

Unit	Research collaboration with established firms	Start of new company
Electrical & Information Technology, Lund Inst. of Technology	Gambro Siemens/Siemens-Elema St. Jude Medical	Epic Life Science
Electrical Measurements, Lund Inst. of Technology	Amersham Pharmacia AstraZeneca ATS Medical (USA) Bioinvent Biotech/Gyros Siemens-Elema Tetra Pak (not medical)	Ceram ErySave Iset
Lund Laser Center, Lund Inst. Of Technology	AstraZeneca STI Medical Systems (USA)	GasPorOx SpectraCure Spectraphos
Biomedical Engineering Group, Lund University	Atos Medical Jolife ProstaLund Siemens (Germany)	New company[84]

Table 5.10. Firm involvement for investigated research environments in the Gothenburg region (since late 1980s)

Unit	Research collaboration with established firms	Start of new company
Biological Physics, Chalmers	Nobel Biocare (until 1998/99)	Q-Sense
Biomedical engineering, Chalmers	AstraZeneca Nobel Biocare Ortivus Medical St. Jude Medical	Medfield Diagnostics Neoventa Medical Oiido Svenska Telemedicin System SACS Medical
Biomaterials, Univ. of Gothenburg	Artimplant Astra Tech Mölnlycke Health Care Nobel Biocare Other firms involved more recently through the Vinnväxt and VinnExcellence programs[85]	(Integrum)[86]

[84] A new company is now being started to develop a patient alarm for communication between patients and healthcare personnel.

[85] The following firms are involved in the Vinnväxt program Biomedical Development in Western Sweden: Nobel Biocare, Mölnlycke Healthcare, Cochlear Nordic, Artimplant, Tataa Biocenter, Doxa, and Alertis A/S. The following firms are involved in BIOMATCELL: Arcam, Bactiguard, Cellartis, Integrum, Sandvik, St. Jude Medical, and Tataa Biocenter.

[86] The founder of Integrum is an orthopedic physician at Sahlgrenska University Hospital. But the supervisor of the founder's PhD thesis was one of the professors at the Department of Biomaterials. It means that the biomaterials research constitutes a crucial part of the company's technology base.

Table 5.11. Firm involvement for investigated research environments at the Linköping Institute of Technology (since late 1980s)

Unit	Research collaboration with established firms	Start of new company
Biomedical Engineering	Cambio Healthcare Systems[87] ContextVision[88] Fältelektronik Perimed[89] Sectra[90] ServoMed Synectics Medical Within NIMED: See Table 8	Bio-Optico LB Index Ldiamon (Estonia) Lisca Development Melerit Medical Optovent OptoQ Saphena Commercial Products Unilink WheelsBridge
Applied Physics	Biacore Biosensor Application	BioChromix Micromuscle RGB Technologies Spago Imaging

Table 5.12. Firm involvement for investigated research environments in Umeå/Luleå (since late 1980s)

Unit	Research collaboration with established firms[91]	Start of new company
Center for Biomedical Engineering and Physics	Bruker Optics Scandinavia Explizit GE Healthcare Maquet (Getinge) Morgan Electroceramics Towser Co Ltd (Japan) Umbio	Biomedia Technologies BioResonator CMTF Affärsutveckling DermaSpection Likvor Videoakt

In this section, we focus on the research collaboration with *established* firms, but in the next section we will come back to the start-ups.

Within many environments there has been a strong and over time increasing interest in establishing collaboration with industry. An important driver has been the researchers' desire to have the results commercialized and used to improve healthcare. The researchers may also see other benefits associated with company involvement. It can be additional funding and access to

[87] Cambio is a spin-off from Linköping Institute of Technology, but has its origin in another department.
[88] This company came in as a partner via a professor who moved to Biomedical Engineering from another department.
[89] Perimed is an earlier spin-off from the department (1980).
[90] This company came in as a partner via a professor who moved to Biomedical Engineering from another department.
[91] There are 8-10 other companies that have been involved in the research, but to a less extent.

valuable resources and knowledge (e.g. about markets or production). Another contributing factor is STU/Nutek/VINNOVA's demands for industry involvement in the research. In some cases, partnership with industry has been a necessary condition for grants (e.g. competence centers).

These ambitions also reflect a general trend in society where there is increasing pressure on the universities to contribute more effectively to the industrial and economic development ("the third mission"). The universities have been developing their own support systems for innovations (technology transfer offices, holding companies, incubators, science parks, etc.). These support resources have increasingly been used by the medtech research environments (e.g. for getting help with patenting and selling licenses to companies).

As shown in the tables, there are in total a fairly large number of established firms that have had some kind of collaboration with the investigated medtech research environments over the past twenty years. Of course, the intensity of the collaboration, as well as the form and duration, has varied a great deal. There are some examples of very long-term and successful collaborations, which have brought major benefits to the companies. We have already mentioned Biacore-Applied Physics in Linköping and Nobel Biocare- and Astra Tech-biomaterials researchers in Gothenburg. Electrical Measurements in Lund has established a fruitful collaboration with AstraZeneca (see comment on contract research below). Within both of the medtech competence centers there are a few firms that have been actively involved in research project over the whole ten-year period. But in many other cases the collaborations have not been so deep or long-term and the effects have been small or non-existent. Generally, it is not unusual that collaborative projects are described as failures in the sense that the results have not been commercialized by the companies.

In many cases the researchers' attempts to establish more extensive collaboration with medtech firms (especially the larger ones), and having the research results commercialized by them, have encountered difficulties. The following quotation from a research leader illustrates a kind of experience that does not seem to be unusual:

> *We wish that the results that come out of our research will be used by industry – since there are obvious practical applications. Regrettably, however, it has been difficult to establish collaboration with firms. The small ones cannot afford to do it, and the large ones are too sluggish and too bureaucratic. Even if they are interested in what we are doing the decisions are taken "seven levels away in their organization". They also tend to be short-sighted and follow the*

trends on the stock exchange. These experiences have made me quite cynical.

Another research leader tells the story about a large Swedish medtech company where the R&D manager in one of the divisions was interested in starting up a collaborative project. However, these plans were stopped by the group management, who decided that the resources should instead be used for the existing core products. It was not a matter of money but about how to allocate people. Other researchers confirm that even if there is some enthusiastic person in the company it may sometimes be difficult to get project ideas anchored at the management level.

Applied Electronics at Chalmers and Electrical Measurements in Lund have already been mentioned as historical examples where the researchers have experienced difficulties in getting the Swedish firms interested in collaboration and commercialization. But there are others who also complain about the difficulties to get the established firms interested in "real collaboration". If we consider the long time span (twenty years) there seem to be relatively few examples of successful commercialization – in the sense that new research results have been transformed into new products brought to the market by an existing firm. However, it is important to point out here that there are other types of benefits that companies can get from the collaboration with an academic institution – knowledge and competence development, for example. This will be further discussed in the next chapter, where we look at the university-industry interaction from a company perspective.

But yet we must conclude that over all the collaboration between the medtech research environments and the established medtech industry has not been as frequent and extensive as one could have expected – given, for example, the applied nature of the research and the intentions of some financiers, such as STU/Nutek/VINNOVA, to promote closer links between academia and industry. Especially the large firms, with a few exceptions, have not played such an important role in the commercialization of academic research. Instead, it seems that the most important route for bringing academic inventions and research results to the market – for the benefit of healthcare – is the formation of new start-up companies.

There may be several reasons why the established firms do not, as a rule, constitute an efficient channel for commercializing research results from academia. The large firms in particular tend to be very focused on their existing product lines, many of which were relatively mature already in the 1990s. Most of their R&D activities have been directed at improving these products (e.g. by developing new features, new product generations, new applications and new complementary products). If there are academic research projects that happen to fit well with the company's current product plan the company may become interested in collaboration – provided that the time horizon is not too long. As one manager puts it: "If we have to wait 3-4 years to see the results we cannot go in". And yet we know that this is not a very long time perspective when it comes to academic research. Furthermore, if we consider that the medtech research carried out in Sweden is broad, together covering large parts of the scientific and technological spectrum of relevance to healthcare, while the firms tend to be specialized in narrow niches, we can understand that much of the results coming out of the research does not fall within the interest sphere of the Swedish firms. If the researcher still wants to see his or her invention commercialized, it remains to find a partner abroad or start-up a new company.

In the case of competence centers (and the now ongoing VinnExcellence Centers also funded by VINNOVA) there are always a number of companies involved, mainly in the form of bilateral projects. But despite the fact that both centers were started more than ten years ago there are so far very few examples of new products that have been developed and commercialized by established firms. In some cases projects are still ongoing and may lead to commercialization later on. For example, based on NIMED research Atos Medical is developing a new optical method for diagnosis of ear inflammation. Elekta has been involved in a project on lesioning in brain tissue, which has resulted in system for optical intracerebral guidance and RF-lesion size estimation. The technology has been transferred to Elekta for further product development (one of the researchers is now employed by Elekta).

The lack of commercialization does not mean that participation in the competence centers has necessarily been useless to the firms. Instead, at least for some companies the joint research projects have given valuable opportunities for learning. Thus, thanks to the contacts with the academic research environment the companies have been able to acquire new knowledge. Let us give a couple of examples from NIMED[92]:

- Perimed: NIMED gave access to broad competencies in data and image processing and specific competencies in laser Doppler flowmetry theory, modeling, signal processing and general tissue optics. The company also got knowledge build-up in general biomedical optics. This knowledge has been important not only for future products but also for improving and maintaining current products.

[92] Source: Final Report from 2006 and interviews.

- Flodafors LEGO: NIMED gave an improved insight in the area of biomedical engineering. This was very valuable to the company since prior to its cooperation with NIMED it had had little to none business in medical technology.

It should be noted that despite the general tendency of university researchers to seek closer ties with industry, there are some researchers who resist too much involvement of established firms. One of them says:

> *We actively try to keep industry outside. I have seen how other departments have been driven towards too short-term goals. High-quality research requires academic freedom and long-sightedness. We patent and like to see them used, but prefer to license to start-up companies.*

This comment highlights that industry collaboration does not only bring advantages. Obviously, from the academic researchers' point of view there is a risk that too strong dependence on companies under certain conditions can have negative effects on the scientific level of the research (e.g., by pushing the researchers to focus too much on practical problem-solving, at the expense of advancing scientific knowledge). In general, it seems that the academic medtech research in Sweden has not suffered from this problem – at least not to a large extent (see, e.g., our discussion on contract research below). Thus, leading medtech researchers have kept their integrity relative to industry. As we have seen, the general problem is rather to make the firms more interested in collaboration.

Contract research

The above discussion pertains to firms' involvement in research funded by Nutek/VINNOVA and/or other financiers. But the researchers may have collaboration with firms also in other forms, and this includes contract research. Usually, such projects aim to solve technical problems for the firms and build upon knowledge and capabilities generated in previous academic research funded, for example, by STU/Nutek/VINNOVA. In that way, these collaborations and their outcomes constitute an indirect effect of the grants. The following example illustrates the experience gained by one research group. But it seems that other researchers have made similar experiences and have the same opinion about this collaborative form.

Case: Electrical Measurements, Lund Institute of Technology

> One of the medtech research groups at this department works on microsystem engineering and nanobiotechnology. Initially supported by the Mikonik and KOFUMA programs the group was able to establish a platform for microtechnology research, which later enabled the development of microfluidic platforms

for analyzing and processing liquids on the nano/picolitre scale, for example, for blood purification and particle separation. In parallel to a research project funded by KOFUMA, and involving PhD students, formalized contract work was carried out on behalf of a company that was developing a novel technique for biochemical analysis. The purpose was to develop a microfluidic device based on ink-jet technology – a kind of "nano-pipette" – that could be a part of the company's system. This was perceived to be a good application. The researchers built up in their lab a full-scale experimental set-up based on the company's product concept where the device was developed and tested. However, at the end the company chose to use another, more conventional solution. Hence, the device was never commercialized by the company.

Nonetheless, the practical result of this project in the form of a nano-pipette has proved to be of great value for the researchers themselves. The device has thus been used as an important instrument in other research projects.

Despite this positive outcome, after all, the group leader is not too happy about the contract research project as such. He means that in this case the researchers did not benefit enough from the collaboration. They rather became a sub-group within the company's own product development project, which restricted their freedom of action and made the knowledge exchange one-sided. He would prefer an arrangement where the cooperation is mutual and where the company contributes with its own knowledge. "It is not good if the companies use the universities as suppliers because they are cheap", he says.

Now there are more positive experiences from a later collaboration, this time with a large pharmaceutical company, namely AstraZeneca. In this case, there were two agreements. According to one of them the research group carried out contract work on a new protein analysis robot, also based on the department's microfluidic technology. This research was done in close collaboration with AstraZeneca's global proteomics network. In 2005, after four year's work a prototype could be presented and tested using AstraZeneca Lund as a pilot site.

In parallel to this contract work, the research group has received grants for more independent research in areas of mutual interest. The results have to be reported to AstraZeneca and are jointly owned, but the company has an open attitude and allows the researchers a great deal of freedom. The availability of such "curiosity money" has enabled the researchers to be bold and address broader research questions within the field of lab-on-a-chip. Also this research has been carried out in close collaboration with scientists at AstraZeneca, and it has resulted in a wealth of joint publications.

One effect of the AstraZeneca collaboration is that the research group has acquired knowledge in proteomics, which they did not have before. This is now resulting in new projects being initiated together with academic partners in Lund and Stockholm. A new project together with AstraZeneca is currently also in progress.

This latter example shows that under favorable conditions contract research built on competencies generated in previous or parallel "academic projects" can have a number of positive effect on both parties. As it appears from our data, however, it does not seem that generally speaking contract research has been an important source of income for the medtech research environments, or an effective means for commercialization. Two notable exceptions described in the previous case on biomaterials research in Gothenburg are Astra Tech and Nobel Biocare. It seems though that these cases are not representative of the general pattern. Some environments do not at all engage in contract research. For those who do, the amount of money is usually relatively small and the effects on the companies seem to be minor as a rule. Our telephone survey with the large, established firms (see Chapter 6) also shows that these firms have rarely used medtech researchers for carrying out contract research. One of the interviewed managers maintains that contract research is good neither for the companies nor for the researchers themselves. He means that the latter should focus on what they are good at, namely, doing true academic research. The biomaterials researchers in Gothenburg benefited (not least financially) from the research contracts but became during a certain period of time too dependent on the companies. This situation was not perceived to be good from an academic standpoint.

Regarding Electrical Measurements' successful collaboration with AstraZeneca, it should be noted that this company does not come from the medtech business, but is a pharmaceutical company. As such it may have a different approach to university collaboration compared to what is common in the medtech industry.

5.3.5 Formation of start-up companies

Over the twenty-year period that we cover in this study there has been, generally, an increasing interest in starting up new firms in order to commercialize research findings. This reflects the general trend, already commented on, that society is putting increasing demands on the universities to disseminate new knowledge and contribute in a more direct way to the economic and societal development. This is very relevant for medical technology since the research has great potential to create innovations and bring about improvements to healthcare. The perceived difficulty to get the established firms in Sweden interested in commercialization has in many cases driven medtech researchers to start up their own businesses. The objective can be to create a new industrial firm that can build up a strong position in a global market niche or to further develop the product idea to a stage where it can be sold to some existing firm. The creation of incubators, science parks and other support mechanisms targeting in particular university-based innovations has of course facilitated spin-off activities and given the academic researchers increasing stimulation to start up companies.

Against this background, we have concluded that in the field of medical technology the formation of start-up companies has become the main alternative for commercializing product inventions from academic research – rather than going the traditional "licensing route" by selling the IP rights to some established firm, or developing the invention in collaboration with industrial partners.

Tables 5.8-5.12 show that over the years a fairly large number of new companies have spun off from the medtech research environments. It can of course be debated whether this is a high number or not, considering that we are covering a period of twenty years. Maybe it is more interesting to ask the question what has happened to these companies. That is, to what extent have they succeeded to grow and generate new jobs (directly and indirectly)? Are there any success stories among these firms? It has not been possible in the present study to analyze in detail how the medtech start-ups have developed over time. However, collection of employment and turnover data for 2007, by using company information available through the Retriever database, show that a large majority of these firms are still very small. To a certain extent this can be explained by the fact that approximately half of them were founded during the last 4-5 years. But there are others that have been around for many years but still remain small. In addition, some companies have gone bankrupt (Spectraphos, SACS Medical and Micromuscle) while others have been taken over by other firms without having taken off (Lisca Development and Optovent).

It is in fact striking that so few start-ups have become commercially successful. The only companies that have realized substantial sales of products are Neoventa Medical, Q-Sense and RaySearch. Table 5.13 gives some key data for these firms.[93]

Table 5.13. Some key data for Neoventa Medical, Q-Sense and RaySearch (2007)

	Year of foundation	Product	Turnover (MSEK)	No. of employees
Neoventa Medical	1987	Products for prenatal care	30	20
Q-Sense[94]	1996	Research instrument for surface analysis	24	18
RaySearch	2000	Software for radiation therapy of cancer	65	37

Overall, we must conclude that from an economic point of view the performance of the medtech start-up companies as a group is poor. This observation illustrates the high-risk nature of this business and the difficulties these firms have to deal with in the commercialization. In a previous study carried out fifteen years ago (Laage-Hellman, 1993) the problems and challenges that R&D-based medtech firms have to cope with were analyzed. It seems that many of these problems and challenges are the same today. For a number of different reasons the process of building up a new medtech company of considerable size is a difficult one, and the process tends to be very time-consuming and require a great deal of endurance – not least financially. This leads to high failure risk and long lead-times.

It should be noted that the tables do not give a complete picture of how many medtech start-up companies that have been formed in Sweden during the period (and the contribution of such firms to the development of the industry). First, there are companies that have spun off from other academic research environments than those covered in this study. They can be medtech or clinical. One example of a successful company is Aerocrine, a spin-off from Karolinska Institutet. It has in ten years gone from foundation to IPO (Initial Public Offering). Second, there are start-up companies which cannot be classified as university spin-offs. Some of them have spun out from existing firms. Entific Medical Systems (today's Cochlear Nordic), which is a spin-off from Nobel Biocare, is one of few examples. Moreover,

[93] RayClinic with roots in KI's radiation therapy research has reached a turnover of MSEK 22 but is to be regarded as a healthcare company.

[94] Q-Sense's products are used as research tools mainly for characterization of bio-interfaces. Therefore, Q-Sense is not a typical medtech company but should rather be classified as a biotech company.

there are other companies that have been founded by inventors or businessmen who come from a non-academic environment. Here we can mention Breas Medical as an interesting example. This manufacturer of home ventilators was started by a group of people with experience from the automotive industry.[95]

In some cases, as we could see in the tables, there are no or very few spin-off companies. One notable case is the biomaterials research in Gothenburg. The explanation here is that the research groups both at Chalmers and the University of Gothenburg, unlike many other medtech research environments, had in fact a close and long-lasting collaboration with existing firms. These firms were able to absorb and commercialize the new knowledge generated by the research, and therefore the researchers themselves did not need to start up their own companies. This situation may of course change in the future, since the groups have in recent years entered on new research tracks. Given the historical and successful reliance on collaboration with existing companies, one may ask the question if such a conceivable shift towards more emphasis on start-up activities will require a changing culture within the research groups. This brings us over to the issue of entrepreneurial climate.

Entrepreneurial climate

If we accept the idea that start-up companies constitute the main route for bringing research-based product ideas to the market, then the entrepreneurial climate becomes an important factor. That is, to what extent is the researchers' involvement in patenting and commercialization activities supported by the culture and tradition of the research environment? In accordance with our previous discussion on the role of universities, the general trend is an increasing interest in starting up companies for the purpose of commercializing research findings. Of course it can be debated whether the entrepreneurial climate is good enough, for example, within the medtech research environments. There is certainly room for improvements in many places and we also know that at the university level the support structures are steadily being developed (a recent example is the VINNOVA-funded Key Actor Program).

Within several of the research environments that we have studied an entrepreneurial climate emerged quite early, which illustrates that this is not a new phenomenon. One example is Applied Electronics at Chalmers (see the historical section in the beginning of this chapter). As a response to the lack of interest from the established industry, this department started up its own commercialization activities in the mid-1980s, and these have resulted

[95] See Laage-Hellman (1998, Ch. 4) for a case description of Breas Medical.

in several spin-off companies. STU actively supported this early initiative and by so doing contributed to build up an entrepreneurial spirit within the department. Also at Electrical Measurements in Lund a commercialization culture evolved early supported by Hellmuth Hertz and his successors. The PhD students learnt that patenting was important and many of them founded their own companies to handle the patents. However, it seems that in this case commercialization has taken place mainly through sales of licenses and consulting rather than by starting up new R&D companies or industrial firms.

At Biomedical Engineering in Linköping we saw that during the NIMED period the entrepreneurial activity level decreased, since the competence center model implied a focus on collaboration with established firms. This held back the start-up activities for nearly ten years. But now it seems that the entrepreneurial climate is on the rise again. KI’s competence center for radiation therapy also built on collaboration with a number of existing firms. However, in this case several new companies have spun off from the center. This includes the above mentioned RaySearch, which has grown fast in recent years. Several other spin-off companies with related businesses have been brought together in a corporate group called C-RAD. At the KI center, the researchers were able to start their own companies since the industrial partners in these cases had chosen to not exploit the inventions.

Concluding comment

Obviously, the university spin-off companies identified in this study have as a group made relatively small contributions to the growth of the medtech industry – this in spite of our conclusion that starting up new companies should be seen as the main route for commercializing new inventions from research. In the next chapter we will present some data on the development of the medtech industry since the late 1980s. As we will see, one conclusion is that a small group of older university spin-offs and other research-based start-up companies have accounted for a large share of the employment growth. This illustrates that the lead-times for building up new research-based companies, and for realizing tangible economic effects, tend to be very long in this business. Thus, what one could hope for is that some of the small start-up companies identified in this study will prove to have growth potential and ability to realize it.

This raises questions about the growth conditions for this type of company. It is not enough to create a large number of start-ups. If all of them remain small the economic effects at the national level will still be marginal. There must be at least some companies that manage to achieve significant growth in the global market and become key players in the Swedish medtech industry (like today's Gambro, Elekta, Nobel Biocare and Sectra just to mention a few examples).

Given the assumed importance of start-up companies for the future development of the medtech industry in Sweden – whether these firms are university spin-offs, corporate spin-offs or have other origin – we think it would be worthwhile to carry out a more in-depth study on how the conditions for growth of such firms can be improved.[96] Medical technology is an important part of life sciences, which is one of the prioritized areas in the national innovation strategy. Sweden has a proud history in medical technology, both in terms of research and innovation. However, as pointed out in several recent reports, such as ActionMedtech (2007), there is a need for renewal of the industry if Sweden is going to defend or strengthen its position in the global medtech industry. One of the important challenges is to improve the country's capability to turn research-based ideas to industrial products and growing companies. Here, obviously medtech start-ups have an important role to play. By analyzing the factors that enable or hinder the companies' development it should be possible to gain new knowledge and insights about the development conditions and how the commercialization processes can be supported by various policy measures.

5.3.6 Effects on education

Postgraduate studies

An intended effect of the research programs as well as the competence centers is to train researchers. This is important both for the development of the research environments themselves but also for providing industry with highly skilled R&D personnel. In Table 5.14 we give for some of the larger research environments that we have studied the number of persons who have obtained a PhD degree, during the period under consideration, and how many of them who have gone to industry.

The financing of the PhD students has varied, of course, but it is clear that many of them have got funding from STU/Nutek/VINNOVA. Without the medtech research programs and competence centers, the number of graduates would have been much lower.

According to estimations made by our interviewees, as we can see in the table at least one third of the PhDs have started to work for companies after having received their degree. For most environments, however, more than half of the graduates have gone to industry. This corresponds to at least 6-7

[96] Such a study should include a mapping of medtech start-up companies founded since, e.g., 1980 and analyze what has happened to these companies.

PhDs being employed by industry on average every year during the 20-year period. This indicates that the research grants given to these environments, irrespective of source, have had the intended effect of strengthening the scientific competence level in the industry. To what extent these recruitments have affected the companies R&D activities and innovative performance, we do not know.

Table 5.14. Number of PhD graduates (in medtech)

Unit	Number of PhDs in medtech (since end of 1980s if not otherwise stated)	Number or share of PhDs who have gone to industry
Research Center for Radiation Therapy, KI	18	6
Biomedical and X-Ray Physics, KTH	13	10 (two of which work in medtech companies, both located in the US)
Center for Image Analysis, Uppsala	20	More than half (7 in medtech companies)
Electrical Measurements, Lund	25 (since 1992)	Majority
Electrical and Information Technology, Lund	10	Majority
Lund Laser Center	More than 20	Majority
Chemical Physics, Chalmers	15	More than 4
Applied Electronics/Biomedical Engineering, Chalmers	30-40	10-15
Biomaterials, Univ. of Gothenburg	46	More than half
Biomedical Engineering, Linköping	56	Approx. half

We do not have complete data about which companies the PhDs went to, but we have reason to believe that the majority of the firms belong to the medtech sector. But there are also a relatively large number of PhDs who have become employed by other types of high-tech companies (e.g. Ericsson, Saab or technical consultancies).

It seems that in proportion to the size of their R&D organizations, the large medtech companies in Sweden have not recruited so many PhDs in the past. In this respect, the medtech industry has not had the same tradition as the pharmaceutical industry, which is more research intensive and employs large numbers of PhDs. One professor says that the established medtech firms do not employ PhDs since they do not understand what such a person can be used for. He means that this is unfortunate. A PhD can be used, for example, to follow the research frontier and keep the company abreast of the state-of-the-art in technology. Investing in such a resource would give the company a good return. It seems that the competence centers might have had some positive effect in this context. By being involved in academic research projects the companies have learned more about how academia functions and got insights into the postgraduate education. This has made them less afraid of recruiting PhDs. However, if we look at NIMED only three of the seventeen PhDs who have been funded by the center has started to work for medtech companies so far (Atos Medical, Elekta and Sectra). One more has been offered a job by the industrial partner he has collaborated with. Three others have been employed by other (non-medtech) companies (the rest work in academia or at university hospitals). Out of the 18 PhDs from KI's Center for Radiation Therapy six have been employed by industry. Two have founded their own companies (RaySearch and RayClinic). One has been recruited by another spin-off from the center (C-RAD). Three have been employed by Nucletron Scandinavia, which is also a small R&D-based company (previously Helax, a university spin-off in Uppsala). In other words, none have ended up working for a large company.

The impression one gets is that the smaller R&D-based companies are more inclined to recruit PhDs than the large medtech firms. These firms are often spin-offs from universities or at least have their roots in an academic environment. It means that they tend to have close relationships with universities and have a good understanding of academic research. Two other examples are SpectraCure, a spin-off from Lund Laser Center, which has recruited four PhDs from that center, and Perimed. The latter is an early spin-off from Biomedical Engineering in Linköping commercializing products based on the laser Doppler technology (a research field where the department has a world-leading position and has produced some 15 PhD theses). The company has two PhDs among its employees and has since a few years back a standing job offer to a third person (who has chosen to stay at the department).[97] [98]

The university spin-offs are usually founded by professors or other senior researchers, but there are a few examples where newly graduated PhDs have started companies based on their own research. Two examples from KI were mentioned above (RaySearch and RayClinic). One of our interviewees from Linköping complains that so few of the new PhDs from Biomedical Engineering have become entrepreneurs. One explanation previously

[97] In addition to these recruitments, Perimed has gained access to new knowledge by collaborating with the department, for example, by participating in NIMED, and the new center (CBDP) that has been created in order to continue research collaboration. Perimed is also involved in another research project financed by VINNOVA for the period 2008-2011.
[98] Interestingly, as pointed out by one interviewee Perimed's competitor, which is a British company, has employed many PhDs and built up a strong academic base. He believes Perimed would benefit from having more PhDs in-house, which would help the company to keep abreast of the technological development.

discussed is that during the NIMED period the focus was on collaboration with established firms, which held back entrepreneurial activities. In addition, many PhDs have worked on the laser Doppler technology. Given the relatively small market potential in this field there has not been room for starting new companies.[99]

Basic education

The effects of the research on the basic education (BSc and MSc levels) have not been analyzed in detail. However, as expected it is common that knowledge and competencies built thanks to the research grants have been useful, sometime a prerequisite, when developing basic courses, for example, for various engineering programs. If we take the Center for Image Analysis in Uppsala as one example, this center has been responsible for courses in Basic image analysis and Computer graphics and visualization. In addition, throughout all years the center has given courses for postgraduate students in other disciplines, such as medicine and biology, which has provided them with a toolbox. In total, more than 200 such PhD students have been trained in this way. As another example, Lund Laser Center gives a basic course in Biomedical optics which is very much research-based.

As mentioned previously, Linköping Institute of Technology has for a long time been Sweden's largest educator of clinical engineers. Many of the courses in the Master program in biomedical engineering are given by the Department of Biomedical Engineering. As several persons have testified, the department's own research activities have been very important for the quality of the education. A large number of the clinical engineers working at Swedish hospitals or in Swedish medtech companies have received their Master degree from Linköping.

It is also common that the medtech researchers supervise Master theses in their field. For example, at Lund Laser Center some forty Master theses have been carried out in the field of "laser medicine".

5.4 Academic results: Innovative food and Medical technology

We now turn to the next step in the chain-linked effects, namely academic results in terms of the project leaders' total publications and citations unless specifically compared to results reported in the policy initiatives studied here.

[99] From the point of view of commercialization opportunities, one may wonder if the department should not have directed its research activities more towards other technologies.

The academic results are more complete for innovative food than for medical technology. As to the former, we have examined all project leaders (although only 53 were represented in the databases). For medical technology, we have only looked at two specific but interrelated programs – Biocompatible materials and Biocompatibility. Here complete project leader information could be found. We have also run an econometric analysis for innovative food, but only provide descriptive statistics for medical technology.

5.4.1 Innovative food

This section considers patents, publications and citations of project leaders, focusing upon their total production. We then do an econometric analysis studying the effect of funding on publishing.

Patents

We have examined patents for all project leaders, with two sources. We examined self-reported patents in the final project reports, and the KEINS academic patent database (see Chapter 3).

Table 5.15 and Figure 5.2 show the results of the analysis.

Figure 5.2. Patents %

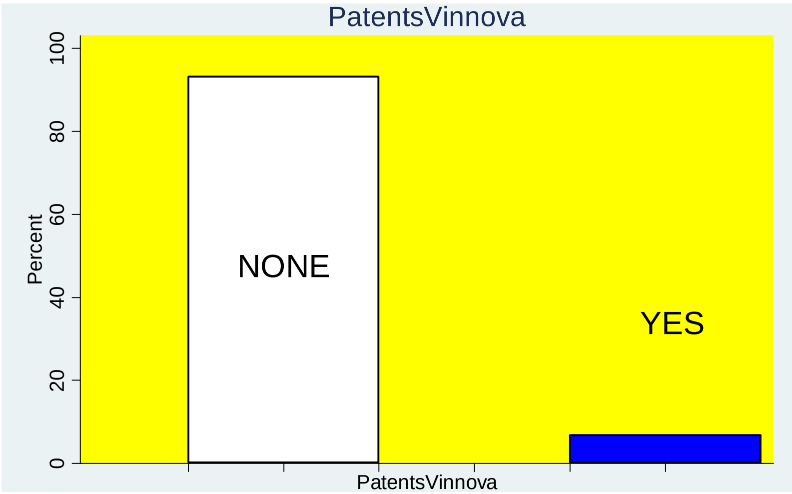


Table 5.15. KEINS patent

Patents VINNOVA		
	Freq.	Percent
0	41	93.18
1	3	6.82
Total	**44**	**100.00**

We also discussed the patents that project leaders reported via interviews. However, when we examined the project leaders' name in the KEINS patent database, we found only three patents total for their careers. Therefore, we can assume that for self-reported patents that were not visible in the database, either they were excluded from the database, or they are planning to apply for a patent, or they already applied but were not granted the patent.

Descriptive statistics of publications and citations

We have done so, to analyze the project leaders in relation to their total publications. While most projects report on scientific publications, it is difficult to quantify the number and impact of publications that are a direct result from the projects. This is partly because the project reports seldom quantify the number of articles produced or where they have been published. Another difficulty is how science is funded, that is, many projects are running in parallel. Many times, the projects analyzed here also interact with other projects, which sometimes makes it difficult to assign a particular article to only one particular project or sub-project. Individuals are often funded from several projects.

Some evidence for the impact and importance of the publications may be derived from citation indexes of people involved. Regarding citation indexes, several of the researchers involved in projects in the two programs exhibit a high impact in terms of citations. Among the 61 most highly cited Swedish researchers on ISI Web of Knowledge, six are projects leaders in one or more projects in the two programs analyzed here (www.highlycited.com). We find this result interesting, because it indicates that Sweden has a relatively good position in fields related to the food industry, and that these are highly scientific fields (even if also applied).

We also examined total publications for each project leader. Bibliometric analysis indicates that the fields of Innovation food and Medical technology are an area where there are many publications in Web of Science. As most of the leaders´ publications were found on SCI, we can say that it was a proper database to be based for the bibliometric analysis.

Figure 5.3 presents the distribution of publications for the 53 project leaders, for which data was found.

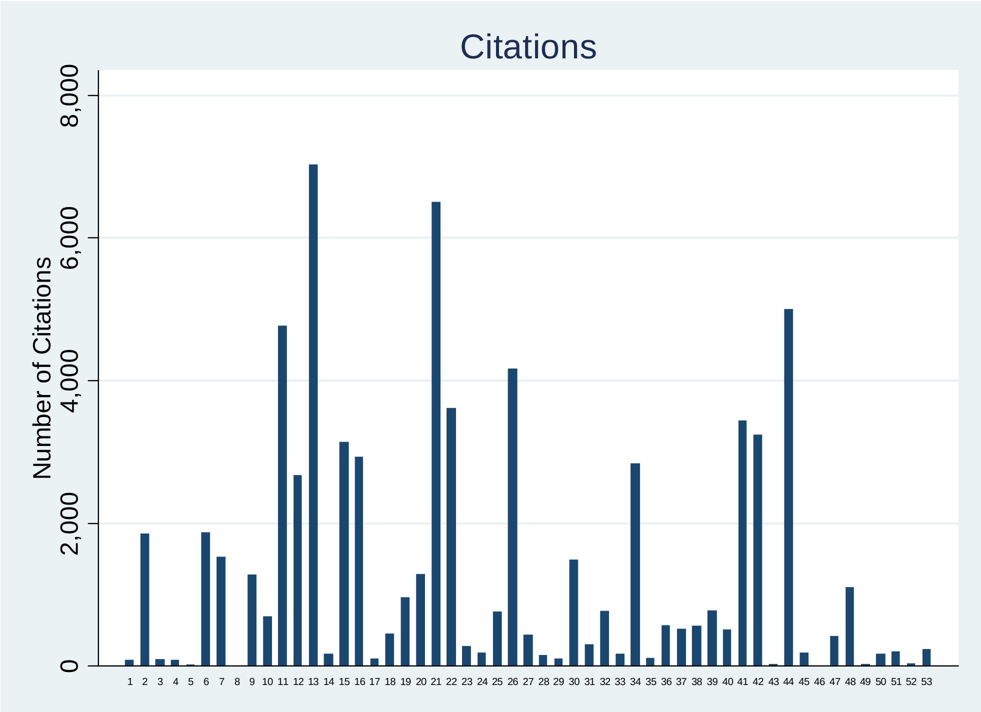
On average every author has published approximately 67 publications. The minimum was 1 publication and the maximum 359 publications. The authors with the most publications were Göran Hallmans with 359 publications, Bengt Vessby with 337 publications and Per Åman with 225.

Figure 5.3. Number of publications on ISI

Hence, there is a distribution of total publications (in their careers), but 11 of the project leaders have more than 100 publications each, as visible in Web of Science.

We did a similar analysis for the number of citations. On average, every author was cited 1320 times, which is again a high figure relative to many disciplines. Not surprisingly, the same persons are in the highest positions, with different order though. Bengt Vessby has 7029, Göran Hallmans 6500 and Per Åman 4998.

Figure 5.4. Number of citations on ISI



Because the number of citations is directly connected to the number of publications, we found it be more interesting to look at the citations/publications ratio. On average, for every publication, every author gets about 16 times cited. As we can see in the following table, Ulf Hammerling has the highest ratio, with almost 33 citations per publication.

Table 5.16. authors in citations/publication

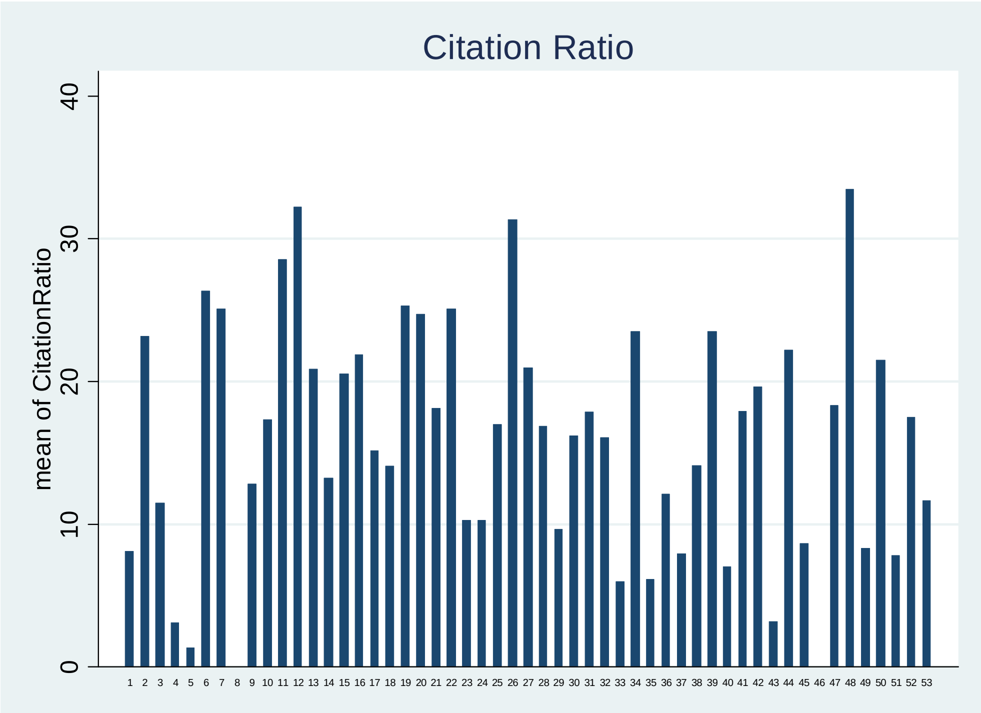
	Name	Publications	Citations	Ratio
1.	Ulf Hammerling	33	1105	33.48
2.	Ann Sofie Sandberg	83	2676	32.24
3.	Inger Björck	133	4168	31.34

The corresponding table for the three authors with the most publications is Table 5.17. Taken at the aggregate, the numbers are as shown in Figure 5.5.

Table 5.17. Top Authors in Publications

	Name	Publications	Citations	Ratio
1.	Göran Hallmans	359	6500	18.10
2.	Bengt Vessby	337	7029	20.86
3.	Per Åman	225	4998	22.21

Figure 5.5. Citations per publication



Innovative food: Econometric analysis

This section reports on the result of an econometric analysis of the effects of funding on publishing. We first describe the methodology in more detail, before going on to the results and the implications.

We use the panel data to estimate the effect of funding on publishing. For details about the panel dataset used in the econometrics here as well as for the database used in the above statistics in this chapter, see Appendix 3. We used three different methods, but the later there is one preferable. The three methods are: Pooled OLS, random effects and fixed effects. In the first method, we use dummy variables to count for the time, for the years 1996-2007. For the random effect, as well as for the pooled OLS, we include the variable category, which is dropped from the fixed effect where we have to use the interactive variable cat98 to count for the category variable.

The most preferable method after performing the Hausman test is in this case the random effect. The coefficient which is our main interest is lnFunding_2 because we assume that there is a 2 year-lag in the effect on publications. The p-value in the random effect for the lnFunding is 0.022 which means that the variable is important in a 5 percent level of significance. The coefficient is positive and equal to 1.56. This means that funding plays an important role in publishing and has a positive effect. According to the above numbers, if funding increases 100 percent, that is if we if double the funding, then we will get 1.56 more publications with a lag of two years.

The results of the analysis are depicted in Tables 5.18-5.20.

Table 5.18. Variable Descriptions

NumberPublications	**Total number of publications annually**
funding	Funding that project leader's received in annual basis, in Swedish crowns
lnFunding	Funding that project leader's received in annual basis, in Swedish crowns in logarithm form
lnFunding_1	Funding that project leader's received in annual basis, in Swedish crowns in logarithm form, with one year lag
lnFunding_2	Funding that project leader's received in annual basis, in Swedish crowns in logarithm form, with twp years lag
clnFunding_2	lnFunding_2 – lnFunding_3
Category	Scientific category of the publication according to the Leydesdorff index, constant during time
Cat98	Interaction term of category with year 98, used for the fixed effect as indicator year

Table 5.19. Summary Statistics

Variable	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Funding	1584496	4797387	7500	61000000
lnFunding	13.56	0.97	8.92	17.92

Table 5.20. Regression Results

Dependent Variable: NumberPublications			
Independent Variables	**Pooled OLS**	**Random Effects**	**Fixed Effects**
lnFunding	—	0.4 (0.46)	0.33 (0.46)
lnFunding_1	—	-1.31 (0.67)	-1.51 (0.75)
lnFunding_2	—	1.56 (0.68)	1.3 (0.73)
clnFunding_2	1.33 (0.77)	—	—
Category	0.12 (0.16)	-0.02 (0.1)	—
Cat98	—	—	0.8 (0.38)

As we see in Table 5.20, we get a positive correlation between funding and a two years lag on publishing in all models. Nevertheless, the coefficients did not come significant in the pooled OLS and in the fixed effect model. The coefficient was significant only in the Random Effect model, but in every case this was the most appropriate for our data as we said before, taking into account the hausman test too. The negative values of the lnFunding, as well as the values of the lnFunding are not on main interest for two reasons. First we assume that funding will have result on publishing with at least a two years lag. Second, the coefficients were not significant in any case.

Summing up, the econometric analysis of this database showed that the participation in a funded program affects the publication output of project leaders. More clearly, an increase in funding of a program is responsible for an increase in the number of publications in a period of two years lag.

5.4.2 Medical technology: the case of Biocompatible materials and Biocompatibility

The following section contains quantitative data reported from the research programs ‘Biocompatible materials’ and ‘Biocompatibility’ as well as bibliometric results for the 15 project leaders of these programs (NUTEK 1996b, p. 25).

The bibliometrics are based on the “Web of Science (ISI)” database. The “Biocompatible Materials-Biocompatibility” reports, from where the rest of the data where extracted, were pretty clear. The detailed list of publications and co-participants was also helpful for the bibliometrics analysis, working as a tool for verifying the publications found on ISI. Therefore the bibliometric mistakes are eliminated.

The data for the patents came out of the KEINS database.

In Table 5.21 there are the fifteen project leaders and all the concentrated data.

Table 5.21. Biomaterials bibliometrics

	Name	Publications Reported	Co-participants	Manuscripts	PhDs	External Co-operations	Publications ISI	Times Cited	Citation Ratio	Patents KEINS database
1.	Magnus Jacobsson	8	8	.	2	.	29	626	21.58	0
2.	Håkan Nygren	20	6	.	1	.	171	3171	18.54	1
3.	Lars Sennerby	9	6	.	.	1	121	2201	18.19	0
4.	Peter Thomsen	23	53	.	8	8	112	2537	22.65	4
5.	Pentti Tengvall	10	.	.	1	.	113	2273	20.12	4
6.	Lars Bjursten	58	.	.	.	.	63	1067	16.94	4
7.	Lars Lidgren	7	5	.	.	.	198	2700	13.64	0
8.	Åsa Ljungh	33	17	5	5	5	216	3222	14.92	0
9.	Torkel Wadström	6	8	2	1	3	486	9276	19.09	0
10.	Bengt Wesslen	11	4	3	.	.	77	1301	16.90	0
11.	Ann-Christine Albertsson	102	.	.	17	4	287	4761	16.59	0
12.	Stefan H Jacobson	18	8	.	2	2	133	1570	11.80	0
13.	Per Olsson	20	6	.	3	.	135	1756	13.01	0
14.	Martin Malmsten	20	2	.	1	2	160	3154	19.71	1
15.	Ulf R. Nilsson	23	2	.	3	2	55	853	15.51	0

In the column Publications Reported, we see the number of publications which are reported as a result of the participation in the program and in relation with it.

Next, we see the number of Co-participants for each leader in his/her project. Every leader is reported for one project apart from Peter Thomsen for whom we will explain explicitly later.

Some projects report manuscripts in addition to the publications. They might have led to publications later but here they are reported separately in the column Manuscripts.

In most projects there were some PhD students connected with the research where different theses and graduates are reported. They are concluded in the column PhDs.

In the next column, named External Co-operations, there are the external co-operations with different institutions, companies or industries that have taken place within the projects. The number denotes how many partners that have been involved.

The previous five columns contain the information given in the "Biocompatible Materials Biocompatibility". The next three columns contain the information from the bibliometrics. The first shows the total number of publications found on the "web of science". Then how many times the publications are cited totally and last the citations per publication, which is the quotient of the two previous columns. In the very last column there are the patent data were we can see how many patents every project leader has registered on his name in the KEINS database.

As mentioned, Peter Thomsen's case was treated differently because he was project leader in four projects instead of one, as all the rest. In the three last columns, in this case, and the bibliometrics reported there, things are done as with the rest of the names. But the first five columns contain the aggregate number from all four projects for which Peter Thomsen was leader. In that case, the number of Co-participants does not denote the total number of single partners, but the sum of the total number of single partners of every project. Therefore this number can contain the same person even four times, as many co-participants took place in more than one project. The Publications Reported, the Manuscripts, the PhDs and the External Co-operations are the sum of the corresponding values from the four projects. In Table 5.22 there are the analytical numbers for the four projects where Peter Thomsen was leader.

Table 5.22. Bibliometrics Peter Thomsen projects

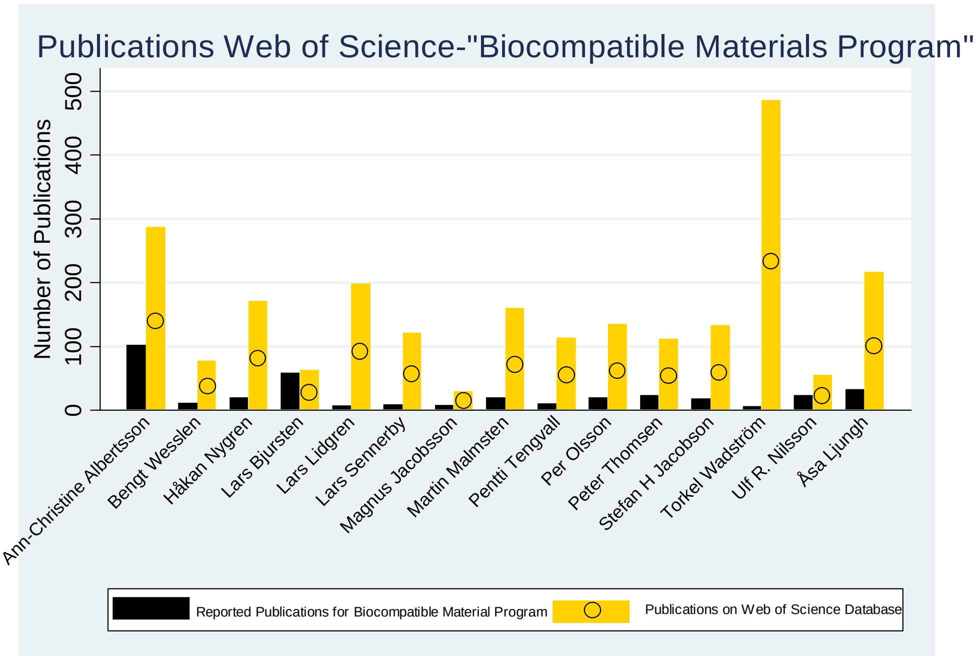
Peter Thomsen	Number of Co-Participants	Related Publications	Manuscripts	Phd	External co-operation
Project 1	16	14	0	5	4
Project 2	17	3	0	2	2
Project 3	14	3	0	0	1
Project 4	6	3	0	1	1

In the graph in Figure 5.6 we can see and compare on the yellow color, in the bars with the circle mark, the total publications, its leader has according to ISI, with the publications done for the purpose and as a results of the programs on the black color.

The three top leaders in the total publication's list are: Torkel Wadström, Ann-Christine Albertsson and Åsa Ljungh.

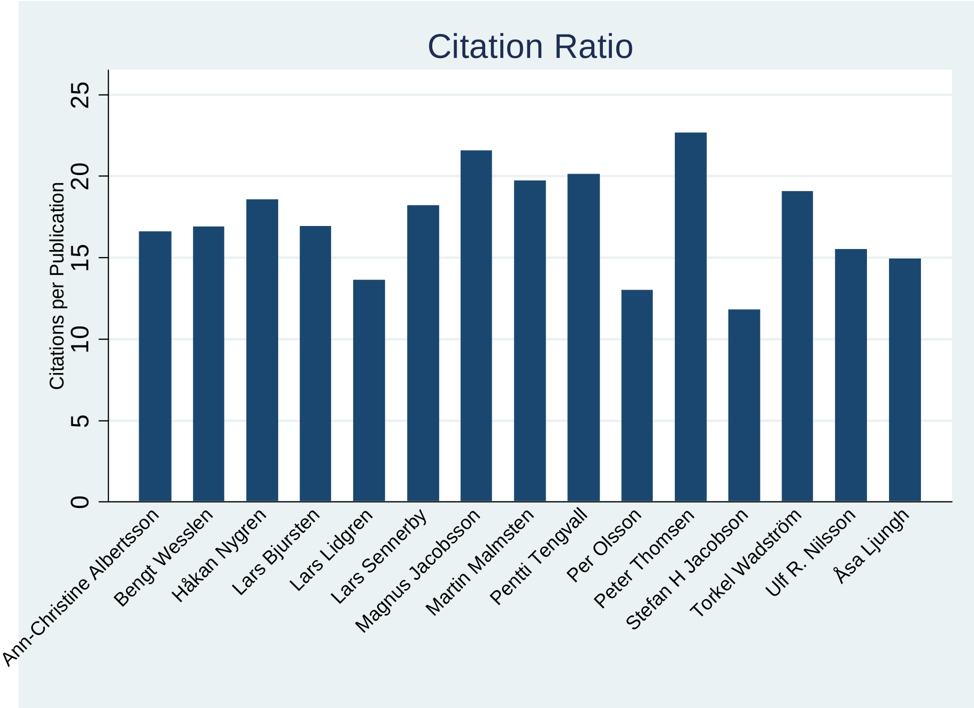
From the other hand in the reported publication's list they are: Ann-Christine, Lars Bjursten and Åsa Ljungh.

Figure 5.6. Publications totally and for the biomaterials programs



Another interesting point we can extract from the bibliometrics is about the citation ratio of every project leader (see Figure 5.7). That is, which leader is the most cited in others' publications? The first in the list are now: Peter Thomsen with almost 23 citations per publication, Magnus Jacobsson with about 22, and Pentti Tengvall with about 20. It is mentionable that there are no huge differences of this rate among the authors. That means that all of them are in the same level of reputation, according to their papers, and are cited almost with the same frequency by others. They are also working in the same discipline and most of them have many publications, which implies that they are known in the field.

Figure 5.7. Citation ratio for biomaterials project leaders



6 Effects: From the perspective of industry

This chapter turns to effects from public policy initiatives, from the perspective of industry. This is thus a parallel to Chapter 5, where we looked at this from the perspective of academic research.

At a general level, many questions are of course of interest about the relationships between public policy initiatives and the future impacts upon growth and the shifting trajectories of the sectoral system of innovation towards higher growth in terms of new competencies, actors and products. From the perspective of industry as well as public policy, we would ideally want to know about the direct effects of innovation in terms of production and sales as well as whether 'value was added' through revenue, productivity increases in existing firms and by the development of venture creation in the form of spin-off companies. We will discuss some of these issues, if directly relevant. In Chapter 4 and also below, this report has provided information about the broader industrial development during these decades (which, note, is based upon other affecting variables, although policy initiatives can impact the developments).

This report has a more specific focus, namely on the relationship between academic research and industrial R&D. From there, to the extent relevant, we can also examine the more general issues identified above, such as directly related impacts on growth. This chapter thus looks at university-industry interactions in these collaborative projects, from the companies' perspective. How, for what reasons and in what forms have they collaborated with the universities? What effects have come out of this collaboration? We thus have a specific focus on the two-way arrows between academic research and industrial R&D in our effect chain model (see Figure 2.2).

Given this focus, we felt it was useful here to remind the reader of the different possible effects and mechanisms for university-industry interaction that were detailed in Chapter 2. Salter and Martin (2001) identify six major mechanisms for diffusion of university research to industry. In our interpretation for this report, this means that this interaction can be valuable to the innovative capabilities of the firms by:

- Increasing the stock of useful knowledge;
- Educating skilled graduates;
- Developing new scientific instrumentation/methodologies;

- Shaping networks and stimulating social interaction;
- Enhancing the capacity for scientific and technological problem-solving
- Creating new firms.

Some of these mechanisms were already discussed in Chapter 5, as they also have effects from the perspective of academic research. Where necessary, we will therefore refer back to that chapter. This list of mechanisms is useful for this report and analysis, because it provides a broader range of impacts than the more common and more easily measured outputs – that is in terms of start-up companies and patents.[100]

As with Chapter 5, this chapter starts with Innovative food and then proceeds with Medical technology.

6.1 Innovative food

This section considers the effects of the innovative food programs, from the perspective of industry. The analysis of this sector focuses upon specific results from the projects, as self-reported and as further illustrated and explained in interviews with some project leaders and with company representatives. This is the main analysis, but we also wanted to touch upon the more general questions identified above, as related to growth, employment, and sales but also the national-international aspect of ownership. Hence, the final part of this section describes the overall context that is the broader industrial transformation of the food industry located in Sweden, during these decades. While this is not directly related to the results from the projects studied per se, this section does provide information useful to interpret the context in which these firms were engaging in the projects.

A general question arrives from our starting point of two-way arrows between academic research and industrial R&D. In this context, what does company involvement mean, and how does collaboration occur?

The focus here is upon projects, where according to the criteria and set-up of those projects, industry is involved. Still, companies can be involved in different ways, and to different extents, and hence we should expect that what the effects – or what companies get out of the projects – are to some extent related to what the company puts into them. There may also be many different effects, and what is useful to the firm depends on other factors, such as their strategies. Those effects can include the development of firms' competencies per se and their products, but also more diffuse aspects such

[100] Note that creating new firms is only one of six mechanisms, and that patents are considered one way to increase the stock of useful knowledge.

as access to the stock of useful knowledge, access to skilled labor and networks and social interaction. Based on the interviews and project reports it is possible to discern possible reasons and ways of being involved in these projects. The variation likely ranges from companies that are actively involved and engaged research partners, to companies providing certain components or raw materials to enable the project to run at all, to companies just participating (but not very active) to stay updated in a certain area.

In many of the projects, the largest part of company funding was in kind, which is common in Sweden.[101] When we examined what in kind financing meant through interviews and examinations of a few specific projects, we found that the companies often financed work related to products, materials and development work. For example, several projects were designed to testing the effects of different biological components in food. In these cases, someone must develop products specifically for the project. These products have specific characteristics that are being studied, such as the right composition of fibers or specific sensorial characteristics of food. Such product development is not easy to perform, and it takes a lot of specific knowledge to develop products that correspond to those characteristics. Since the universities may not have the expertise nor have the equipment to develop these products themselves, industry involvement and contribution in kind is important in this respect. In several of the projects, the division of labor has therefore been to together with industry work out what products to use, the industry develops the products, and then the researchers do the tests as specified in the projects.

We found this result interesting, and suggest that more work should be done in later studies to understand what companies contribute to collaborative projects (e.g. our arrow from industrial R&D to academic research).

We have done an analysis of the more specific effects that we see at the project level. Most of this section considers categories which have been used in the self-assessment evaluations, and we provide illustrative cases of why these effects are of interest to industry. Those categories are new practical methods, a broad category of technology for business (new technology, equipment, prototype, product development, products, and patents) and new firms. We then examine two issues of relevance to both

[101] In kind contributions are distinguished from cash contributions, which are sent to the university or research institute. In kind contributions are counted as the partners' financial input, and can include items like cost of firm staff involved in the project, cost of materials, costs of running expensive equipment and so on. Many STU/Nutek/VINNOVA projects require specific industrial contributions through the last decades, usually reported as in kind.

the perspective of academic research and of industry, namely technology and knowledge transfer as well as new networks.

These categories are in decreasing order of importance, as indicated in Table 6.1 and as discussed in the subsequent text. The following discusses each of them in more detail, giving illustrative cases from projects and firms. Chapters 7 and 8 return to the issue of how to interpret these results, relative to the key issues and the public policy tool-kit.

Table 6.1. Reported categories of effects of relevance to industry

Category	Number of projects reporting, per category	Number of projects reporting, combined
New practical method	23	28
New technology/new equip-ment	9	
Prototype	10	17
Product development	14	
Product*	5	
Patents*	3	
New firm or center	2	2

* *The numbers are based on the assessment reports. At least two more projects resulted in products after project completion, and at least three more projects resulted in patent applications (one of which was not pursued however*

6.1.1 New practical method and/or technology/equipment

This category ‘New practical method and/or technology/equipment’ is particularly focused upon the technological and practical aspects of innovative food.

The single most important implication of the program as reported to VINNOVA by the project leaders is that the projects have provided industry with new practical methods and/or new technology and equipment. About half of the projects report these results as important outcomes. This category covers many different things of relevance to industry. Most are related to new practical method that range from new, fast methods for quality assurance when frying in fast-food stands to new ways of preparing food.

The payoffs of these results vary with the aims of the projects. Two illustrative cases follow, in that they provide insight about the value of specific scientific and technological problem-solving, in a business context.

One project was run by the Department of Food, Technology, Engineering and Nutrition at Lund University on self-contained factories in food.[102] This project had the objective of reducing waste in dairy production. Company participants include major equipment producers in Sweden such as ABB and Tetra Pak as well as a large dairy company, Skånemejerier. New sensor and filtering techniques were introduced in the dairy firm in order to reduce unnecessary waste from the flows in the production. Improvements in such aspects are of interest to the whole production chain from farmers to dairy producers. The project required, among other things, the development and testing of several new filtering methods. This development was conducted by PhD students involved in the project, together with the production technicians at the dairy company. The results of the projects proved valuable to the dairy company as it learned, among other things, what membranes to use when filtering, how to wash them and also how to clean those fluids. These are procedural changes in knowledge, applied to the specific context of their business. These developments thus reduced waste in production. As a result, the technique has already been introduced at some of the company's dairies, and will be introduced in more of its production plants. According to the firm representative, the return on investment in these techniques, and in the particular project, is estimated to one, one and a half years.

Another illustration of the importance of methods comes from the dairy industry. The dairy company Arla has been involved in several projects. A relevant one for this discussion is a project aimed to find out about health effects of functional foods.[103] The project addresses how probiotic bacteria influence the genes that regulate fat metabolism in the body, and includes much basic research. According to the company, they have specific reasons for why the relationships between the basic research and the methods are valuable to them. 'The advantage of this project, even if there is much basic research, is that the techniques and methods can be applied to several biomarkers in parallel. This in turn enables us to relatively quickly find different applications that are then of interest within the company.' Hence, the scientific methods are directly useful.

This project thus illustrates how academic research contributed from the perspective of industry, where the practical methods are also closely linked to scientific methods. The project employed a new technique that was being developed by the research environment and others (but not developed within

[102] P13648 – Slutna livsmedelsfabriker – minimering av blandfaser med komplicerade egenskaper
[103] P25075 – Maintained health with functional food (Bibehållen hälsa med funktionella livsmedel)

the VINNOVA financed project). This technique was of interest because it was new to the participating firms. Taken together with the biomarkers, it thus provides one way to map the effects of lacto bacteria in the body, something that clearly was of great interest to the participating dairy firm. While the project is still ongoing as of 2009, many scientific results have already been achieved, and the representative of the participating firm believes that several of these results are potentially very interesting commercially. However, even though the dairy company has worked within the area prior to the project, and could translate some of the results into aspects useful for the company, they also recognize that commercialization and pay-off are uncertain and may come far in the future.

The importance of methods to industry can further be illustrated in a project on acrylamide.[104] This project can be seen as a direct response to the alarm about acrylamide in food (in e.g. potato chips and bread) in 2002, and the project was established and running in parallel to a larger EU project addressing the same issue (where the project leader was also involved). The project studied here was concerned with how to reduce acrylamide in bakery products, especially bread, and specifically to develop methods that could reduce the amount of acrylamide that results from the bakery process in bakeries. The project identified two methodologies that could reduce acrylamide, and about 20 companies were in the network and monitored the results. As far as the project leader knew at the time of the interviews in 2008, neither method had been implemented at any of the several bakeries participating in the project. His explanations were three-fold: Firstly, debates at World Health Organization (WHO) level are on-going about the health effects of acrylamide and hence legislation does not yet require such changes to be made; secondly, implementing especially one of these specific methods required significant changes in production through capital investment; and finally, that the project was more of preparatory project to increase understanding and awareness in case legislation would change. Hence, from the perspective of industry, the project enabled them to be prepared, and learn more on these issues (rather than resulting in knowledge about methods to implement immediately into new production facilities).

6.1.2 Prototype, Product development, Product, and Patents

Results such as prototypes, product development and actual products are closely linked and many of the projects that report on product developmental also report on prototype and/or products as project results. Altogether there were 17 projects, or close to one third of the projects that

[104] P25085 – Innovative process technologies for positive health effects (Innovativ processteknik för positiva hälsoeffekter)

checked any of the categories. As many of the projects are fairly recent, more products or product development can be expected to come in the future, which at least was our impression from the interviews conducted.

The discussion of these categories relates back to discussions in Chapter 2 about the heterogeneous competencies and interests of the actors involved – or, in other words, what do they do in the projects together? In many of the projects, there is a division of labor. The actual product development, or product, was not a joint effort, rather the projects provided the groundwork for it, and thereafter the companies made the actual product development much an internal affair. “That is the way it is, you are in the projects, sometimes with competitors, you learn and then you take the knowledge back home and try to translate it. And once in product development on our own, we cannot be that open about it anymore, we do not just call the researcher for help on specific problems. At that stage, the project has become a company internal and secret project”. Many times, thus, the projects served to lay the groundwork for later products, sometimes intentionally so other times unintentionally so.

Sometimes the companies take on direct product development work, linked to the research. In the project that aimed to develop consistency-optimized food for health and well-being in elderly,[105] many stakeholders were involved to develop a new product line, or at least to provide the base for the participating firm to develop the product line. That is why this project involved not only the company that was to develop the product line but also key suppliers and end users in the form of elderly care takers. The results that they learnt in terms of how and why certain types of consistency would be appropriate for the elderly was useful not only for the product line (about 1% of turnover in 2008 and expected to grow) but also the whole Special Foods unit. They have learnt useful knowledge about elderly, as well as published in peer-reviewed journals with academic researchers, which is very useful for the export market. Here, the company clearly took over the product development, and has expectations for the future. Moreover at the research level, at least two more Swedish projects have been run up to the present as well as a large EU project.

Other times, the product development is not an explicit aim of the project, but more a result of the increase in stock of useful knowledge and networking. A large dairy firm, Skånemejerier, illustrates a case where product development was more of an unplanned result from two different

[105] P20510 – Konsistensoptimering och sensorisk design för hälsa och välbefinnande hos äldre.

academic projects.[106]The dairy firm participated in two projects that were thematically somewhat similar, but involved collaborations with two separate research groups (Chalmers and Lund, respectively), at two different points in time. In the first project, the idea of a potential product formed when discovering the effects in relation to bacterial properties upon fermentation. The second project, together with a human intervention study outside of the project, largely confirmed the knowledge and ideas they got from the first project. Based on these results and own internal competencies, the company created its own development project, and at that stage it also became more of an internal development project. Still, they felt that they could rely somewhat on one research group with which they have had kept close contacts over many years.

Interesting enough, in this illustration from the dairy industry, the company was not sure if the academic researchers would understand the link to product development. "If you ask the researchers in the two projects, they may not see our product as a direct consequence of the projects, but for us it was". Today, about two years after they started their own development work, the product is on the market and they expect a product turnover of about MSEK 10 in its first year. Apart from this product, the two projects have together provided the firm with knowledge and ideas that they believe they can translate into even more products. "We have only just begun to scratch the surface of this area".

It is well known that the lag between idea and commercialization may take many years, and we have examples of this as well. Another case may provide for an example where the commercial potential was discovered on a fairly early stage, but where the actual product development has taken somewhat longer time. The idea was originally developed in a smaller project outside the VINNOVA programs of current interest. The researchers behind the project patented their discovery and set up a firm around the patent in order to commercialize it. The timing was, however, bad. Just after the dotcom crash it was difficult to raise money and after a few years of struggling, the rights to the patent were sold to a larger Swedish company. This company, which had invested some time and money in the project already from start, continued to participate in research collaborations in the area, which among other things lead to two dissertations in the area. One of these dissertations formed part of a project funded within VINNOVA's Innovative food program.

[106] P11811/21511 – Fermenterade grönsaker och bär som Funktional Foods (with CTH, Dpt. for Food Science) and P26049 – Probiotika i synergi med antioxidativa fenoler i frukt/bär minskar oxidativ stress och inflammation (with LU, Dpt. for Food Technology).

While they still have not developed a final product, the issues concern less process aspects and more of sensory aspects such as taste, aroma, and consistence. These latter aspects were also part of the research topics for the second PhD dissertation[107]. Another reason for the delayed introduction of a product has been other product rollouts by the company in possession of the rights to the product. However, with those rollouts underway, the company expects that work to finalize the product will speed up. The company moreover sees a great market potential for a coming product, domestically as well as internationally, whether they produce it themselves or license production to other producers. Hence, this project illustrates that long time spans are often involved, before an idea has been tested and developed, to reach the stage of commercialization of products. In the present case, commercialization is coming closer 10 to 15 years after the original idea was contrived.

Hence, the results from the projects, as complemented by the interviews and illustrative cases, indicate that the direct impacts often involve fairly complex processes inside the firms (especially in relation to their core products) and also outside the firm (in relation to their markets, sources of knowledge and so on). Several of the interviewees point out, and as the last example above demonstrates, that it often takes a long time to translate discoveries into products. In those projects that have already resulted in products, however, the payoff from investments in the projects seems to be considerable. Many project participants in firms as well as at universities/research institutes also expect that several of the projects will bear more direct financial returns in the form of products in the years to come.

Patents have been touched upon in Chapter 5, with three reported cases. As for patents, both self-assessments and interviews point to that some projects have resulted in patent applications, but the database search found only one of the three reported. The interviews provided the answers to why the self-reported data differs from the databases. In one case the patent application has still not been granted, in another case neither the company nor the university wanted to pursue the patent application further as they did not deem it commercially interesting. Some other projects concern research on ideas that were patented in projects prior to, or outside the VINNOVA programs. In either case, it is difficult to estimate the importance or commercial value of these patents at this point in time. As one researcher puts it, “we have offered the companies the rights to use it, but it hasn’t led to anything so far, partly because publications of the results in the project

[107] P20105 – Nutritionella effekter av nya livsmedel från svampförädlade spannmål

have reduced their interest. It is hard to tell what we can do based on it or not at this point, perhaps you can say something in 5 years time".

6.1.3 New firm or center

Two projects reported that they were involved in venture creation. One resulted in a new firm, and the other resulted in new center, which was incorporated as a firm.

One project in the first of the two Innovative food programs aimed to develop an online measurement based on microwave technology for the detection of foreign bodies in food.[108] The original idea was conceived of in 1997, in an earlier project with a French dairy firm (outside the present program). The idea was, however, incorporated into the present project where it was further developed. The project was based at SIK and performed in close collaboration with Chalmers. According to the firm founder, the Nutek/VINNOVA funding was very important as it provided financing for the early phases of development. This allowed for a further development of the idea, and a patent was applied for within the project. In the year following project completion, the company Food Radar Systems was established as spin-off from SIK. In 2006, the company was awarded further funding through the VINNOVA program Forska&Väx that is oriented towards research-intensive small companies. In 2007, Food Radar Systems employed 5 people and had a turnover of MSEK 2.5.[109] As of 2009, the company has developed a system, and is involved in discussions with potential international clients.

Another project was designed to support a research center that could do tests for industry.[110] Hence, the project objective was to create a unit that industry could use to do tests of the effects of health on food. The research environment at the university had developed the methodology and technology needed to make the tests. They then started to receive requests from industry to perform such tests, but were not so interested in doing tests per se, as they were time consuming and not always clearly related to the research objectives. They therefore saw a center oriented towards industrial needs as a useful development. During a build-up period, the center received support from two universities, The County Council (*Landstinget*), The County Administrative Board (*Länsstyrelsen*) and from VINNOVA. The National Food Administration also served as an advisor to the project. VINNOVA acted as partial funder the first three years, and this support was very important and beneficial as it worked as "a catalyst, or rather, as a

[108] P11837 – Radarteknik för detektion av främmande föremål i livsmedel
[109] Source: the database Affärsdata
[110] P21615 - Centrum för Klinisk Prövning

venture capitalist apart from that they did not take any ownership in the center". As of 2004, the center already had several national as well as international clients. In 2008, the center became an independent shareholding company, and at this time, the center has succeeded fairly well, it is profitable and continues to grow in terms of employment. Apart from that, the center is also important for the infrastructure in Uppsala, as much other food industry has moved from Uppsala. There is also a continuous bilateral exchange between the center and university departments, where both keep learning from each other.

This next part of this section addresses technology and knowledge transfer, and therefore de facto includes the perspective of both academic research and industry. Table 6.2 provides an overview of reported categories of results at the intersection of research and industry.

Table 6.2. Reported category of results, interaction of research and industry

Category	Number of projects	Categories combined
Technology transfer	10	10
New research network	9	11
New company network	3	

6.1.4 Technology and knowledge transfer

A little less than a fifth of the projects reported specifically on technology transfer, however, the final reports and interviews suggest that more projects experienced if not technology transfers at least knowledge transfers. This could relate to, for example, the transfer of knowledge on how to perform new methods of analysis, the transfer of a specific technology, or general knowledge on what technologies actually exist.

A research group in Lund, for example, has over a couple of projects building upon each other been involved in developing better, and faster diagnostics and analysis in order to improve food safety. This development occurred continuously over time through roughly three stages. The first stage concerns identifying the presence of different organisms, the second stage concerns determining the number of organisms in a sample, and in the third stage they try to determine the activity of the organisms in the sample. This last stage is important as it may be used to see how, for example, natural additives inhibit or increase the virulence of organisms in food. A series of projects are thus involved in this case.[111]

One very important part of the research environment's work in these projects has been to transfer the knowledge of the new analysis methods to the companies involved. In particular one of the participating firms that focuses its business in this area has benefited from this, as it has gained competence in, for example, molecular analysis of DNA. Knowledge transfer in this case was much facilitated by an industry PhD student, financed by the company and supervised by the research unit. However, upon project completion also some of the other larger food producers that participated in the project have set up new platforms to utilize the analysis methods. In these cases, knowledge transfer occurred more through workshops and active involvement in the project. In a way therefore, the research unit has served an important role to educate industry through these projects. A similar but more general point was made by another researcher, that one important effect of the projects is to make the industry realize what techniques and competence that actually exits within Sweden.

One problem in relation to this, though, is that it is primarily the larger food producers that have been involved and tried to develop the competence in-house. The smaller companies rely to a large extent on external companies for these kinds of analysis, which is a problem since these companies thereby lose in-house competence in the area that affects both their ability to order the right kinds of analyses and to interpret the results once the analysis is made. The hopes of the research environments in academia are to be able to raise knowledge more generally about these analysis methods in the future.

For the firms that participate in the projects it is difficult to describe exactly how the transfer of knowledge or technology occurs. Three of the firm representatives that have been involved in large number of projects suggest that an important part for a successful transfer of knowledge in the project is the intensity of the projects. That is, the extent of involvement as well as the frequency and regularity by which meetings and contacts are held, and the use of workshops. A university researcher on the other hand suggests that where it is possible, the best way to ensure a transfer is to have something that continuously delivers products, or to have something that they can set up in the firm's environment in order to make it concrete.

[111] P11789 - PCR-baserad detektion och genetisk karaktärisering av patogena bakterier i livsmedelsproduktion, P13624 - Snabbanalys av yersinia enterocoliticia i livsmedelsprover med realtids-RCR-teknologi, andP 21517 - Molekylära mikrobiella analysmetoder i livsmedelskedjan

Whatever the process of transfer, the transfer is naturally regarded as very important, perhaps more so for some than for others. In one dairy firm, Skånemejerier, the projects with universities were deemed particularly important, as the firm had no research department itself, and is too small to set up the different projects by themselves. The firm therefore relied extensively on these collaborations with universities. Pointing to the specific projects within the VINNOVA program, the firm believed these to be very important, as they had exposed them to new knowledge in areas of interest for current and future development of functional food products. The projects have lifted the knowledge generally as knowledge of the area was fairly new, as well as specifically about the relation between bacteria, fermentation and nutritional uptake.

We would like to finish this section by returning to the issue of two-way arrows in our model. The transfer of knowledge and technology not only took place from university to industry, but also the other way around. The researchers involved in a product development, for example, expressed that they learnt about the practical aspects of the product development process, concerning, for example, what problems that can arise in the scale up of processes, and how long time it sometimes takes. This, together with lessons on how to translate theory into practice was deemed important for future project work.

6.1.5 New networks

There are about one fifth of the projects that report on either new research networks or firm networks as results of the projects. Most of these new networks pertain to new research networks, although the interviews suggest that some more company networks were created than actually reported. Still, fairly few new networks came out as a result of the projects and one explanation to this may be that many projects do not start nor end with the VINNOVA funding.

In many instances, the projects that received funding built on prior projects funded either by VINNOVA or other funders. As already stated elsewhere, this is hardly surprising as "you rarely apply for money for something which you don't know at all or have been into before".

As a consequence of the importance of previous competencies, many of the project constellations also have a long history. As one illustration, even though a project between SIK and Karlshamns in the first program involved a new constellation, SIK had worked together with Karlshamns for years prior to the first program, and so has Skånemejerier with a research unit at Lund University. Moreover, even in those cases where a project forms new constellations of companies and universities or institutes, this needs not necessarily lead to the formation of new networks and continued collaboration.

Sometimes, whether or not networks were formed may relate to the stage and the nature of the project. For example, in two different projects that involved companies from different parts of the supply chain, one led to continued collaboration between the producer and the supplier, whereas the other project did not. The former project, however, also resulted in a new product line, which encouraged further interaction, while the latter project had not yet reached the stage of product development. This contention is further supported by comments from the interviews that “when you don’t have a project with common resources, you don’t keep much contact, unless you have a personal contact, or try to keep someone attached to your department through, for example, an unsalaried associate professorship”.

In the projects that did create new networks, these networks were regarded as useful by industry. One project of particular interest in this regard involved several dairy firms for hygiene issues. Although these firms were competitors, one result of the project was a lasting network among the participating firms as well as to other contacts of the institute leading the project. The reason this worked out so well was that although the companies were competitors product-wise, the project focused on hygiene issues that was a problem common to all companies. “If one dairy company gets problems with hygiene, it does not only hit that company but all dairy firms collectively”. The network thus proved very useful to exchange knowledge, also after the project ended, and has resulted in that the dairy firm has got to know how to investigate different problems and how they can work with hygiene in production.

These network linkages took different firms. Stated benefits to firms included information flow, similar to the above example but also in other fields. In the field of DNA analysis, the benefits are clear because “while we are many different actors, we all work with the same basic technology and face the same basic challenges, so by creating connections among us we can speed up the progress of our field”. The Innovative food program also resulted in that one university actor, KI, came to be involved in the food area as financed by VINNOVA, thereby creating new relations with industry. Finally, at least a few projects also report on new or better connections between research groups within the Swedish food research system, taken broadly

While there are only a few projects that report on new international networks, the projects may still have led to more such networks although indirectly. Several of the interviews at the project level showed that they formed part of, or run alongside larger projects funded by EU or Nordic organizations. Hence, it is possible that international relations reside more at the level of the research environment. This could also, together with the relatively small funding of many projects, explain the limited international presence reported in the projects within the program.

Finally, while projects may not always create networks that are maintained and used on a frequent basis, they do result in connections across the sectoral system of innovation that make it easier to get into contact with people. These connections may not lead to new project collaborations, but are still useful in other ways. “We don’t use the connections we make to primarily call researchers for consultation on specific problems. But if we have a research question that we need feedback on, we know where to turn to, and we can also use these connections to get a hold of right people in, for example, advisory board functions”. The projects thus provide benefits in terms of network creation on different levels, firstly in terms of that they may lead on to concrete new collaborations, secondly in terms of that they increase the connectivity among the community members.

Now we turn to the other issue, namely what has changed in the industrial context during the last decades.

6.1.6 The industrial context: Regulation, market, and global ownership

The effects of public policy depend to a large extent upon the industrial context. Hence, the preceding analysis of direct effects from the perspective of industry must be understood within the broader trends. The reason for introducing the industrial context is that the structural characteristics of the food industry have been fairly dramatically changed, during the last couple of decades when these public policy initiatives were running. We feel that the industrial context is necessary to understand, as it relates to competencies and incentives of actors to be involved within Swedish-based sectoral system of innovation, as well as global ones of the sector. Three relevant changes in the context are therefore discussed below, namely an increased rationalization of the industry, a change in ownership structure, and an increase of exports.

The first structural characteristic which is changing is rationalization and decreasing employment in Sweden. The rationalization of the food industry has been on-going, partly driven by the new competitive environment resulting from the EU membership. The regulations of the Swedish food industry prior to the EU membership in 1995 effectively protected much of the food industry from international pressure. A McKinsey report pointed out that this lack of strong competitive pressure was the most important factor for poor productivity levels in the Swedish food industry, at that time.

According to the report (McKinsey 1995 in SOU 1997b), the productivity levels of the Swedish food industry in 1990 were about 60 percent of the American food industries and similar figures can be found in government reports, with about 75 percent of the Danish food industry's productivity levels (SOU 1997a, 1997b). Instead of the lack of competition, a different reason given in the government inquiry relates to the geographical context of short growing season, harsh climate and similar aspects. Hence, another reason for the need for efficiency lies with natural cost-disadvantages that characterize many parts of the Swedish food industry, as well as inputs from the agricultural industry. The Swedish dairy production, for example, has natural cost-disadvantages in relation to production in the majority of other producing countries. The short season leads to higher costs of production and the industry must continue to rationalize and improve efficiency in order to be competitive (SOU 1997a, 1997b). Similarly, strong regulation to protect animal welfare leads to higher costs than in countries with lower standards of animal welfare protection. Hence, the trend towards higher efficiency and more rationalization has been going on for many decades, but Sweden remains relatively expensive. The governmental inquiry noted that the food sector has been characterized by a continuous rationalization, increase in efficiency, centralization, and the building up of a large structure in all parts of production. Moreover, the broadening market of the EU in agriculture and food accentuated this national need for more rationalization and further increased efficiency.[112] Primarily, the need for increased efficiency was in those sectors that were not exposed to international competition earlier, and that also did not have the opportunities to, in contrast to their competitors in the EU, to develop on a large market (SOU 1997a).

These processes of rationalization can be seen in the number of employees within the food industry. The trend is a decreasing number of employees, decade per decade. In 1985 the Swedish food industry employed over 70 000 persons, by 1995 it employed about 66 0000 persons, a number that had decreased to 59 000 persons ten years later, and further decreased to 56 000 persons in 2007 (as available at www.scb.se). Reduction in employment primarily concerns the abattoir- and charcuterie-industries, the bakery, dairy and brewery industries.

The prediction of the Swedish Food Federation (*Livsmedelsföretagen*) is that this trend of reducing employment will likely continue (Li 2008). The reason is that companies likely need to continue increase efficiency in response to continued pressures on companies' profitability. Increasing

[112] Of course, another aspect of EU is regulation and support to the agricultural industry, but we are here focused upon the food industry.

salaries and quickly rising costs for raw material has generally put much pressure on the profitability of companies. Other reasons for this need to further rationalize production is that grocery chains and shops have put a strong focus on price during several years, and that the pace of developing new products has also increased, which incurs additional costs during R&D (Li 2008).

The second structural characteristic which is changing is the ownership structure of companies based and/or active in Sweden. One can view these changes as two phases, which have occurred during the past decades, where many companies first consolidated their national base, as a sort of national champion and then became increasingly internationalized.[113] In the 1980s there was a strong trend towards conglomerates in many parts of the Swedish economy, with the conglomerates holding companies in diverse sectors, including many of the food companies. Towards the end of the 1980s and into the 1990s, there was a push towards specialization, and hence a move away from conglomerates. For example Volvo sold Procordia Food to the Norwegian company Orkla in 1995. Since then, it has been rare that the Swedish food companies are part of conglomerates also producing engineering and other industrial products (SOU 1997a).

More recently – but also a trend running over many decades – the ownership of Swedish food companies has become increasingly international. In 1986, foreign companies accounted for about 14 percent of the employment. Ten years later in 1996, that share had doubled, foreign companies now accounting for nearly 28 percent of the employment, and by 2006 38 percent of all employees in the food industry worked in a foreign-owned company. The corresponding number for the Swedish industry at large is 35 percent. Note that this increase occurred at the same time that employment as a whole was reduced. We can also see that the foreign-owned companies' share of production value and export has continuously increased. By 2006, foreign-owned companies accounted for about 35 percent of the processing value, and represented about 45 percent of the exports of the food industry (Li 2008).[114]

During 2007, moreover, large changes continued, and so the share in foreign-owned companies in the food industry should have increased to about 45 percent. The primary reason is that many acquisitions occurred, including the Finnish purchase of Swedish Meats, the Norwegian purchase of Frödinge, the Swiss purchase of Semper, and the Danish purchase of Ugglarps. During these decades, many companies which are strongly

[113] See also McKelvey 2005
[114] See also ITPS 2007 for figures over the period 2003-2004.

associated as ‘Swedish’ have been totally or partially acquired by foreign owners, with a few prominent examples being Arla (dairy), and Absolut Vodka (spirits). This internationalization of ownership has also raised some concern among trade organizations regarding the long-term effects on the food industry in Sweden – especially, when it comes to situations where the head offices and several key functions, not least R&D, are relocated outside Sweden (Li 2008).

The third structural characteristic which is changing is the exports, and hence the relative importance of the domestic market as compared to exports. Probably as related to the first and second structural characteristic, since the EU entrance and opening of these markets, Sweden as a national economy has proved successful in terms of exports of processed food. At the EU entrance in 1995, the import of foods was about 3 times the size of export. In 2007 imports were about twice the size of exports, even though the trade deficit increased somewhat during 2007 to SEK 35 billion (Li 2007). The food export in 2007 was of a fourfold increase compared to the entrance into the EU.

During the period 1996-2007 the export increased with on average 11 percent per annum, compared to the 6 percent increase for the total industry exports. Important success factors behind the exports, according to the Swedish Food Federation, are higher processing, fast product development, and new products that often create niche markets. Another plus factor is the user-friendly, logistics- and mall-adapted packages (Li 2008). A significant share of imports consists of raw material and goods that are requirements for exports of consumer foods (Li 2008). While domestic competition increased with the EU membership, many companies also managed to make use of the new market opportunities, and thereby increased their production and exports. Hence, exports have become more important, and many reasons may be given, including actors’ competencies in specific areas of technology of relevance to competitiveness in this industry.

6.2 Medical technology

This section considers the effects of public medtech research initiatives on industry. In the first section, we describe the development of the medtech industry in Sweden over time and make comments on the importance of academic research. This description provides a background against which we in the following sections focus on the large, established firms and how they have interacted with and been affected by the medtech research. Next we present and comment some results from a previous study regarding effects of research programs on production, sales and employment in industry. We conclude with a short discussion on some effects that the university-industry interaction has had on the innovation system.

6.2.1 Development of the medtech industry over time

In Chapter 4 we presented an overview of the Swedish medtech industry as it looks like today. Here, the development of the industry over the past twenty years (i.e., since around 1987 when the first of our focal programs started) will be described, mainly building on various secondary sources. Available data does not allow a detailed analysis in quantitative terms, but we will at least be able to catch and discuss some important changes that have taken place during this period, and which are of relevance to the present effect analysis.

The medtech industry is usually described as science-driven. It is also true that historically the emergence and growth of the global medtech industry is to a large extent founded on scientific advances emanating from research at universities and university hospitals. Some of the basic technologies and innovations that today's medtech industry is based upon began to develop several decades ago and could be described as relatively mature already in the 1990s (e.g., X-ray, fiber optics, defibrillators, dialysis, ultrasound, laser and computers). Certainly, there has been a continuing technological development that has led to major improvements in product performance in these areas. The academic research has in many cases contributed to improve the technologies and develop applications as well as to bring forward completely new technologies – being integrated with the old ones or used separately (e.g., digital imaging, virtual reality, nano-technology). Therefore, in the very long term it is reasonable to assume that the industrial development is affected by developments in the public research sector – providing new knowledge, inventions and other key resources that can be used by companies in their R&D activities. How the industry has evolved in aggregate terms, since the late 1980s, is thus of relevance to our effect analysis. However, the industrial development over a specific period of time is affected by many other factors – including, for example, business cycles, general business climate and industrial policy in the country as well as strategic decisions taken by firms (note that several key medtech companies in Sweden belong to multinational groups, where the parent company and the headquarters can be located either in Sweden or abroad). Therefore, it is very difficult to measure, at the aggregate level, how the realized development of the Swedish medtech industry has been affected by science in general and, not least, the research efforts made by VINNOVA, its predecessors and other financiers. Nonetheless, the observed development presented below can give some hints on the effects of research. In the following sections in this chapter we will analyze more closely how the companies have collaborated with medtech research environments and what effects that have come out of these interactions.

VINNOVA's cluster study (VINNOVA 2007c) referred to in Chapter 4 describes how the employment in the life science industry, including the medtech sector, has developed over the ten-year period 1997-2006. Among the different sectors, medical technology has shown the highest growth rate, namely 80 percent expansion.[115] The industry grew rapidly from 1997 to 2003 (from approximately 7,000 employees to more than 12,000, not including disability aids). Since then the employment has slightly declined indicating stagnation in the industry, at least in terms of employment. Among those segments that have grown fastest, one finds Medical disposables, Anaesthetic/Respiratory equipment, Active and non-active implantable devices and Diagnostics. Electromechanical and imaging equipment, one of the largest segments, has not shown any increase at all during the ten-year period. Probably, this can partly be explained by the disappearance of Siemens as a key player in the Swedish medtech industry (see case description below).

Despite some uncertainty regarding VINNOVA's estimation of the employment in 1997, the numbers arrived at are pretty much consistent with a previous study (Laage-Hellman 1998). This study showed that the medtech industry – if we (like VINNOVA) exclude disability aids and do not count SCA Incontinence Care – employed more than 6,350 people (to be compared with 7000).[116]

The above-mentioned study (ibid.) tried to estimate the growth of the Swedish medtech industry from 1988 to 1996 (i.e., the first half of the 20-year period covered by this study). There is however no figure available for the total industry employment in Sweden in 1988. But the study nonetheless gives a rough picture of what happened in the industry during that period. It was concluded that several of the large firms – like Gambro, Getinge and SCA – had expanded internationally (partly through acquisitions of foreign firms) but did not increase their employment in Sweden. Another of the large firms, Siemens-Elema, had started to reduce its business activities in Sweden (e.g. by selling its pacemaker division to St. Jude Medical in 1994). The main growth of the medtech industry in this period instead came from a group of small or medium-sized companies. This includes equipment and

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[115] See the original source (VINNOVA, 2007c, p. 25-26) for a discussion on the methodology, which motivates a cautious interpretation of the numbers (due to uncertainty for the period 1997-2003).

[116] The 1996-figure is primarily based on firms with more than 50 employees and thus does not take into account a large number of small firms. This means that it underestimates the total employment in the industry.

systems manufacturers such as Althin Medical, Elekta and Synectics Medical, and the following producers of various disposables (in a broad sense): Astra Tech, Atos Medical, BOC Ohmeda, HemoCue, Nobel Biocare and Radi Medical Systems. Interestingly, most of these firms base their core business on innovations with origin in the Swedish academic research (not seldom partly funded by STU or Nutek). This illustrates the historical importance of the academic research (irrespective of who is funding it) for the long-term development of this industry. It can be added that several of the mentioned firms – such as Astra Tech, Elekta, HemoCue and Nobel Biocare – have continued to grow rapidly in the subsequent ten-year period and by so doing have made important contributions to the growth of the entire industry. We can thus conclude that the development of the medtech industry in a certain period of time is strongly affected by public as well as private R&D investments made several decades earlier. Hence, this illustrates the long lead-times typically characterizing innovation and industrial development processes in this business (and supports our conclusion in Chapter 5 that start-up companies play a key role for the long-term growth of the medtech industry).

Regarding the sub-field of disability aids, the 1998 study concluded that the growth rate had been modest and that fast-growing firms were lacking. There were many firms, but most of them were small. It can be noted that since then Getinge, through its subsidiary Arjo (acquired in 1995), has established itself as a major player in the field.

As a complement to this attempt to describe the development of the industry in quantitative terms (employment), we would like to add some other comments on important changes and trends in the medtech industry. One of the more dramatic changes is Siemens' dismantling of its medtech operations in Sweden.

Case: Siemens

> In the 1980s and early 1990s, Siemens-Elema was one of the largest medtech firms in Sweden with more than 2,000 employees. The company had a long history in Sweden and had successfully commercialized on the world market several important technological inventions with roots in Swedish universities and hospitals (such as the pacemaker, the servo ventilator and the electronically controlled ink jet printer just to mention a few examples). The company had four divisions: Pacemakers, X-ray equipment, Electrocardiography and Life Support Systems. The first step meaning a major reduction of the company's industrial activities in Sweden was the selling of the Pacemaker Division to St. Jude Medical in 1994. The

background was a strategic decision by Siemens AG to not be involved at all in implantable devices. Given scandals related to breast implants, severely affecting the US manufacturer Dow Corning, the group management in Germany considered the risk for possible future damages to the Siemens brand to be too high. Other events that may have contributed to Siemens' decision to divest was, firstly, Siemens-Elema's delay in developing certain new pacemaker technology, which forced the company to buy this kind of technology from a competitor and, secondly, the loss of a patent litigation with another competitor. The Pacemaker Division had for many years been a profitable business for Siemens-Elema, and it has continued to thrive under the new ownership of St. Jude Medical.

Thanks to its historical innovativeness, profitable business and strong local management Siemens-Elema had for many years had a strong position within the Siemens Group. Among other things, this has led to several new technologies being transferred from corporate labs in Germany to Siemens-Elema for product development and commercialization. One example is an implantable drug delivery pump for diabetes therapy which became a major R&D project run over a long period of time. However, due to the selling of the Pacemaker Division Siemens-Elema lost an important cash-cow and prestige product. This affected the financial performance negatively. There were some other events that further contributed to weaken the power and freedom of the company within the Group. The launching of a new anesthesia apparatus, in which large R&D resources had been invested, failed and there were quality problems with some X-ray equipment sold in the US market. The company got German management which resulted in some cultural clashes.

The X-Ray Division became the next one to disappear. Around 2000, Siemens had received state subsidies to build a new plant in the eastern part of Germany, and in order to fill up the plant a large part of the production of X-ray equipment was moved from Sweden. Other parts were moved to another plant in Spain.

During the same period, the Electrocardiography Division was also divested (with the exception of a major R&D project on heart catheterization). ECG equipment had become a commodity and the business was characterized by intensive price competition and small margins. It was not considered an attractive business to be in. Instead of investing in Siemens-

Elema, which at the time had old technology, Siemens decided to outsource the production to OEM suppliers.

The fourth division, making anesthesia and ventilation systems, was a few years later sold to the Getinge Group, which in 2000 had acquired the German medtech company Maquet. Siemens' Life Support Systems business became a division within Maquet called Critical Care.

The previously mentioned heart catheterization project became the last piece of the old Siemens-Elema to disappear. This development project, which had employed 20-30 people, was in 2007 moved to the US and to India.

In summary, these developments (from 1994-2007) has resulted in the total disappearance of a major medtech firm in Sweden – a company that historically has played an important role for commercialization of Swedish medtech inventions.[117] Two divisions have been moved out of the country, while two others have been taken over by other companies, which continue to operate in Sweden. Both of these businesses seem to be doing well. St. Jude Medical has today more than 700 employees in Sweden (which can be compared to 400 in 1996). Maquet Critical Care employs some 350 people in Sweden.

As the case shows, the background to these major changes in Siemens is partly related to internal events and developments in the company. But to some extent the changes reflect some important trends in the industry. During the period in question the development of the medtech industry was characterized by increasing globalization and substantial structural changes expressed in the form of consolidation activities and numerous mergers and acquisitions. For example, mature businesses have been merged in order to take advantage of scale economies. At the same time, it is not unusual that established medtech firms have grown in new technological areas by acquiring smaller companies. Given the global character of the industry, this is something that has taken place on the international arena, and still does.

Besides Siemens-Elema, there are other medtech companies in Sweden that have been affected by these trends. Scanditronix, founded already in 1965, was a classical Swedish medtech company involved in commercializing technologies and inventions from Swedish universities and research institutes. It had promising products both for diagnostics and therapy. The

[117] Siemens has remained as a supplier of medtech products to the Swedish market through its sales subsidiary.

diagnostic business, focusing on PET (positron-emission-tomography) was in a two-step process sold to General Electric in 1990 and 1992. A part of the business (tracer systems) has remained in Sweden under the name GEMS PET Systems. In 1998, the remaining Scanditronix (with some 100 employees) was sold to the Belgian radiotherapy company IBA. The acquired Swedish company is now called IBA Dosimetry and has 25 employees. Two subsidiaries have been spun-off by selling them to present or previous managers. Other examples of small Swedish medtech firms that have been acquired by foreign companies during the last twenty years are Breas Medical, Carmeda, Diaphon Development, Entific Medical Systems, Guidor, Helax, HemoCue, Olmed, Resound and Synectics Medical. In some cases, the acquired business has been transferred abroad (directly or in a step-wise manner), but in other cases it has remained in Sweden. One example of the latter is Cochlear Nordic (previously Entific Medical Systems, originally a spin-off from Nobel Biocare). Cochlear, the parent company in Australia, is now investing in its Swedish subsidiary and promotes closer links with Swedish universities.

At the same time as several small Swedish medtech firms have been bought by foreign corporations, some of the larger ones have, the other way around, acquired foreign companies. Gambro for some time expanded aggressively by making foreign acquisitions. More recently it has entered a concentration phase, where it is focusing on its traditional core business, renal products, and the US-based blood-handling business. The latter is considered to be a growth area. In both of these fields Gambro is considering to make “bolt-on acquisitions” to gain access to new complementary technologies and products. In fact, acquisitions and in-licensing of new technologies have become an important element of Gambro’s growth strategy. In 2005, some thirty companies around the world were being evaluated (*Affärsvärlden* 2005).

Getinge has been very active buying up foreign as well as Swedish medtech firms – thereby establishing itself as one of the two largest medtech firms in Sweden, measured in terms of total turnover (the other one is Gambro). Elekta has also made several foreign acquisitions. Besides incorporating Philips’ division for radiation therapy it has also bought several smaller companies.

Interestingly Sandvik, which for a long time has manufactured materials for medtech products (e.g. orthopedic implants), is now investing in the field and has acquired a UK biomaterials company.

These structural changes have their origin in global industry trends. The medtech industry – in order to cope with environmental challenges such as increasing demand for system solutions, tougher regulations and demanding market acceptance processes – has thus been undergoing consolidation through numerous mergers and acquisitions, some of which have concerned Swedish companies as we have exemplified. In the short term there is not much public policy can do about that. In the longer term, however, it is obvious that Sweden's research and innovation policy will influence how the global trends affect the medtech industry. For example, by helping to create a strong research base in disciplines that are important for the development of medtech products, policy-makers such as VINNOVA can improve the prerequisites for positive outcomes of the structural changes. In combination with other aspects of the business climate, this would increase the incentives for established firms, whether they belong to Swedish or foreign groups, to invest in and develop their businesses in Sweden. This is not a unique idea, of course. In recent years, several organizations have come up with proposals for how to strengthen the medtech industry, where increasing public investments in academic research is one of the cornerstones (see Focus Medtech Agenda 2005; Action MedTech 2007; and MTF 2007).

The Swedish Society for Medical Engineering and Medical Physics (MTF) is one of the organizations that point to the need for renewal of the medtech industry – given its present structure with dominance of mature companies. According to MTF's proposal for a national research strategy the medtech research in Sweden should supply the industry with new competencies that enable firms to take advantage of new scientific advances and by product development contribute to the ongoing paradigmatic shift towards more distributed healthcare.

6.2.2 Effects on established firms

In the preceding chapter we distinguished two principal routes for commercializing results from university research, namely, through collaboration with established firms and through formation of new start-up companies. As to the former mode the following main forms of research collaboration can be distinguished:

- Participation in academic research projects, which are financed mainly by the universities themselves and/or through external grants.
- Contract research
- Industry PhD students
- Informal contacts and exchanges

In the first case, the company participates in a research project where the operative work is carried out mainly by the academic researchers, but with more or less active support of the company. An important role for the company is to bring in knowledge about the market, customer needs and manufacturing prerequisites, but it may also contribute scientifically (and this may lead to co-publishing of scientific papers). In addition to the public funding through the university and/or external grants the company may contribute financially both in cash and in kind (e.g. by paying salaries for own researchers who work on the project or by supplying materials or instruments). It can also be that the company finances doctoral students at the department. The mixing of in cash and in kind contributions is common, for example, in the former competence centers (and in the current VinnExcellence Centers).[118] Projects may be bilateral or multilateral. There may be different kinds of agreements regulating the ownership of patents and other intellectual properties (IP) coming out of the project.[119]

Contract research means that, in principal, all costs are covered by the company, which also retains all IP rights. Typically, the objective of the project is to solve certain technical problems identified by the company.

A special form of collaboration, also formalized, is when companies send Industry PhD students to work at the university, usually on a part-time basis. The research topic is usually related to the company's needs and it is expected that the results will be useful to the company in some way or another.

Besides these formalized modes of collaboration, there may be informal contacts and collaborations (e.g. information exchange, performance of mutual services and borrowing of resources).

Companies may draw on the universities' resources also in other ways, such as by in-licensing of existing IP rights, buying consulting services, or using researchers as scientific board members or speakers at internal or external events.

Survey

We have acquired valuable data about the university-industry collaboration through our personal interviews with research leaders and company representatives (see Appendix 2 for a list of interview persons). As a complement to this data and in order to get a broader picture of the

[118] In NIMED, e.g., the industrial partners accounted for 35% of the total funding out of which 40% came in cash.
[119] A special case is when a company sponsors a research project without involving itself in the execution of the project. In return for its financial contributions the company usually has an agreement with the researchers giving it the right of first refusal, in case there are results with commercial potential.

interaction patterns we have conducted standardized telephone interviews with the largest established firms. The main issues dealt with were[120]:

- The extent and importance of collaboration with clinical and medtech research environments
- Forms of collaboration
- Effects of collaboration
- Changes in collaboration patterns
- Cooperation with and acquisition of start-up companies

Eighteen companies were covered by the survey, carried out normally through telephone interviews, but in some cases through personal interviews. One company requested to remain anonymous. The other seventeen companies are: Attends Healthcare, Becton Dickinson, Elekta, Gambro, Getinge Infection Control, ArjoHuntleigh (Getinge Group), Maquet Critical Care (Getinge Group), HemoCue, Mölnlycke Health Care/Wound care Division, Mölnlycke Health Care/Surgical Division, Nobel Biocare, PhaDia, Q-Med, SCA Incontinence Care, Sectra, Siemens-Elema, and St. Jude Medical. For two of the corporate groups with diverse business activities (Getinge and Mölnlycke Health Care) the interviews were carried out at the business area level.

The companies were selected starting with VINNOVA's cluster study, where we chose to focus on firms with more than 250 employees in Sweden. Some firms on VINNOVA's list were excluded for various reasons: Kronans Droghandel since it is mainly a distribution company and Promech Lab which is mainly a manufacturing firm. Fresenius Kabi and Octapharma were excluded since they are more like pharmaceutical firms (this is also how they describe themselves). We intended to include Cederroth International in the study, but we did not succeed to arrange an interview with this company.

We also added a few companies. Elekta has less than 250 employees in Sweden but has large international operations, and must be regarded as an important medtech firm in Sweden. Sectra also has less than 250 employees in Sweden. But it is a publicly listed and successful medtech company where we for other reasons did a personal interview. Siemens-Elema does not exist any longer, but during a large part of the period covered by our study Siemens-Elema was one of the biggest medtech firms in Sweden. Data has been collected by interviewing two previous employees, both of whom have had senior management positions in the company.

[120] The complete interview guide (in Swedish) is reported in Appendix 4.

The importance of university collaboration

In the survey we have asked the companies to what extent they have collaborated with academic researchers (during the last twenty-year period) and how important this collaboration has been for the company's development – technologically and commercially. The answers are shown in Figures 6.1 and 6.2. We can distinguish two types of university collaboration. One is collaboration with medtech researchers, that is, the type of academic partner that this study focuses on. We see that such collaboration has been very common and that it is generally attributed high importance. In what sense the collaboration has been important to the established firms will be discussed in more detail later on.

Figure 6.1. The extent to which the companies have had R&D collaboration with academic research units

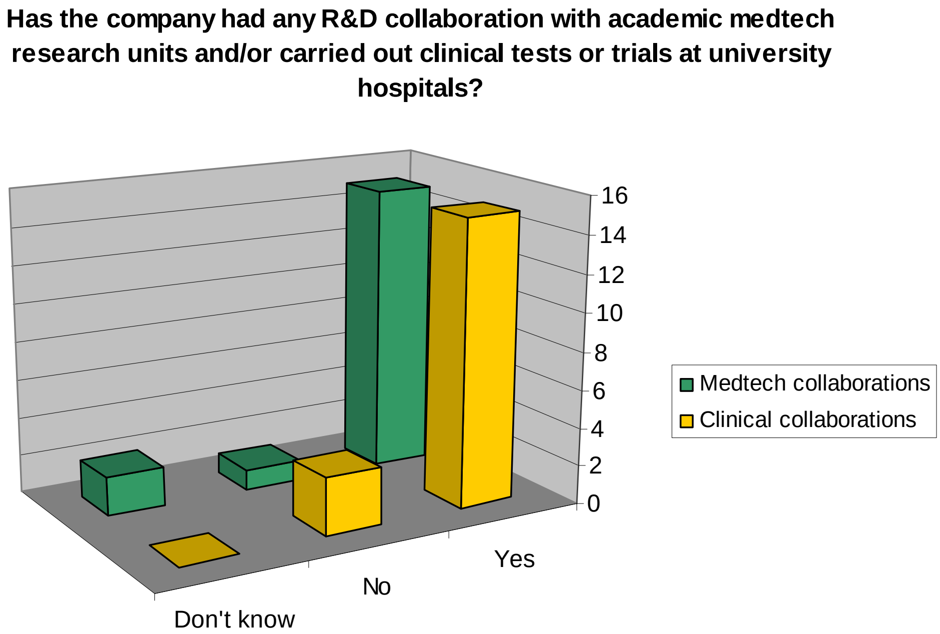
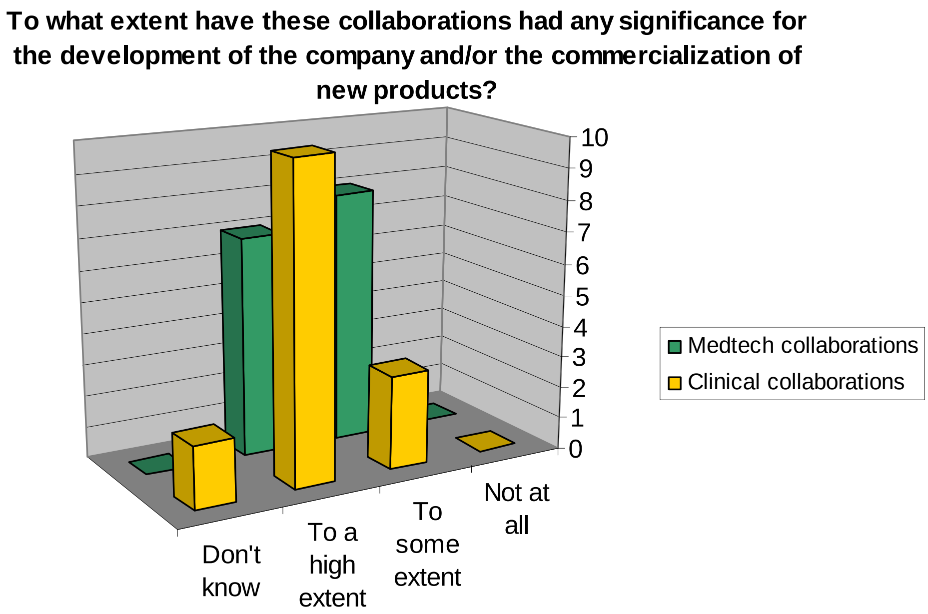


Figure 6.2. The extent to which the academic R&D collaboration has been important for the company's development



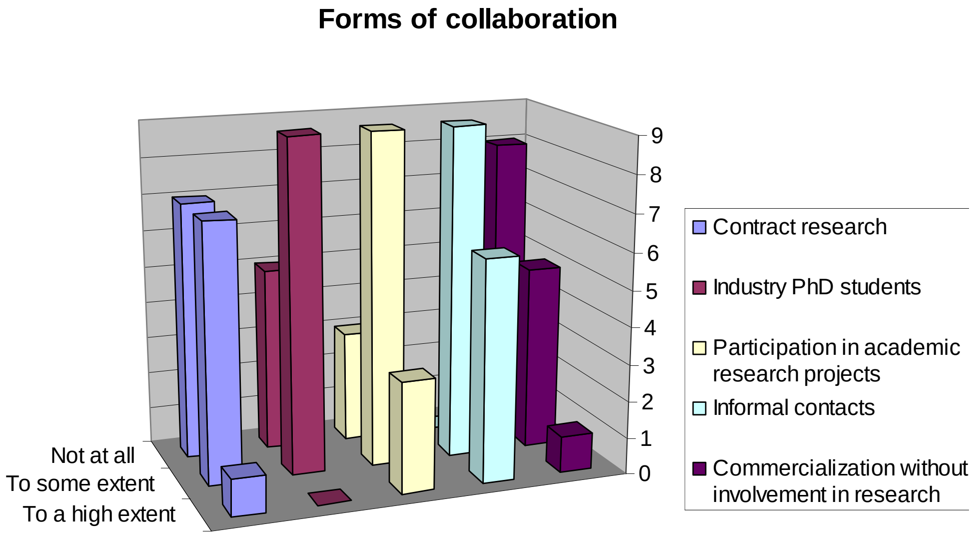
We have also asked about the companies' collaboration with university hospitals regarding clinical research and testing. As expected this is also very common. As we can see this type of collaboration has been even more important for the companies' development than the medtech collaboration. This is not really surprising since this survey is targeting firms that have been well established in the markets for many years. It is well-known that clinical testing in different places is crucial for the development and market introduction of new medtech products. The clinicians are not only scientists but also current or future customers/users, and they can provide important information about the use of the product. However, this type of collaboration is outside the scope of this study, since it takes place with other research environments than those that we are primarily interested in here. But we will come back with a short comment on this issue at the end of this chapter.

Three companies have answered that they have not had any collaboration at all with medtech research environments. One of them is a mechanical engineering firm which manufactures a relatively mature product sold to hospitals (and to some other types of customers). The two other firms produce the same type of medtech consumables. We know from another study that one of these firms has had a great deal of collaboration with a university of technology. However, these academic researchers work in other technical fields (e.g. chemistry).

Figure 6.3 shows to what extent the companies have used different types of collaboration forms. Generally, informal contacts are quite important.

Participation in academic research projects is of particular interest for the present effect analysis. A majority of companies have been involved in such projects but usually only to some extent. Some have not at all taken part in such projects. Only three companies have participated to a high extent. There are no obvious similarities among these three firms that distinguish them from the others.

Figure 6.3. Forms of collaboration



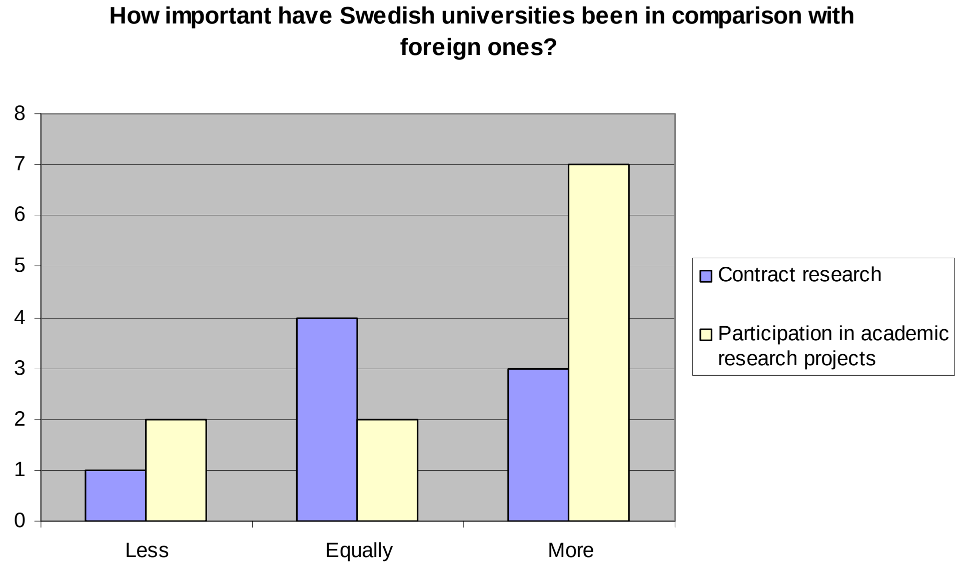
Industry PhD students are another common form of collaboration, but the extent is limited. No company has used it extensively. Normally, we are talking about a few individuals over a relatively long period of time. But the interviewee from one company, which is historically a university spin-off, says that this is the most important form of collaboration for his company. By taking part in the university's own research the PhD student can acquire new knowledge and bring it back to the company.

Using medtech researchers as a resource for contract research is not so common. About half of the companies do not contract out research at all, while one half do it to some extent. Only one company answers that it assigns contract research to a high extent. Swedish and foreign research environments are equally important to this firm, and all the other forms of collaboration are used only to some extent. Another company says that the high overhead costs charged by Swedish universities make it more attractive to carry out contract research abroad.

If we look at how important Swedish partners are relative to foreign ones, we find that for participation in academic research projects the Swedish partners are generally more important than their foreign counterparts (Figure

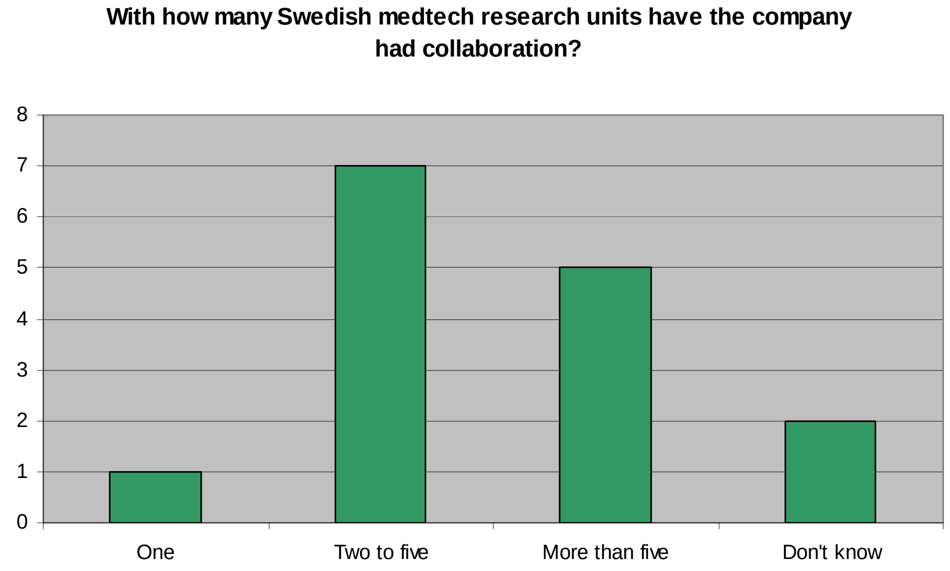
6.4). When it comes to contract research, the data shows that the importance is more equally distributed among Swedish and foreign contractors.

Figure 6.4. The importance of Swedish versus foreign partners



Regarding the number of Swedish partners with which the companies have had collaboration we see in Figure 6.5 that the majority of firms have answered 2-5 partners. But there are also those that have had more than five partners.

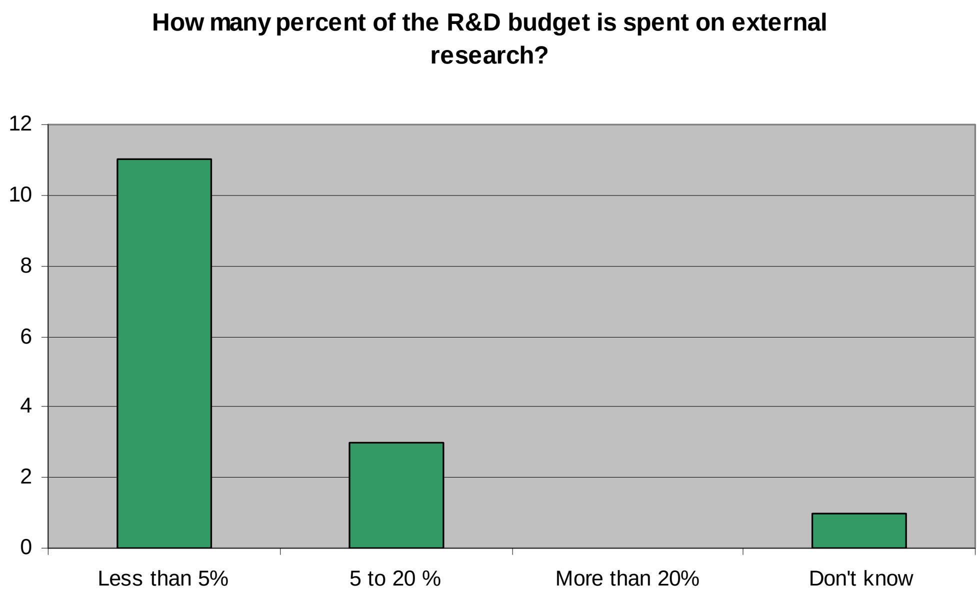
Figure 6.5. Number of collaboration partners



We have also asked the companies to what extent they have commercialized academic research results without having been involved in the research itself. They may for example have bought patents. As Figure 6.3 shows the majority of firms have not done that at all. But there are a few companies that have done it to some extent. This indicates that commercialization of research results by the established industry normally requires that the firms are involved in the research in some way.

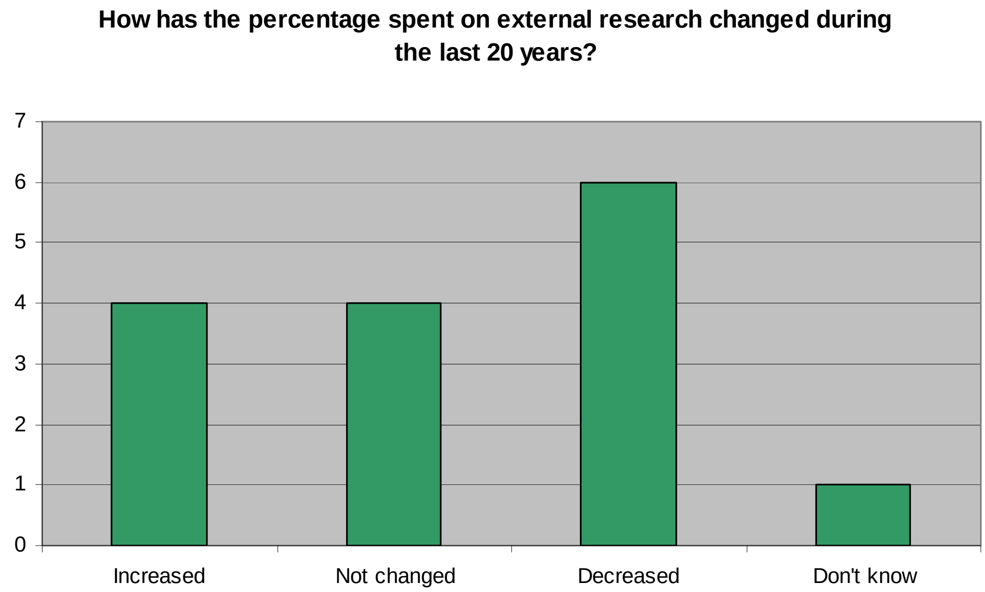
If we look at how many percent of the R&D budget that firms have spent on external research, we see in Figure 6.6 that most firms have spent less than 5 percent (this includes contract research as well as research grants). But there are in our sample three companies that have spent 5-20 percent. One of them has participated in academic research projects to a high extent. This company has had long-lasting collaboration with several medtech research groups in Sweden, and is today also involved in close collaboration with foreign universities. One of the other companies, which is producing a somewhat less R&D-intensive product, has not at all participated in academic research. But instead it has spent a great deal of money on contract research. As concluded above this is rare strategy.

Figure 6.6. Percentage of R&D budget spent on external research



When we asked the companies how the allocation of the R&D budget has changed over the past twenty years, we got mixed answers (Figure 6.7). While some companies spend more money on external research today some others spend less. The pattern of variation can be more complex than so, though. As one company explained, its involvement in one of the competence centers, for a period of ten years, meant that the percentage increased during that period. Now, the center has been winded up and as a consequence the company is spending less on external research.

Figure 6.7. Changes in external research expenditures over time



The effects of university collaboration

We can distinguish a number of possible effects that university collaboration (irrespective of form) can have on established firms:

- Solution to technical problem that the firm has encountered in its own R&D
- Access to research-based inventions/ideas that the company can commercialize (i.e. in the form of new products, processes or services)
- Access to new knowledge and competencies that can be used in the firm's own R&D
- Changes in the company's research direction (e.g. start of new R&D projects)
- Better knowledge about trends in science and technology
- Recruitment of highly skilled R&D personnel (at the licentiate or PhD level or similar)
- Establishment of contacts/collaboration with other academic research groups in Sweden or abroad
- Establishment of contacts/collaboration with other companies
- Improved image

The answers that we have obtained are reported in Figures 6.8 and 6.9. An interesting result is that commercialization of research findings, in the form of new products, does not seem to have been very important for these companies. However, this is fully in line with what we concluded in Chapter 5, namely, that the collaboration between Swedish medtech research environments and the established (mainly large) firms was not as frequent and extensive as might have been expected. In particular, in terms of *commercialization of inventions or product ideas* we must conclude that the *direct* effects of medtech research on the established firms have in general been relatively small – at least in the perspective of the total turnover of these firms and the presumed commercial potential of the research supported by STU/Nutek/VINNOVA (and other financiers). Instead, it seems that formation of start-up companies has become the main route for commercializing inventions from the academic research. This does not mean, however, that the established industry is not affected by the commercialization. This issue will be elaborated later on in this chapter.

Figure 6.8. Effects of collaboration (part 1)

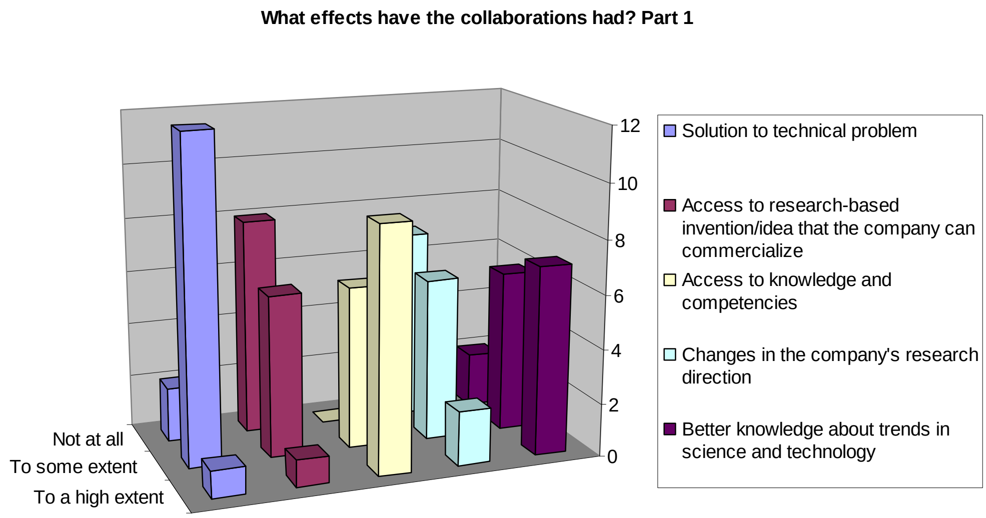
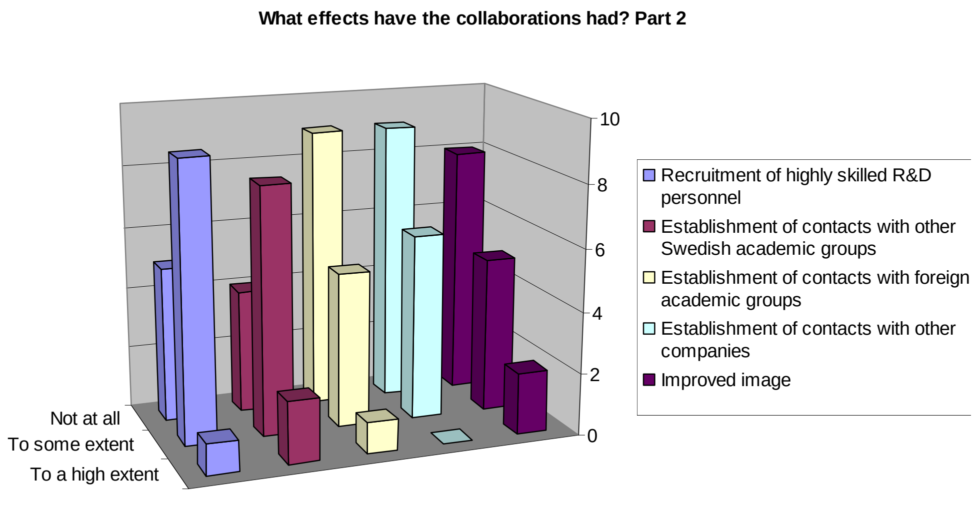


Figure 6.9. Effects of collaboration (part 2)



But first it should be observed that according to our data the established firms have obtained other important benefits from their collaboration with medtech research environments. Above all, they have been able to gain access to new knowledge and competencies, which they have used as valuable inputs to the R&D process. A majority of the firms say that this type of effect has taken place to a high extent. This proves that the collaboration, for example within the frame of academic projects, can bring major advantages to firms, even when it does not result in concrete products which can be traced back to specific research results. Another important effect of the collaboration is that it can help the companies to monitor scientific and technological trends. Obviously, this opportunity has been appreciated by many firms (Figure 6.8).

These results from the survey are strongly supported by the data that we have obtained by interviewing research leaders as well as company representatives. As several interviewees have pointed out, the main effect of medtech research on industry has witnessed a major shift over time. A few decades ago, it was common that medtech researchers developed new instruments or devices that could be taken over by a company and brought to the market.[121] This type of event has become less common nowadays. There may be several reasons for this development. One is that the large medtech firms have in many cases become suppliers of large, complex systems consisting of various hardware and software components and sub-systems. These are often sourced from sub-contractors. If an academic research project, for example, brings about an invention that is potentially useful as a component or module the systems manufacturer may prefer to buy it from some company. Hence, the importance of start-ups as a mechanism for commercializing university research. We will come back to this important topic.

Figure 6.9 shows that there are some other types of effect that are not crucial to the firms, but nonetheless occur to some extent. We can see that quite a number of firms have taken advantage of the collaboration by recruiting skilled R&D personnel. We have come across several examples where PhD students involved in a joint project with a company has been employed by the latter after graduation. Of course, this is also an effective means for transferring knowledge from the university to industry. Although there are exceptions, what the companies appreciate most is often not the specific results of the graduate's research but the deep competence he or she has acquired within a certain technological field.

[121] As mentioned previously many of today's leading medtech firms are based on inventions that have their origin in academic research.

It seems that the industry has not been drawing to a large extent on the research partners' own networks (Figure 6.9). But for some companies collaboration has resulted in the establishment of contacts with other academic groups in Sweden. In most cases, though, this has happened only to some extent. We know from other data sources that contacts and collaboration with clinicians at university hospitals are important to firms. If a medtech research partner is linked up with clinical environments, where new ideas/products can be tested and evaluated, this is an advantage for the company and increases the value of the collaboration. Hence, it can be assumed that the multi-disciplinary research centers, integrating technical and medical research, that have been created in recent years or are being set up now have positive effects on the companies. It increases the incentives to be involved in medtech research and the probability that the results will be commercially applicable. One example is CMIV (Center for Medical Image Science and Visualization) in Linköping, which is actively supported by Sectra, one of the founders. Sectra appreciates the inter-disciplinary approach very much, since it enhances the industrial relevance of the research.[122]

When it comes to contacts with foreign academic groups and with other firms (Figure 6.9), it seems that the collaboration has had marginal importance in general. It can be commented that one of the ideas with the competence centers is to bring companies together. However, these centers do not seem to have been an efficient means for increasing collaboration among firms. For example, most research projects are bilateral. And even though a fruitful and open discussion takes place among company representatives at board or steering group meetings, this does not mean that collaboration is established at the firm level.

Generally speaking, the collaboration with medtech research environments in Sweden has not affected the companies' image (Figure 6.9). But there are a few exceptions. In one of these cases, the company has had a long-standing and close collaboration with one academic research unit, which undoubtedly has an internationally leading position in its field.

Changes in collaboration patterns

As we can see in Figure 6.10, there is a tendency that the amount of collaboration with medtech researchers has increased over the past twenty years. But, as commented above regarding R&D money spent on external

[122] The CMIV case also illustrates other effects. By being involved in the center – e.g. though Industry PhD students and workshop participation – Sectra acquires new competencies that can be used in the internal product development. CMIV is also a valuable channel for monitoring the environment and mapping trends. In addition, CMIV has certain image-building effects – thanks to the high scientific standard of the research.

research, the extent of collaboration may go up and down for individual firms – for example due to periodical involvement in competence centers. Such variation also illustrates how the policy of STU/Nutek/VINNOVA, demanding industrial involvement in research centers, affects collaboration patterns. Furthermore, a majority of those companies that have answered that the extent of collaboration has increased say that this is an effect of STU/Nutek/VINNOVA's acting. Here follow a couple of comments made during the interviews:

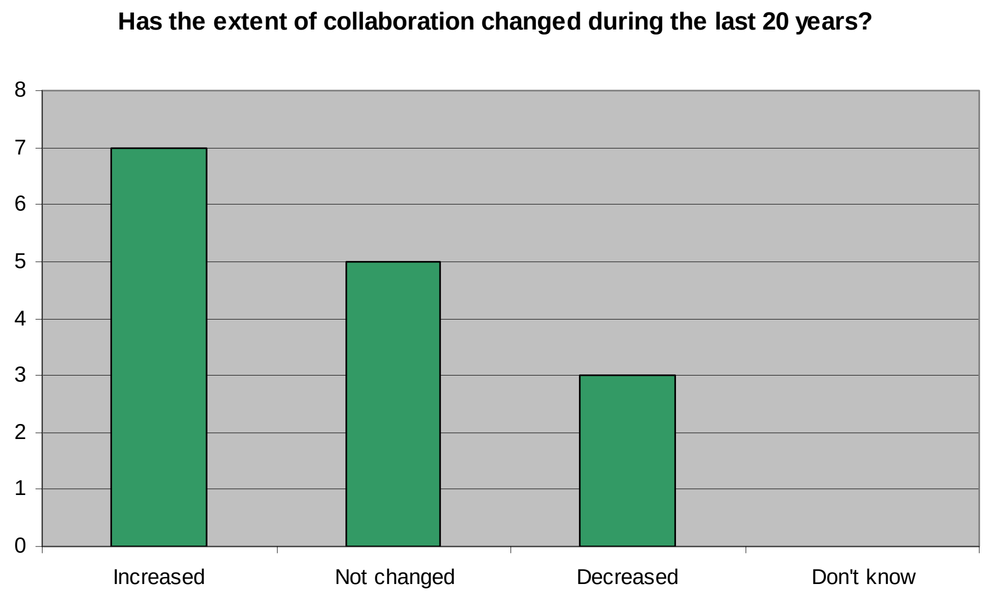
Interview person 1:

> *Previously, we could have more unconditional discussions with the researchers, which led to the formulation of joint projects. Now we feel that the researchers sometimes contact us only because they need financing.*

Interview person 2:

> *In the past, the researchers had more time to have open-minded and creative discussions with the company. Now we have to pay for the researchers' time. The academy is putting higher demands on services in return.*

Figure 6.10. Changes in collaboration patterns



Our data thus indicates that the amount of industry involvement in research has increased to some extent as a result of STU/Nutek/VINNOVA's policy to demand industrial co-funding. Another effect is that this has led to increasing formalization of the collaboration, which at least some companies regret.

It should be emphasized that in this study we have not been able to address this issue in detail. It seems that more research would be needed in order to gain a deeper understanding of the university-industry relationship and how it is affected by policy.

For the majority of companies the geographical proximity of research partners is regarded to be important (Figure 6.11). As commented by several interviewees, personal and informal meetings are important and easier to arrange when the partner is located close by. The saving of costs and time is another advantage. However, the responses indicate that there is a tendency that the geographical proximity has become somewhat less important over time – e.g. due to the use of modern communication technologies and less expensive traveling.

Figure 6.11. Importance of geographical proximity

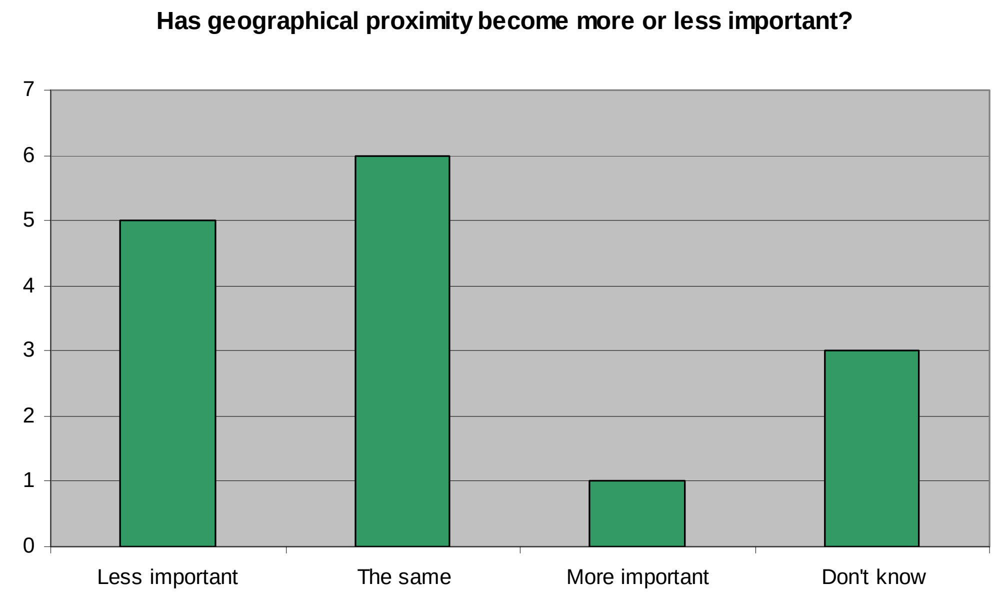
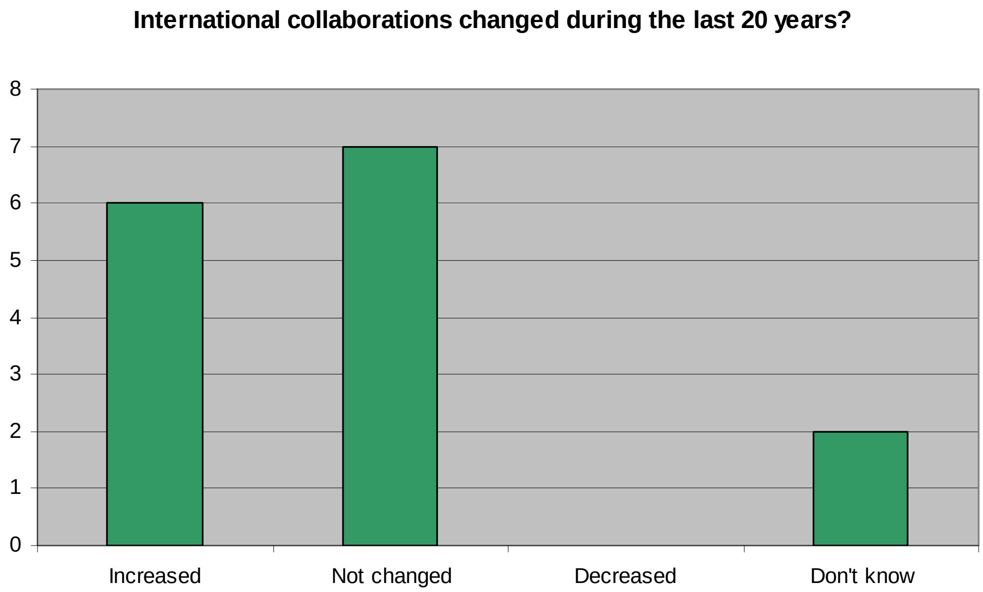


Figure 6.12 shows, as one could have expected, that the share of international collaboration has increased over the past twenty years. Many of the companies in the study have become more internationalized during this period – in terms of sales, manufacturing and R&D. For these firms it is natural to widen the perspective and open up for research collaboration with foreign universities. We know that this has been done to a large extent with regard to clinical testing (for marketing purposes). But obviously, it has also become more common to have medtech collaborations abroad.

Figure 6.12. Share of international research collaboration



Another aspect of the collaboration pattern is the number of participating firms. Our interview data shows that company involvement tends to take place mainly through *bilateral* projects (i.e. with only one company). Especially in the context of competence centers, this is counter to the intentions of STU/Nutek/VINNOVA, which wanted to see more multilateral projects where several companies worked together. At NIMED, for example, attempts were made to create such projects, thereby responding to the demands from Nutek/VINNOVA. But it became difficult to get the firms to unite on common goals. Therefore, in reality the joint projects that were started became more educational in character, rather than research.[123] This pattern reflects the tendency of companies to work on projects that are close to their own needs to develop existing product lines. In addition, involving several companies in one project, even if they are not direct competitors, is perceived to be complicated, for example, regarding IP issues. One company manager says: "Unlike the researchers, the firms do not want to have multilateral projects. Writing an agreement for two parties is complicated enough."

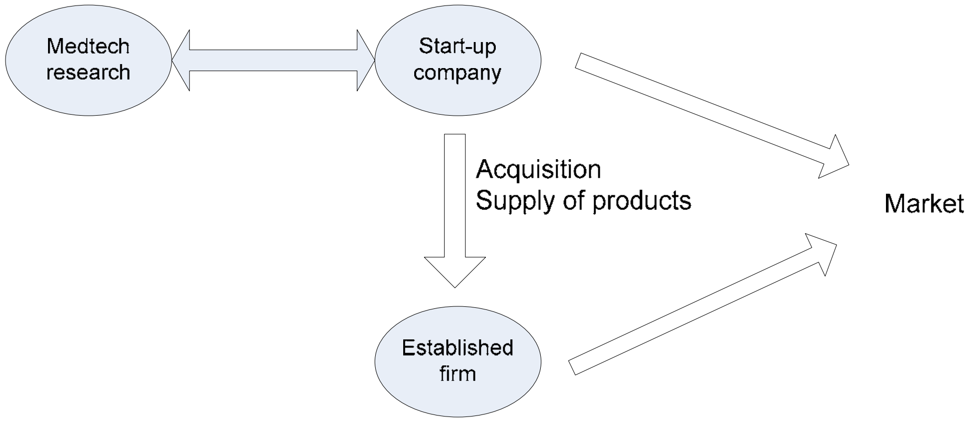
Indirect effects of commercialization

We have concluded that commercialization of research results in the form of new products has taken place mainly through start-up of new companies. These firms have usually maintained close relationships with the research

[123] The chairman of NIMED comments that the dominance of "one-company projects" differed from patterns in other (non-medtech) centers. For example, in the forestry area it was easier to find companies that shared the same interest. This difference probably reflects the fact that the medtech industry is very heterogeneous.

environments from which they have spun off. This observed pattern does not imply that the large firms have not been affected at all by the commercialization. In fact, they may benefit indirectly in at least two different ways (see Figure 6.13).

Figure 6.13. effects of commercialization on the established firms



First, the start-up companies may be future acquisition objects. If such a company succeeds to transform research results into a commercially useful and marketable product, it might be of interest for some established firm to buy this company and integrate it in its own organization. This can be a powerful way to gain access to new (research-based) technologies. The large medtech firms often sell complete system solutions (such as for radiation therapy, dialysis treatment, radiological examination or implantation of medical devices). The hardware or software products developed by the start-ups can be used, for example, as new components, modules or auxiliary products that contribute to broaden or renew the product offer of the established firm. Given the global character of the medtech business, this type of deal often takes place on the international arena. Thus, while Elekta, a leading supplier of equipment for radiation therapy and radio surgery, has for example bought several small companies abroad to gain access to complementary technologies and products, the Swedish start-up company Helax, which had developed an innovative treatment planning system, was acquired first by a Canadian firm and then sold to a Dutch manufacturer of radio therapy products.

There are many other examples of Swedish start-up companies that once they have reached the market place have been acquired by large firms. This includes the following international examples:

Start-up firm	Acquired by
Carmeda (bioactive surfaces)	Norsk Hydro (Norway)
Breas Medical (ventilators)	Vital Signs (USA)[124]
Diaphon Medical (hearing aids)	3M (USA)
Entific Medical Systems (hearing aids)	Cochlear (Australia)
Guidor (dentistry)	(Japan)
Helax (software)	MDS Nordion[125]
HemoCue (diagnostics)	Mallincrodt Medical (USA)[126]
Medidoc (informatics)	CPC (Norway)
Radi Medical Systems (diagnostic equipment)	St. Jude Medical (USA)
Scanditronix (PET)	General Electric (USA)
Scanditronix (radio therapy)	IBA (Belgium)
Synectics Medical (diagnostic equipment)	Medtronic (USA)

There are also examples of domestic acquisitions, but they are not so numerous. Here we find Ortivus-Svensk Telemedicin, Sectra-Mamea Imaging and Perimed-Lisca. It can be noted that all of the three buyers in these cases were initially university spin-offs themselves.

One may ask the question if it is good or bad when a Swedish university spin-off is acquired by a foreign firm. There is no simple answer, and the experiences are mixed. It depends on what happens to the company after the deal, and here we can observe different developments. There are several cases where all or most of the industrial activities have disappeared from the country (e.g. Diaphon Medical, Scanditronix/PET, and Synectics Medical). In other words, the innovation has been lost from a Swedish point of view (if we disregard the payments for the acquired companies). At the same time, there are other cases where the foreign owner has instead chosen to invest in the Swedish company. HemoCue and Cochlear Nordic (previously Entific Medical Systems) are two start-up companies which have continued to grow in Sweden after the acquisition.[127]

There is a second type of indirect effects of commercialization on established firms (Figure 6.13). As an alternative to acquire start-up firms the large companies may choose to use them as independent suppliers of products. They will not get exclusive right to the new technology, but instead the supplying firm may be able to exploit scale advantages and thereby reduce the costs for product development and manufacturing – something that the customers can benefit from. Let us take RaySearch as an

[124] In October 2008, Vital Signs was acquired by GE Healthcare.
[125] Helax is now owned by Nucletron in the Netherlands.
[126] HemoCue is now owned by Quest Diagnostics in the USA.
[127] See Laage-Hellman (1993, Ch. 8) and Laage-Hellman (1998, p. 43-45, 83-86) for discussions on international mergers and acquisitions in the Swedish biomedical industry.

example. This company is a spin-off from Karolinska Institutet's Research Center for Radiation Therapy and has developed unique software for treatment planning of IMRT (Intensity Modulated Radiation Therapy). Sales takes place through five partner companies, which are established manufacturers of radio therapy equipment. None of these firms is Swedish.[128] Another example is Ldiamon, a spin-off from the NIMED competence center in Linköping. This company has developed sensors for non-invasive regulation of haemodialysis. The product can be used to upgrade existing dialysis machines by adding new functionality. Ldiamon, which is based in Estonia, has now distribution contracts with several internationally leading machine suppliers.

Talking about indirect effects of medtech research on the established industry, it should not be forgotten that education and training is probably the most important type of effect. As we saw in Section 5.3, the research funded by STU/Nutek/VINNOVA among others has contributed to raise the quality of education at different levels. Needless to say, the availability of competent and well-trained biomedical engineers is of immense value to the companies and a prerequisite for maintaining competitiveness in the Swedish operations. Furthermore, as we have also seen, a fairly large number of PhDs graduated from medtech research environments have been recruited by industry, and most of them probably work with R&D.

Concluding comment

Despite the importance attributed to collaboration with medtech research environments, the overall impression – supported by our interviews with research leaders – is that the involvement of the established industry in medtech research has not been as extensive as one might have expected – given the applied nature of much research and the presumed commercialization opportunities. As discussed in the preceding chapter many of the academic researchers themselves have experienced difficulties to build close and long-term ties with established companies – and therefore chosen other ways to commercialize the findings.

If we look closer at how the large medtech companies function, we can understand better why many of them are not more actively participating in the academic research. Even if we go back to the 1990s, many of the products supplied by these firms can be characterized as relatively mature, despite being technologically complex. In many cases, the basic

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[128] Interestingly, Elekta, which participated in the KI center, is not a partner to RaySearch. One possible reason may be that the radiotherapy business area is not headquartered in Sweden but in the UK. The people who represented Elekta in the center came from the Swedish organization.

technologies and product concepts had been developed in the 1950s, 60s or 70s. The market tends to be characterized by fierce competition and low profit margins (especially in the diagnostic field). Most of the large firms focus on developing their current product lines and cutting costs in order to defend market shares and remain competitive. This means that these firms tend to be rather short-sighted and focused on incremental change (rather than radical innovation). They may be interested in university collaboration if the projects, for example, lead to technical solutions that can be integrated in the ongoing product development. Even if there are exceptions, of course, the firms are reluctant to invest resources in longer-term academic projects with uncertain outcomes. If the new technology is of potential interest for future product development the firm may prefer to wait until the technology has proven its commercial viability and been brought to the market by someone else, for example, a start-up company (see our discussion on indirect effects above).

Moreover, some of the very large firms have had their own central research laboratories, which have made them less dependent on external sourcing from universities. Siemens is one example. Siemens-Elema in Sweden had for many years access to corporate research facilities both in Europe and the USA. In several cases, new technologies were brought in from these centers for further product development in Sweden.

The availability of public co-funding of joint research projects is of course an incentive for involvement in academic research. Thus, if the own resources can be leveraged with public money companies can be induced to engage in more long-term and risky collaborative projects. We can see that in the competence centers. But the experiences show, as was commented already in Chapter 5, that when the public funding ends, it is difficult to get the participating companies to continue making cash contributions. This indicates that in many cases the research projects have not been crucial for the firms' development, given the relatively short time perspective of the firms. This does not mean, however, that the firms regard the research to be of low quality or commercially irrelevant. It is rather a question about how to allocate available (usually scarce) resources among different types of R&D activities (e.g. short-term vs. long-term).

In a previous Nutek study of the medtech industry in Sweden, carried out already fifteen years ago, it was concluded that the willingness and ability of the established firms to commercialize research-based product ideas and inventions were limited (Laage-Hellman, 1993, p. 32-39). Thus, these findings are very similar to the picture that has emerged in the present study. Several of the largest firms, such as Gambro, Siemens-Elema and Mölnlycke, said that they rarely managed to commercialize product ideas coming from the universities. They got many proposals from researchers but most of them did not fit in. In other cases where collaborative projects were started the commercial outcome was often disappointing. For Gambro, for example, the main problem was usually not to make a useful product, but it was rather market-related – that is, the existing sales organization was unable to sell the new product (ibid. p. 32).

6.2.3 A comment on clinical research collaboration

It was concluded previously that for the established companies R&D collaboration with clinical research environments at university hospitals is regarded as even more important than collaboration with medtech researchers. The following comment pertains to the role of medtech researchers in connecting industry with clinicians.

The large medtech firms are highly internationalized and this type of collaboration therefore occurs globally. That is, most clinical partners are situated abroad (and have been so for a long period of time). Thus, these firms are not dependent on collaboration with Swedish research environments. But still, due to the geographical proximity it goes without saying that access to domestic clinical partners can be advantageous, especially for products where the development takes place in Sweden. The current efforts to strengthen the clinically-oriented research in Sweden, which has experienced a long period of decline, should therefore have positive effects on the established medtech industry.

For the small research-based companies, typically involved in commercializing new medtech methods, access to clinical partners in Sweden is of utmost importance especially at the early stage of the companies' development – since they often lack the resources needed to establish and carry our clinical research in other countries. Many of today's large firms (e.g. Elekta, Nobel Biocare, St. Jude Medical and Gambro) are based on Swedish innovations developed jointly by clinical and engineering researchers. These historical examples illustrate that the emergence and growth of new medtech firms is dependent not only on good engineering research but also on the availability of clinical partners which are open to industry collaboration and have capability to carry out high-quality studies. Finding solutions to the current problems with clinical research and re-establishing Sweden as an international leader in this field will thus have positive effects on the future growth possibilities in the medtech industry.

We have previously emphasized the importance of linking the medtech research to clinical environments, in order to direct the technical research towards real clinical needs. Not least, this is important from a commercialization point of view. We have mentioned examples where companies participating in competence centers have asked for closer links with the clinical side. The more recent initiatives to form different types of centers where technical and clinical research is integrated within one organizational unit can thus be expected to have positive effects on the commercialization possibilities. In particular, the small start-up companies should be able to benefit from these interdisciplinary collaborative arrangements.[129]

6.2.4 Effects on production, sales and employment

Increased production and sales (with associated employment consequences) is one of the assumed long-term effects of public research investments. Since it is methodologically very difficult to measure these effects this is not a selected key issue for the present study. However, we concluded above – against the background of how the medtech industry had developed over time – that in the very long run the public research is likely to have affected the industrial growth that has taken place in Sweden, for example, through the creation and development of new research-based companies. Without these research efforts, made several decades ago, the growth of the medtech industry would probably have been significantly lower.

To shred further light on this issue, we will in this section present some data from a previous study (Nutek 1996c). This is an evaluation of STU/Nutek's medtech efforts from 1987 to 1996. The authors made an attempt to estimate the effects on sales and employment for five programs run during this ten-year period. The results are summarized in Table 6.3.

Table 6.3. Quantitative effects on sales and employment (forecast for 2000)

Program	Sales MSEK/year	Employment No. of people	No. of firms
Biomedical measurement technology and Minimal invasive medical technology	800-1,600	200-400	11
MediBild	180-370	90-180	11-12
Biocompatible materials and Biocompatibility	520-780	270-410	>12
Total	1,500-2,750	560-990	>35

Source: Nutek (1996)

According to the estimations, which according to the authors are impaired by a high degree of uncertainty, the total effects of these five programs amount to approximately BSEK 2.1 in annual sales and 800 jobs according to forecasts for 2000. For all programs the largest effects, both in terms of

[129] A discussion on clinical evaluation and its importance for the commercialization of new research-based medtech products can be found in Laage-Hellman (1993, p. 70-73).

sales and employment, have taken place in large internationally established firms (such as Siemens-Elema, Elekta, Gambro, Pacesetter/St. Jude Medical, Nobel Biocare and Pharmacia). The report concludes however that for these firms the importance of STU/Nutek's grants has been relatively small. The new products usually belong to established product lines and it can be assumed that these products would have been brought to the market also without public support of academic research. Furthermore, the employment effects mainly pertain to already existing jobs. That is, thanks to the new technology the companies' competitiveness has been secured. These comments thus indicate that the real effects of the research projects have been lower than those reported in the table.

For the smaller companies, where the estimated quantitative effects are relatively small (at least up till 2000), STU/Nutek's grants have been more important for the companies' development. Given the long lead-times for developing and commercializing research-based products in the medtech field, an interesting question is what has happened to these firms in the longer-term. We have not done a systematic follow up of how these companies have developed after the programs were ended. But it can be observed that several of the mentioned companies – such as Perimed, Radi Medical Systems, Sectra and Atos Medical –have developed relatively well during the past ten years. To what extent this can be attributed to the research efforts of STU and Nutek is difficult to say.

Here, we would like to repeat that these firms originally were research-based start-ups. They only exist thanks to public research carried out in earlier periods. The report mentions a few new companies that have spun-off from the investigated programs.[130] Thus, the role of STU/Nutek has been crucial for these firms, but the quantitative effects were still small at the time. Today, more than ten years later, none of these firms has grown to become medium-sized. We argue in this report, though, that formation of start-up companies is the main route for commercializing academic research results in the field of medical technology. But as these examples illustrate, the company-building process is not easy and is very time-consuming. But as some of the older examples show, there are such firms that have in fact managed to establish themselves in the world market and achieved sustainable growth.

6.2.5 Some effects on the innovation system

The medtech companies are parts of a nation-wide sectoral innovation system. The structure of such a system is commonly described in terms of

[130] These firms are Teltec, Lisca, Mezona, Helax, TMS, Camurus, Medicarb, and Metacot.

actors, networks and institutions (Bergek et al 2008). As discussed in the introductory chapter an interesting question is to what extent the STU/Nutek/VINNOVA-funded research, via the companies' R&D and other activities, has influenced the development of the innovation system. In terms of the *actor* dimension, as we have already seen, the public research efforts made during the past twenty years have resulted in an increasing number of start-up companies, which have now become vital parts of the innovation system. These companies tend to be R&D-intensive and involved in commercialization of new technologies and inventions, not seldom emanating from academic research. There is no doubt that the emergence of these firms has vitalized the innovation system and increased its innovation capability. It is true, however, that most of these firms are still relatively small. Even if they are innovative they have difficulties to establish themselves in the market and to start growing. Nonetheless, it is reasonable to assume that the increasing number of small R&D-based companies have had positive effects on the renewal capacity of the innovation system and the long-term growth potential of the medtech industry.

The innovation capability of the innovation system is also dependent on the *network* characteristics. The majority of the start-up companies can be characterized as university spin-offs. These firms tend to maintain close linkages to the parent research environments. The existence of these relationships, which can be more or less formalized, means that there is a continued flow of knowledge and other resources between the companies and the research units – usually going both ways. These relationships can be used, for example, as channels to bring new research findings to the market (in the form of improvements to the company's core product or development of new complementary products). It seems that in general these firms, which have their origin in academic research, are more inclined – compared to the large, established companies – to collaborate with the researchers.[131]

We have previously argued that the established industry can benefit from the universities' spin-off activities by interacting in various ways with the start-ups. However, our data from the telephone survey indicates that the large Swedish medtech companies have not done this to a large extent (Figures 6.14 and 6.15). There is not much collaboration, neither with Swedish nor with foreign start-ups – but there is a slight tendency that this type of collaboration has increased in importance. Thus, this type of

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[131] Note that too strong dependence on the parent may be a risk if it prevents the company from developing collaborative relationships with other research environments that can supply complementary technologies necessary for a successful commercialization.

network linkage seems to be missing in the innovation system. This can be seen as a weakness, if we assume that innovations can be brought about by combining the strengths of large firms and small start-ups. But more in-depth studies would be required in order to draw more reliable conclusions in this regard.

Figure 6.14. Collaboration between large medtech firms and start-ups

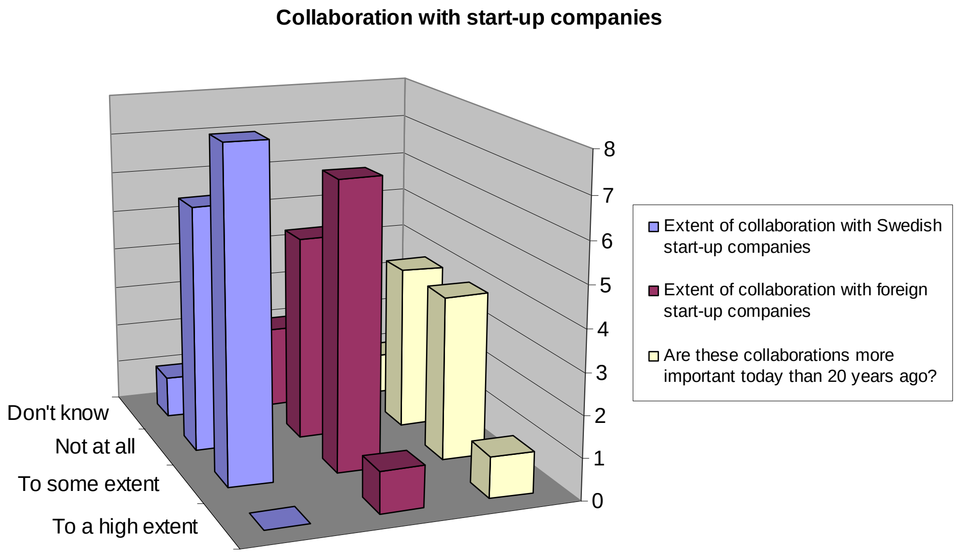
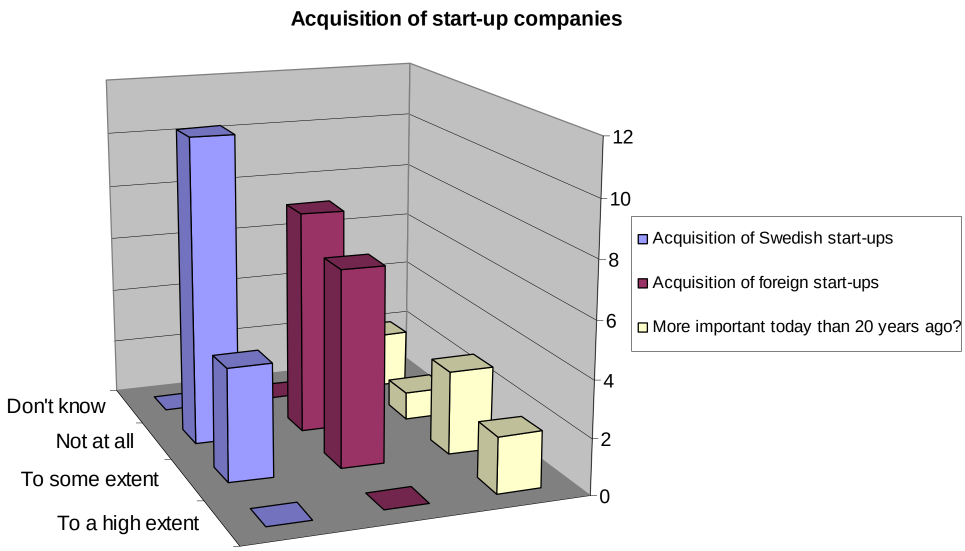


Figure 6.15. Large medtech firms' acquisitions of start-ups



As to what extent the large firms source products from the start-ups (without having technological collaboration with them), we do not have any information since there was no question on that issue. We know, however, that outsourcing of production is common in the medtech industry. Given the global character of the industry it can be assumed that many suppliers to the large firms are foreign. It would be interesting to know more about these firms' sourcing structure and the importance of start-up companies as suppliers.

Furthermore, as shown in Figure 6.15, the Swedish medtech companies have not been very active acquiring start-ups, particularly not in Sweden. Given the global character of the medtech business and Sweden being a small country, it is not surprising that foreign acquisitions are somewhat more common than the domestic ones.

7 Summary of key findings

7.1 Introduction

This chapter summarizes the empirical findings in terms of the key research issues identified in Chapter 2. We do that for the targeted two sub-fields, Innovative food and Medical technology. In relation to the objectives of this study we address the following two purposes as formulated in Chapter 1:

> Purpose 2: To analyze the large amount of empirical material which has been gathered about the targeted research projects in life sciences, i.e., the two targeted areas medical technology and innovative food
>
> Purpose 3: To identify and answer the key issues, in order to propose and analyze the empirical results in terms of the concepts and analytical framework of interest to the public policy debates.

7.2 Effects upon Research

In terms of effects upon research, we have primarily focused on the following key issues:

I. How has the research policy pursued by STU/Nutek/VINNOVA affected:

1 development of research environments over time?
2 education and training provided by the supported research environments?
3 academic results in terms of publications and patents?

II. How does the industrial collaboration benefit the research environment?

III. To what extent do the research environments engage in venture creation?

7.2.1 Innovative food

Development of research environments

The empirical analysis indicates that the cumulative development of academic competencies – including methods, theories, training and so on – have been important for understanding developments in these fields over a number of years. The Swedish research environments evolved during the period studied, although this report has had more focus upon specific projects and interactions with industry, as compared to the medical technology case that explicitly examines research environments. The food related projects are also more recent in time.

Most of the research funding has gone to existing research environments in the food area in the three geographical areas of Lund-Malmö (Lund University including Lund Institute of Technology, LTH; and the University Hospital MAS in Malmö), Gothenburg (SIK/Chalmers) and Stockholm-Uppsala (Uppsala University and the Swedish University of Agricultural Sciences, SLU). These research environments are likely the key Swedish academic actors with competencies in the areas, including project leaders with significant academic track-records. We do see that some actors like Karolinska Institutet (KI), which had not previously had VINNOVA funding, did enter into these projects, first as participants and then as project leaders. Hence, encouraging research related to the nutritional and medical effects of food did stimulate new linkages and actors as well as support research environments with competencies to develop and carry out the research.

We also see that the programs have stimulated interaction between the research environments although primarily within the specific regions. However, such interaction is also important to strengthen each region and one of VINNOVA's sub-goals with the Innovative food program was to stimulate interaction between, for example, the branch of SIK in Lund and Lund University/LTH. Given that several projects have run with members from both these organizations, VINNOVA appears to have succeeded with this aim.

Another aspect of collaboration is across industry and research. Whereas the projects in the Innovative food programs addressed the food area, it is interesting to note that important linkages and collaborations from the research projects were not necessarily confined to the food industry. This has implications for the future. Some of the basic challenges in the food area, for example in the analysis of DNA, are similar to key challenges faced by other research areas. Identifying and stimulating connections between such different actors could thus be one possible way for driving development further also in the food area.

Moreover, these research environments often had multiple sources of funding – at the same time or over a period of years. The project leaders have identified specific results and effects of the Nutek/VINNOVA funding in self-assessment reports and we have further examined these results through interviews. We have also found many cases of project leaders receiving funding from the other major additional financiers of research[132], which gives support to the idea that policy-makers need to consider the 'real projects' of the research environments rather than only evaluate the immediate impacts of one project.

The cumulative nature of grants and of being able to obtain the next grant, based upon the results of the previous projects, was identified as important. Several of the projects within these two programs were themselves the results of successful applications that built upon funding in previous STU/Nutek/VINNOVA programs or from other funders. The benefit of this accumulation of competencies – and ability to move between financiers – is that it allows the researchers to continue work on a particular research track. According to one interviewee "The greatest benefit [with the VINNOVA funding in several stages] has been that it allowed us to work in an unbroken chain until we received the larger grant for the Excellence-center. There actually was a gap in funding for three years but we managed to cover that by funding from SSF instead. This funding was furthermore more research-oriented so it enabled us to put more effort in developing methods. With the Excellence-funding we could then accelerate this". The econometric analysis of the relationship between funding and papers also suggested the importance of continuous funding.

Our analysis suggests that several projects managed to obtain further funding on the basis of the project results, in many cases with the same or a similar constellation as in the project funded within the VINNOVA initiatives studied here. This follows quite naturally from the progress of research, according to one interviewee, "That's what it's like, you have to take one step at a time. One thing builds on another … and the results from one project, although perhaps not strong, lead to new ideas and studies". In two cases, this continued funding was quite substantial as the projects partly laid the groundwork for successful applications to become Centers of Excellence. One addresses methods and techniques. The other, which has led to the Functional Food Science Center in south Sweden around Lund-Malmö (Nilsson et al 2002; Asheim and Coenen 2006), can be seen as a direct continuation of the aims of the Innovative food programs.

Given the Swedish science policy environment since the mid-1990s, most research environments rely upon external sources of funding (and not on fixed government funding). Hence these programs are important to stimulate and carry out the research projects studied here, and to make sure

[132] Additional financiers of research include research councils (Formas, VR), foundations (SSF, KK) and EU funding.

that Sweden has academic competencies to develop and innovate in the food industry.

Education and training

Education and training has been primarily analyzed in terms of the work done by PhD and Master students. About half of the projects report this as an important part and outcome of the project.

The involvement of Master thesis students in projects is interesting, especially in an industry with low internal R&D, and we therefore wish to point out some of the benefits of this system. Master theses in technical subjects are often done in close collaboration with the companies, which enables the students to obtain practical experience in applying their knowledge to company problems and also enables the companies to test and transfer ideas, at a low cost. As could be expected, the research environments also use the Master period in order to identify and choose potential candidates for PhD studies. These results are not unique to the food industry, but the overall results and the interviews and illustrative cases do indicate that these mechanisms are working in the food industry as well.

The analysis of labor mobility following one of the PhD programs – called LiFT – shows two interesting things. One is that 27 out of 47 PhD students later got jobs in the industry. Provided the overall low numbers of R&D employees with research education in the food industry (SCB 2006), it is encouraging that the majority of these (21 of 27) were hired by companies producing food or equipment for the food industry. This suggests that hiring PhDs is a strong mechanism for knowledge transfer and continuing linkages with academic research. Note, however, that in the interviews, the companies indicated that they did not hire the person to continue upon the same research project per se. Rather, they hired them for their competencies and needed them to apply their academic training to the specific development work and projects of the companies.

Another aspect is that at least nine of these PhD students have been involved in or part financed through projects in the two Innovative food programs. In addition to these projects, another 19 out of 55 analyzed projects report on the involvement or part financing of one or more PhD students. This suggests that VINNOVA plays an important role in stimulating the further build up of knowledge in the food industry through PhDs.

Academic results

The academic results were analyzed both in terms of specific results of the projects and in terms of the career publications and citations of the project leaders. In terms of self-reported evaluations, 45 of the 66 projects reported scientific publications and conference papers. Moreover, these project leaders are highly published and cited, indicating clear research strength in these fields. (Note, though, that the bibliometricians remind us that the results need to be normalized by discipline, if one wants to compare to publications and citations in other fields).

The econometric results also examined the relationship between the funding and publications, at the level of the project managers. The results indicate that funding plays an important role in publishing and has a positive effect. According to the figures presented in Chapter 5, if funding increases by 100 percent, that is if we double the funding, then we will get 1.56 more publications with a lag of two years. This supports the idea from above that accessing additional funding is crucial for the development (and survival) of the research environment, also in terms of academic outputs.

Patents were not, however, common from these projects. Three were self-reported (but two did not materialize) and only one could be identified in the KEINS database, which is a specialized database on academic inventors, based upon EPTO data. We also scanned for all patents held by the project leaders but did not find additional patents. We do not find this surprising, if we relate these results to other findings.

The research on the role of academic patents suggests that the frequency and likelihood of taking patents varies greatly by field. Lissoni et al (2008) also show that European academic inventors tend to patent as much as American ones, if you normalize and examine at the level of individual inventors (e.g. persons working at the universities and research institutes) and not at the level of ownership of patents by universities and research institutes. In Sweden, academic researchers own their patents (unless they assign), due to the professor's privilege. Hence, this is a methodological issue, related to who owns patents in different national institutional contexts. Based on that comparison, our hypotheses would be that: 1) This represents a field of science where few academic patents are taken and 2) The Swedish 'professor's privilege' does not explain the low number of patents identified. However, these are hypotheses, and should be tested.

Industrial collaboration

This report has discussed many different ways in which academic environments and industry have collaborated, as detailed in Chapters 5 and 6. The question in this chapter is more focused upon the benefits of industrial collaboration for the research environments.

The public initiatives studied were designed for direct collaborative research, but this could consist of many forms, from direct cash contributions to, more commonly, various forms of in-kind contributions (such as accounting for the time of the industrial researchers, use of instruments and equipment, and so on).

Clearly, in some projects, the companies also contributed biological material and specialized products, which made it possible to carry out the research and also for specific tests to be run. Without this input, the research could not have been performed, even in cases where the academic researcher was the one formulating the main issues and how to run the tests specifically. In some cases, the companies were also clear that publishing the scientific results as papers, also enabled them to demonstrate the positive results of their products, which of course later helped in sales. In this example, both partners benefit from the actual publication, but for different reasons.

In line with the results reported for medical technology, it should be noted that the development of research environments is not only about internal resources such as skilled staff and laboratory facilities. In our innovation systems approach, one important aspect of environment building is the establishment of collaborative networks both within academia and with industry. Such networks may constitute valuable assets that enhance the research capability. This aspect is discussed further below.

Venture Creation

There is not so much evidence of venture creation in the projects studied here, only two. One is a firm and one is a center later incorporated as a firm. The lack of venture creation does seem worrying, given that the overall trend is rationalized and cut employment in Sweden, alongside foreign ownership of medium-sized and large companies.

Still, venture creation plays a role in developing and diffusing knowledge in the innovation system. University spin-offs from previous projects, with examples such as Probi, CeBa, and BioGaia, are participant firms on several projects, and this suggests that these firms are often well situated to take advantage of academic research.

Still, there may be many reasons for this observed lack of venture creation. One reason could, for example, be that the projects are quite recent in time, and we know that there is quite a lag usually from idea to commercialization. In that case, developing a new company could be some years in the future. There may also be structural characteristics of the industry that make it difficult for start-ups to compete, such as economies of scale, costs of initial investment, and so on, but these characteristics should apply more to the food industry per se and less to the innovative food segment.

The spin-offs that we have identified, both from the present programs and spin-offs prior to the programs, are able to exist because they are based upon specific, specialized knowledge. They then apply that specialized knowledge to the problems faced by many other companies and regulators, as further discussed as intermediaries in the next section on innovative food.

7.2.2 Medical technology

Development of research environments

There is no doubt that the policy pursued by STU and Nutek in the 1980s and 90s had tremendous importance for the development of several research environments specializing in medical technology. The different programs started by STU in 1987 and run until the mid-1990s enabled research environments at several universities – in particular Linköping, Lund, Gothenburg, Uppsala and Chalmers – to expand and create strong research groups in several biomedical engineering fields. An important element in the development of these environments, actively supported by STU and Nutek, was the establishment of collaborative links with clinicians and with industry. The involvement of clinicians in medtech research is important both for the quality of the research and for making it clinically and industrially relevant. For most of the large research groups the clinical orientation established many years ago has prevailed and been further developed – more recently by creating formal structures for collaboration. We will comment on industry collaboration further down.

The policy changes in the mid-1990s affected the medtech research environments in different ways. For Linköping University and Karolinska Institutet the long-term funding of competence centers (NIMED and the Research Center for Radiation Therapy respectively) gave opportunities to continue expansion. For several other research environments it instead became more difficult to obtain grants from Nutek (and later on VINNOVA) for their medtech research. This forced them to start looking for other sources of financing. In most cases, however, they have succeeded to get funding especially from research councils, research foundations and the EU, and in a few cases also from industry. Today, compared to 10-15 years ago, the medtech research environments have in general a more varied financing situation, where they are not too dependent on single funders, such as VINNOVA. In that sense, despite periodical funding problems experienced by some research groups, one could argue that the policy of STU/Nutek/VINNOVA has been quite successful. It has helped to build up a range of strong research environments which can now successfully compete for research grants. Nonetheless, in order to strengthen the more applied and needs-driven research (compared to the more basic one), there is a widespread opinion within the medtech research community that larger grants from VINNOVA specifically targeting medical technology (rather than life science in general) would be desirable.

Education and training

Much of the research funded by the research programs and the competence centers have been carried out by PhD students and resulted in a fairly large number of doctoral theses in supported technology areas. These graduates have been important for developing the research environments themselves. There are many examples of new PhDs who have stayed at the department and founded their own research group. At the same time more than half of the new PhDs have gone to industry, and this includes large well-established firms as well as start-up companies. Thus, the STU/Nutek/VINNOVA efforts in the field of medical technology have contributed to raise the scientific competence level in the industry. How this in turn has affected the R&D activities in the firms do we know too little about. But there are good reasons to believe that there are positive effects. Recruited PhDs bring increased understanding of how academia functions and facilitate the establishment of fruitful collaboration. Historically, the medtech industry (unlike the pharmaceutical industry) has not been used to have PhDs employed, and from the academic researchers' point of view this lack of competence and understanding has made the contacts more difficult.

Academic results

The research carried out at the major medtech research environments has over the years resulted in a large number of scientific publications, many of which appear in high-ranking journals. The funding has come from different sources, but for many environments the grants from STU/Nutek/VINNOVA have been crucial, at least during certain periods. In the medtech field we have carried out only a limited bibliometric analysis focused on STU's and Nutek's biomaterials programs. It confirms the general picture we have obtained through interviews and ad hoc studies of publication lists. Without having done a more systematic analysis of the academic results we hypothesize that from a publication point of view the research efforts of STU/Nutek/VINNOVA have been quite successful. But to give a more complete and reliable answer a more thorough investigation would be required.

With regard to patenting, our analysis showed that the project leaders in the biomaterials programs had very few patents. We know however that there are other medtech researchers from other technology fields who have patented, in some cases extensively. Thus, a broader analysis than we have done in this study would be required in order to say something about the patenting patterns in medical technology.

Industrial collaboration

Given the applied nature of much medtech research, the major research environments have for a long time been interested in establishing collaboration with industry, for the purpose of commercializing research findings and bringing inventions into practical use in healthcare. A common experience, however, is that it has been rather difficult to get firms interested in collaboration and commercialization. There are of course some exceptions, but generally the established medtech companies have been very focused on developing their current product lines and tended to take a rather short-sighted perspective on R&D. This has limited their incentives and willingness to engage in commercializing results that do not fit well with their more immediate needs. Against that background, many of the researchers have drawn the conclusion that starting up new companies is often a better way for commercializing the research.

For some of the research programs and all competence centers co-funding from companies has been required. Thus, over the years a fairly large number of companies have been involved in research as industrial partners, usually on a bilateral basis. The activity level of the firms has varied. In some cases they have taken active part in performing the research and have contributed scientifically, often with co-publications as a result. But the more widespread experience, as it seems, is that the firms have not been so deeply involved in carrying out the research. But instead they have played an important role as providers of market related information. It can be, for example, information about customer needs and wishes, manufacturing costs and how to design the product in order to make it profitable. This has been important in order to make the projects more relevant to industrial and clinical needs.

The dominance of bilateral projects is something that is regretted by many researchers. There is a risk that such projects become too much directed at fulfilling the specific and short-term needs of the companies. From an academic point of view, multilateral projects which address broader scientific topics are often preferable. But even within the competence centers it has been difficult to form such projects, despite explicit wishes from the public financier. More recently, however, there are some examples from the new VinnExcellence centers showing that it is possible to formulate research projects where several companies participate and bring complementary competencies (one such example is BIOMATCELL, which focuses on biomaterials and cell therapy).

Contract research is almost always bilateral. In general, this form of industrial collaboration has not been so important for the medtech environments, but again there are some exceptions (e.g. the biomaterials research at the University of Gothenburg).

Venture creation

In line with the conclusion mentioned above, engaging in venture creation has become an important activity for many of the research environments. Given the difficulties to get the existing firms interested in exploiting research findings, the researchers have got incentives to start up new companies, with or without partners from the business world. This interest has also been spurred by the emergence of various publicly financed bridging organizations, which have the task to support commercialization of academic research and help starting up new companies ("university spin-offs").

As many of the academic founders have experienced, however, the exploitation of new research findings by building up new R&D-based companies is a very difficult and demanding task. Among those companies that have spun off from the large medtech research environments that we have studied very few have realized substantial growth. Most of them are still, sometimes after more than ten years, very small – both in terms of employment and turnover. Several have gone bankrupt. This illustrates the high risks associated with this type of research-based businesses and the long lead-times which are common for innovation processes in this field.

We conclude that in medical technology, despite the above mentioned challenges, the creation of new venture firms is an important mechanism for commercializing results from the academic research. One cannot rely on the existing firms' willingness to pick up new inventions and bring them to the market, unless these inventions are well aligned with current product development strategies.

From this perspective, the present building of university-linked support structures to help starting and developing new spin-off companies is positive. We believe, though, that there is a need for better and more systematic knowledge about how the development and growth of medtech start-up companies can be stimulated.

7.3 Effects upon Industry

In terms of effects upon industry, we have primarily focused on the following issues:

I. How has the research policy pursued by STU/Nutek/VINNOVA affected:

1 how and why existing industry interacts with research environments?

2 development of industrial applications (e.g. new products or production methods) based on results from the academic research?
3 development of competencies in technology, research and science?

II. Do academic spin-off companies from previous periods play a role as R&D intermediaries between the existing industry and universities?

III. What types of company account for growth in Sweden?

7.3.1 Innovative food

Interaction with academic research

The long list of companies and other organizations involved in these projects is quite impressive, and suggests that the Nutek/VINNOVA programs were successful in making sure that the needs of a wide-range of actors became known to the academic researchers.

The food industry as studied in this report is very interesting, in that it tends to have low R&D capabilities, but still, many medium-sized and large companies have been involved in the projects studied here. The ones whom interacted in the highest number of projects are Lantmännen (including subsidiaries) and also Arla and Orkla. Most companies and other organizations, however, are only active within one project. The companies involved in the projects are predominantly companies that produce for end-customers, but one finds companies from all stages of the value chain. Depending on the focus of the project, stakeholders such as public care-givers of the elderly are also involved.

Still, many questions could be explored in later research. For example, how are the demands of companies formulated at the project level in the needs-driven research? And whether and how do they match the internal research logic of a specific research environment? To take one example, the center-firm that was started in Uppsala was specifically designed to address the needs of firms (and other organizations) to conduct specific sorts of tests. These tests were not front-line scientific research, because they are more about applying a technique to specific problems of the firms. This illustrates the types of differences which could be identified between the ‘needs’ of firms and the ‘competencies and objectives’ of academic research. VINNOVA has been clear that ‘needs driven research’ should be in the middle of these two actors, but still, this conceptualization is so important and relevant that more detailed analysis could be done.

A related issue is the level and intensity of participation by companies, and it differs greatly. The type of involvement may range from monitoring developments done by the academic researchers, to providing specialized biological materials and products upon which tests can be conducted, to actively participating in collaborative research. In one illustrative case, we can see that the companies and organizations were interested in the results for purposes of monitoring and being able to respond to expected regulatory changes. In other cases, the companies are more directly involved. Two firms were each involved in 13 projects, and if we aggregate all the subsidiaries of Lantmännen (a cooperative), they were involved in 20 projects. Hence, this suggests that some industrial actors have a broad strategy of drawing upon academic research to supplement their internal R&D capacities.

Chapters 5 and 6 have detailed many different ways in which industry has benefitted from collaboration with academic research. Few firms seem to directly commercialize the results of the research into products, and the interviews suggest that the reasons for this are that this requires considerable time lags and that product development takes place later, internally in the company with their specific knowledge. Collaborative research has to be on aspects of interest and open to the different partners involved. Internal firm development often requires secrecy and focus, to remain ahead of competitors.

One of the interesting findings is the reported importance of methods. This holds both for ‘scientific’ methods as well as ‘practical’ ones. While methods, techniques and technologies are clearly important to actors within the food industry, this may be different from some other industries, where research can more specifically focus upon components or final products. Hence, the importance of methods, instruments and technology needs to be stressed, and also explains why firms from processing and instruments – as well as food industry per se – were involved. In the food industry, issues like food safety, quality, consistency and so on are often intimately tied to sensors and instruments to measure and monitor the underlying processes. These are often developed by specialized firms like Tetra Pak and ABB.

While the time period studied is short, the analysis that we have performed suggests that one cannot expect the companies to start paying for collaborative research, upon conclusion of the public policy initiatives. This has to do with the interlinked nature of the innovation system. On the one hand, the companies gain much from the collaborative research, but they have few internal R&D resources even though some companies do develop new products. On the other side, a few research environments have obtained funding from larger and more long-term programs, also involving the companies, and which helps build up a competence base in Sweden. In a few successful cases, then, the development of networks and linkages between actors leads to an intensification of linkages across actors in the innovation system.

The firms thus rely upon an open innovation paradigm with other actors. In the future, having been successful with innovative products may lead them to develop more internal R&D resources, but they may also continue working across the innovation system. An alternative to working with the universities and public research organizations is to rely more heavily upon knowledge-intensive spin-offs. Such spin-offs should play a role to translate academic research to the needs of industry. At the moment, external collaboration is more likely to continue, especially if funded by public money. Within the structure of their industry, the feeling has been that they can only pay (for projects and also in terms of hires), if the work is directly related to their products and commercialization.

The role of the Swedish Sectoral System of Innovation (SSI) in relation to the global SSI in the food industry has not been analyzed in this report. Still, it is possible that the public policy initiatives studied here helped Sweden keep and develop a knowledge base and competencies in specific fields and in specific research environments. If knowledge is an input to competitiveness of firms and industries (as many argue), then developing these accumulating competencies into new and relevant trajectories ought to enable actors located in Sweden to have knowledge assets of interest to the increasingly important international firms. This question is vital, not only for the food industry but for all industries which face international ownership.

The role of spin-off companies

The spin-offs companies can sometimes play a role in the SSI in the food industry, but it is somewhat different from the pattern found in medical technology. In the food industry, we found a few examples where the academic spin-off companies (from previous periods) could be an intermediary of knowledge and projects between academic research and industrial R&D. They tend to retain close links to the research environments at the universities and research institutes, and thereby also to be up to date on the latest techniques. Their intermediary role may be a type of technology transfer, such that they apply their knowledge specialization to the specific needs of the companies. Two examples are likely Probi in the south and also the firm-center in Uppsala called KPL Good food practice. They also interact closely with the medium-sized and large companies, many of which have little or no R&D capabilities in-house. Hence, they must focus more upon specific development requirements of the companies, in applying the knowledge.

Growth of the industry

In the case of the food industry, the industry has not grown in terms of employment in Sweden and in some geographical areas (like Uppsala), business units in the food industry have been closed down due to rationalizations. Still, some medium-sized companies like Almondy have grown during this period, so it is possible for later studies to examine the specific areas in which growth occurred. Likely, the areas of growth are related to internationalization and exports. On the whole, the pattern is not towards growth. Instead, the trends are towards decreasing employment, international ownership, and an increasing percentage of exports.

Policy has contributed to create new network linkages, which may in turn contribute to increase the innovative performance of the system, as seen in terms of exports, but the overall industry is not growing in Sweden. A new analysis of the situation for the agriculture industry and the food industry would be useful as an input to later policy making, as the last major review was in 1997 (SOU 1997a), and with some later analysis drawing heavily upon that governmental inquiry.

In summary, these key findings related to the effects upon industry support the importance of the six mechanisms for diffusion of university research identified in Chapter 2. Those mechanisms include increasing the stock of useful knowledge; educating skilled graduates; developing new scientific instrumentation/methodologies; shaping networks and stimulating social interaction; enhancing the capacity for scientific and technological problem-solving; and creating new firms. Note that the final mechanism, creating new firms, exists in the innovative food area but does not appear frequently, while the other five mechanisms have been substantiated.

7.3.2 Medical technology

Interaction with academic research

The survey of the larger, established medtech companies (reported in Chapter 6) showed that the majority of them have had some collaboration with medtech research environments during the 20-year period that we cover in this study. About half of the companies say that these interactions have influenced them to a high extent. This indicates that research collaboration between established medtech companies and medtech research environments is an important phenomenon that public policy should pay attention to.

The collaboration can have different types of effects on the industry. It is often expected, for example among research financiers and policy-makers, that the academic research projects will lead to new knowledge, product ideas and inventions that can be commercialized by industry in the form of new products or processes. A striking result of our study – given the long time and the large number of research projects funded by STU/Nutek/VINNOVA through various programs and centers – is that the large established firms have commercialized research results to a relatively limited extent (with some exceptions). This observation at the aggregate level is in line with many of the researchers' experience that it has been difficult to get the established firms interested in deep collaboration and commercialization. Our conclusion, which is shared with many academics, is therefore that a more effective mechanism for commercialization in this more narrow sense (i.e. in the form of new research-based products) is the creation of new companies (e.g. university spin-offs). And we can also see that many such firms have been established.

Despite this, many of the established firms have been involved in some kind of collaboration with the medtech research environments. However, the main effect of this collaboration is not that they have gained access to new inventions and product ideas. Instead, what they estimate to be the most important effect is the access to new knowledge and competencies that can be internalized and used in the own R&D activities. This means that it is often difficult to identify a direct linkage between a research result and a specific product. Yet, the collaboration can bring essential benefits to the companies and help them to increase their development capability and competiveness. We believe, although we do not have proof, that this opportunity is not optimally used by industry. Thus, we postulate that if more collaborative links could be established between existing firms and medtech researchers, this would have positive effects on the development of new scientific and technological competencies.

Another related effect that is also highly appreciated by the companies is better monitoring of the scientific and technological advances. Thus, by having close contacts with the academic researchers it is easier for the companies to keep abreast of the technological front and follow trends. Among other possible effects, it seems that recruitment of skilled R&D personnel and drawing on the academic partners' scientific networks are also relatively important effects.

With regard to different collaboration forms between industry and university, informal contacts are the most frequent one. But participation in academic research projects is also quite common. This may include financing of industry PhD students, a form of collaboration that is highly appreciated at least by some firms. Generally, contract research is not a very popular form for collaborating with medtech researchers, although there are some historical and current success stories.

The role of spin-off companies

The medtech industry is characterized by the existence of many small start-up companies, many of which (but not all) can be classified as university spin-offs. Typically, these firms have been founded for the purpose of commercializing some new technology or concrete product invention (such as a new computer-based system for fetus monitoring or a new apparatus for home care ventilation, just to give two examples) and aim to bring this product to the market. In other parts of the life science industry, especially drug discovery, it is common that spin-off companies position themselves as R&D companies. That is, they have an explicit strategy to act as an intermediary between academia and the established industry (e.g. Big Pharma). They run R&D projects, either in-house or in collaboration with industrial partners, with the aim of developing the project to a stage where the results can be sold or licensed to another company. This pattern is not common in the medtech field. As mentioned, the strategy of the medtech firms is instead to bring the product to the market. However, this does not mean that they will necessarily sell directly to the end-users in the healthcare sector. What these companies develop is often a product (hardware and/or software) that constitutes a component or sub-system in a larger therapeutic or diagnostic system. Then, it can be a good solution to become a sub-supplier to the system integrator. In that sense, they can be said to play an intermediary role in the value chain, but in a different way than the typical biotech R&D firm. Ultimately, the small medtech firm might be acquired by one of the system suppliers, which may see advantages in integrating more closely the product with the system (e.g. from a product development point of view).

There are knowledgeable people in the medtech sector who believe that in the future we might see the emergence of "medtech R&D firms" which have a business model similar to what is common in the biotech field. One reason for this could be the ongoing convergence of different science and technology areas, for example, the integration of traditional medical technology and modern biotechnology.[133] It remains to be seen, though, if this development will be materialized.

Growth of the industry

Over the past twenty years, some of the large medtech companies have grown substantially, both in terms of turnover and employment. This includes firms like Gambro, Getinge and Mölnlycke Health Care. However, this growth has in most cases taken place primarily outside of Sweden. This is natural given that these companies are focusing on niche products which they exploit on the world market. In several cases, the acquisition of foreign firms – to gain access to new technologies, products and markets – has been a key ingredient in the growth strategy. Although we do not have as detailed data as would be desirable to make a thorough analysis of the industry

[133] One example from the field of regenerative medicine is the combination of biomaterials and stem cell technology.

development over the 20-year period, we must conclude however that the growth *in Sweden* in terms of employment has not come primarily from the large established firms. For example, as we described in Chapter 6 one of the key companies, Siemens-Elema, basically left Sweden during the period leading to disappearance of many jobs. Other large firms have expanded slowly or not at all.

Instead, major contributions to growth in Sweden have come from a group of other companies. Interestingly, many of them can be characterized as research-based. That is, they have been founded for the purpose of commercializing specific research results with origin in academic environments – either medtech or clinical, or both. In this category we find firms such as Atos Medical, Breas Medical, Cambio Healthcare Systems, Elekta, Entific/Cochlear, HemoCue, Nobel Biocare, Ortivus Medical, Radi Medical Systems and Sectra. Some of them are true spin-offs from universities, but others have been founded by existing firms, but often in close collaboration with academics, and as part of a diversification strategy. Astra Tech, one of the fast growing companies, existed since long but the expansion can to a large extent be attributed to the creation of a totally new, research-based business area (dental implants).

Many of these firms existed already in the late 1980s, but they were small in those days. Since then several of these firms have grown to become – at least by medtech standards – relatively large. Of course, there are many factors behind this growth (company strategies, market developments, etc.). But without previous research efforts made by the Swedish government these firms would probably not have existed. In addition, later publicly funded research efforts have helped these firms to grow, for example, by providing them with new R&D competencies (see the above discussion on the interaction with academic research).

It is true that the firms that we have referred to above were not from the beginning based on research results from the programs and centers dealt with in this study. But at least several of them have benefitted from the research through collaboration with universities. Even more important from an effect analysis point of view, the observed pattern of development shows that public research efforts in medical technology (and in related clinical fields) are of tremendous importance to the long-term development of the industry.

With a few exceptions, the new companies that have spun off from the major medtech research environments during the last twenty years have not achieved significant growth. This observation should be seen in the light of the very long lead-times in the innovation and business creation process. To some extent this is an inherent feature of the medtech business. However, extremely long lead-times are not something that should necessarily be accepted as a given fact. A relevant question is therefore what can be done, e.g. by policy-makers, in order to speed up the growth rate of medtech start-up companies. Further studies would be needed in order to increase our understanding of the barriers to growth in this industry, and provide a knowledge basis for a more effective innovation policy directed at the medtech sector.

8 Policy Tool-kit and Conclusions

8.1 Introduction

This final chapter 'Policy tool-kit and conclusions' provides a synthesis of our analyses, in order to contribute to discussions about the role and effects of public policy for innovation.

This report has several purposes, as defined early on, and this chapter helps address two of them. First of all, this chapter draws upon the empirical description and analysis in Chapters 5, 6 and 7 to further explain how the key issues are of interest in the public policy debates. Moreover, this chapter also directly helps fulfill the following purpose: 'To contribute to public policy, by developing a tool-kit. This public policy tool-kit should include relevant concepts, analytical framework, and models, which are useful to analyze and discuss long-term effects of public policy on research and industry.' This part of the chapter thus presents some implications for policy analysis, by synthesizing the results into specific models.

These specific models thus represent the 'Tool-kit for Chain-linked Effects on Research and Industry'. The idea of 'chain-linked' refers back to a conceptualization of innovation and actors' competencies. This also has implications about how to think about the role of policy. Hence, to advance with this discussion about how and why public policy can affect competitiveness and growth, we wish to start by reminding the reader of our starting point to understand policy. Based upon Nelson (1977) and some contemporary literature as discussed in Chapter 2, our premise is that public policy works best when it helps:

- Enhance the understanding of the problems, based upon the premise that the objective of policy analysis is not to find an optimum. Policy analysis should be focused upon identifying the next moves which are reasonable.
- Influence the discourse and bargaining of democratic politics. In today's language, that means that stakeholders should be more directly involved in setting policy.
- Design an organizational structure for public policy which is flexible. The organizational structure should be capable of learning and also of adjusting behavior and programs, in response to what has been learnt.
- Understand the interlinked nature of modern public policies. They cannot be seen as a straight substitute for market failure. Instead, public policies today require a mix and interlinked set of interactions between public-private, firm-government, market-non-market, and so on.

We interpret these premises as pragmatic suggestions for focusing on four variables when designing and examining policy[134]: Reasonable choices, not optimal ones; Stakeholder involvement; Policy learning, and Interlinked nature of the modern economy and policy worlds.

Based upon this broad understanding of the role of policy, this chapter continues, to make specific contributions relative to research and industry. We first develop a Tool-kit for Chain-linked Effects on Research and Industry'. This set of concepts, frameworks and feedback loops of related phenomena should help specify levels of analysis, processes and phenomena whereby public policy can affect research and industry for competitiveness and growth. The chapter is then concluded with a more abstract and speculative discussion of whether public policy can shift sectoral systems of innovation.

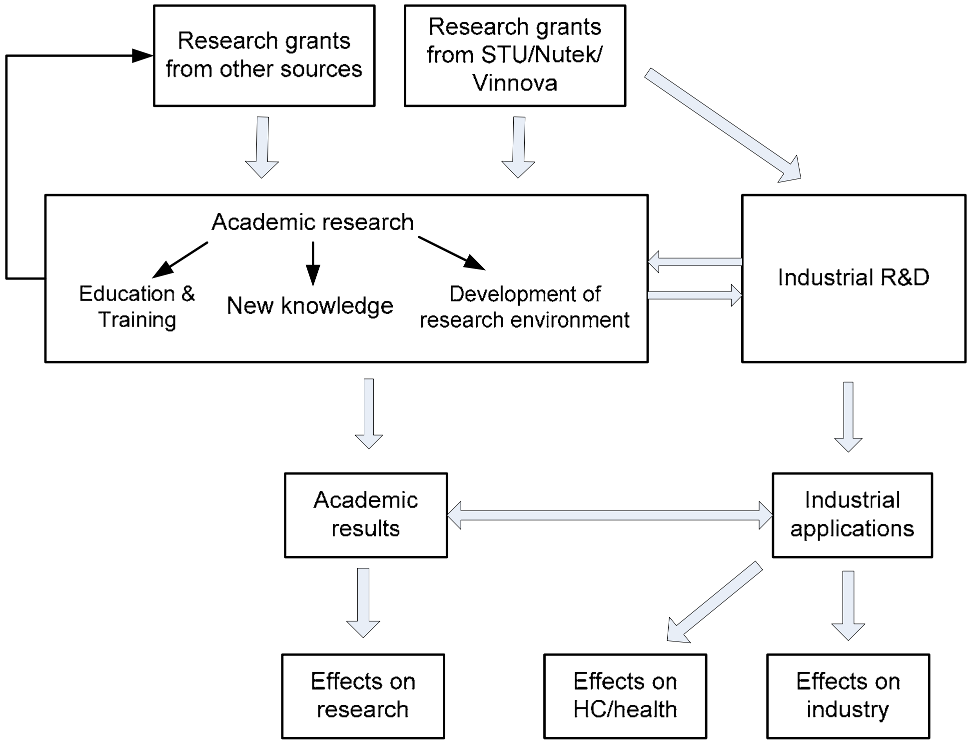
8.2 Tool-kit for Chain-linked Effects on Research and Industry

This section specifies the models for the 'Tool-kit for Chain-linked Effects on Research and Industry'. This tool-kit should be useful for conceptualizing, designing and evaluating policy. Therefore, we also include discussion of specific definitions, metrics and data that can be used to analyze different steps in the processes.

Chapter 2 presented the following model for effects, based on a revised interpretation of previous VINNOVA models (see Figure 8.1). The idea is that STU/Nutek/VINNOVA is one of several possible financiers which invest money into research, some of which goes to academic research and some to industrial R&D. These grants lead, respectively, to outputs in terms of academic results and industrial results, which in turn have effects on research, human healthcare and industrial competitiveness.

[134] They are useful tools, to conceptualize what it is that policy-makers ought to be doing. Of course, the premises specified above can and should be further developed to examine policy discourse and to design and evaluate specific public policies.

Figure 8.1. Our proposed broad chain of effects of public policy for life science



This model was the starting point for our study. The analysis in this report has further developed the idea of where and how that public policy for innovation can be conceptualized, designed, and evaluated in terms of chain-linked effects on research and industry.[135]

Therefore, we need to consider how, more explicitly, public policy affects the processes and heterogeneous actors associated with innovation as well as how parallel public-private processes are interlinked for innovation. In the model, the focus is specifically upon the chain-linked effects on research and industry.

For this report, we narrowed the broader issues that we had previously identified in the pilot study down to specific issues as stated in Chapter 2 and analyzed in Chapters 5 to 7. We felt that the specific issues provided the most important input to the policy debates and analysis of the processes. However, we also felt that it was useful to outline the broad range of issues

[135] This approach condenses a large amount of information, and therefore we felt it useful to restate what and where additional material can be found. Our policy tool-kit includes the following elements: Definition of concepts and variables (Ch 2); Outline processes whereby policy may lead to specific effects upon research and industry (Analytically in Ch 2; Empirically, Ch 4-6); Propose general model for effects (Ch 2); Identify flows and feedback mechanisms (Analytically in Ch 2; Empirically, Ch 4-6); Identify chain-linked effects of public policy on the sectoral systems of innovation (Analytically, Ch 8).

and questions which can be asked. This can be used for the purpose of stimulating additional research on chain-linked effects but also for public policy debates on which phenomena, actors, and linkages within a SSI should have priority when designing policy. Therefore, a few sets of broad issues followed by specific research questions are defined below.

8.2.1 Chain-linked effects of public policy on research

In Figure 8.1, 'Academic Research' is identified as a key intermediary step in the effect model, which was divided into education and training, new knowledge and development of the research environment. For collaborative research projects, we also identified the interactions and flows between academic R&D and industrial R&D to be important characteristics of the SSIs.

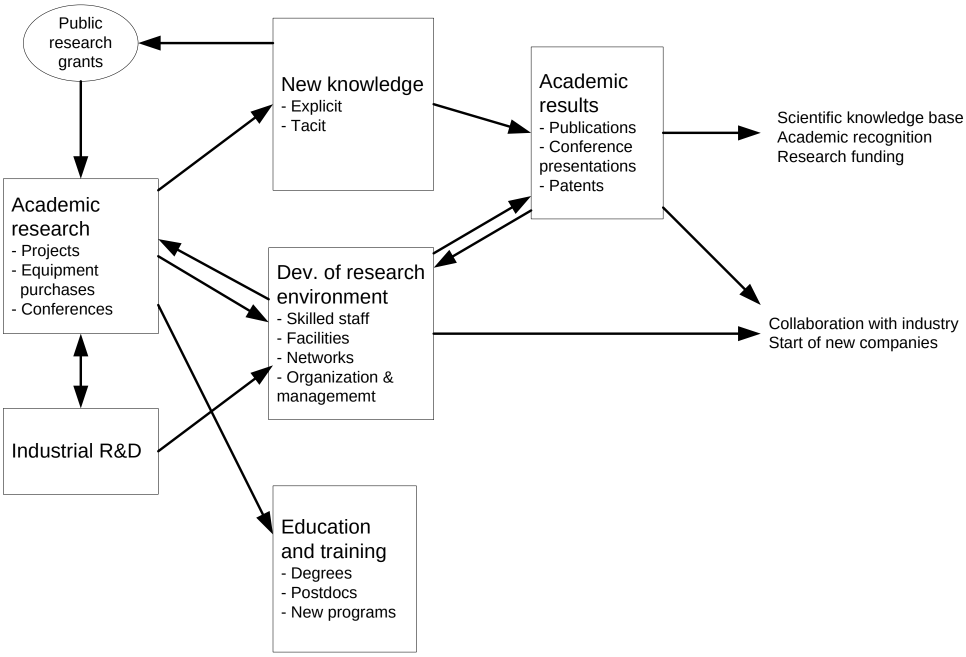
The tool-kit has revised 'Academic research' from an intermediary step to a starting step, because this is a key phenomenon that innovation policy attempts to influence. One should therefore start by examining the sources of funding (public research grants and industrial R&D) and the actual academic research carried out (projects, equipment purchases). Therefore, specific data should be gathered already here, including especially program data about rationale and objectives, research project title, hosting organization, project leader, team members, partners and co-financiers.

Note that by starting the analysis from academic research, we do introduce a certain bias. We are focusing upon research actually funded and carried out, but one could easily include a control group of researchers which applied but did not get funded.

Figure 8.2 outlines the main mechanisms for the longer-term and chain-linked effects of public policy on *research*.[136]

[136] In terms of the specific study carried out in previous chapters, we wish to remind the reader of the limitations discussed in Chapter 3, namely that the innovative food programs studied are more recent in time than the medical technology programs.

Figure 8.2. Effects on research



The main process in focus here is therefore that of the academic researcher, or what we call in Chapter 5, the Research Perspective.

Note that although there are overlaps in projects with industrial R&D, this figure takes its point of departure from the viewpoint of researchers working at universities, colleges and research institutes. Then, from the research perspective, one can also identify and evaluate the relative importance of the feedbacks and chain-linked effects with industry. As shown in the figure, the academic research may be affected by industrial R&D (and vice versa). Problems identified in industry may for example be taken as starting point for scientific research (Harvey 1994). Firms may also be directly involved in the academic research through collaborative projects, as they are in the projects analyzed here. One should thus keep in mind – and analyze – whether and how the industrial R&D may also impact the development of the research environment – especially in terms of competence development, network building and acquisition of new facilities.

Academic research will lead to many activities, which help develop and maintain the competencies of actors within the particular area of specialization. We have divided these activities into three types of effects, namely, New knowledge, Development of research environment, and Education and training.

New knowledge can include both explicit/codified and tacit knowledge, and therefore has in turn a large impact upon the academic results, that is the next step in the chain. The explicit and codified outcomes of new knowledge are primarily visible as academic results, as specified below. Academic research therefore has an arrow to new knowledge, which in turn has an arrow to academic results.

Development of the research environment refers to the 'lab' or 'environment' within which the academic research is carried out. In other words, the research environment refers to a broader concept than the individuals or research group per se. It can be analyzed in terms of the resources, structures and processes built at universities, colleges and research institutes. This can be contrasted with "Research and innovation environment", which is a broader concept used by VINNOVA. In our view, the Research and innovation environment includes industrial R&D carried out by firms and which aims at turning knowledge and technology into commercial products. Since we in this study distinguish between effects on research and effects on industry, we have chosen to use in this particular model the narrower concept of "research environment". The important linkage between research and innovation is captured by studying the development of networks, actor competencies and university-industry interaction within the SSIs.

This report has emphasized the development of research environments, particularly for medical technology. We identified many ways in which it can be examined and organized into case studies. Examples of relevant metrics for quantitative studies which can be further developed are skilled staff (number, background), facilities and equipment (access to specialized resources), network relationships (to different actors and whether they are regional, national and international), as well as organization and management (leadership, support structures).

The development of a research environment involves many factors. Therefore, there are arrows running both ways to and from academic research and academic results, whereas industrial R&D has an arrow running directly to the development of the research environment. Note that there is also an arrow running from the research environment to more aggregate effects, such as additional collaboration with industry and the start-up of new companies.

Education and training is the third way of diffusing new knowledge, skills and techniques in the SSI. Metrics which can be examined empirically include degrees granted (Master, PhD), post-degree jobs for the graduates, and the development of new educational programs. Because we are only examining the chain-linked effects upon research for the moment, the arrow runs from academic research to education and training.

Academic results are the next step in the chain. These can be measured through the well-established indicators of publications, papers, reports, conference presentations, and so forth. Patents (and patent applications) based on research findings can also be seen as an academic result. Academic results are the product of both new knowledge and the research environment (including individuals therein), but also successful academic results feed back to the environment and also help obtain additional recognition and funding. Therefore, there is an arrow from academic results to a broader societal impact. Results in turn contribute of course to enlarge the scientific knowledge base, create academic recognition for the researchers and, given a good track record, pave the way for funding of new projects.

Academic results – both publications and patents – may also lead to chain-link effects as related to industry. There is therefore an arrow running to the broader effect of collaboration with industry and start-up of new companies. As an example, patenting of commercially interesting research results can be used as a means to establish relationships with industry. This may lead to direct co-work, where university scientists for example develop experiences with industrial applications. Patents, in combination with the competencies and resources built up within the research environment, can also lead to formation of new companies – either pure university spin-offs or joint ventures with existing firms.

We propose that there are four key research issues, which are focused around the feedback and chain-linked effects of most crucial importance. They are:

1) Development of research at universities and research institutes;

A first key issue is how the research at universities and research institutes has developed over the period covered by the study. This issue can be divided into a series of broad questions, to be addressed at the sub-sectoral system of innovation level:

- How has the volume of research developed?
- Where has the funding come from? And what is the role and importance of the focal research financiers, as compared to additional financiers of research?
- How have the grants been distributed across sub-fields? Which fields have been given priority by the financiers?
- Has the character of research programs changed over time? If this is the case, how has it affected the direction of research and how the research is organized?
- To what extent have industrial firms been involved in the execution of research projects? Has this changed over time?

2) Long-term outputs of academic research and their effects upon the SSI

A second key issue has to do with the academic results of the research and their long-term effects on the SSI:

- How have the academic publications developed over time?
- How have patenting activities developed over time?
- How have the academic results affected the research institutions, for example, with regard to academic recognition and future funding possibilities?
- Have new actors and new competencies of existing actors been developed during the period?

3) Effects of research on education and training;

The third key issue concerns the effects on education and training:

- How many PhD degrees have been granted?
- Has the hiring of PhDs been a mechanism for diffusion of knowledge to industry or other societal actors?
- To what extent has the training of undergraduates in other fields (such as engineers, scientists, business) been affected by the research programs?
- Does education and training help promote the existence and intensity of linkages between actors?

4) Development of the research environment, including collaboration with industry.

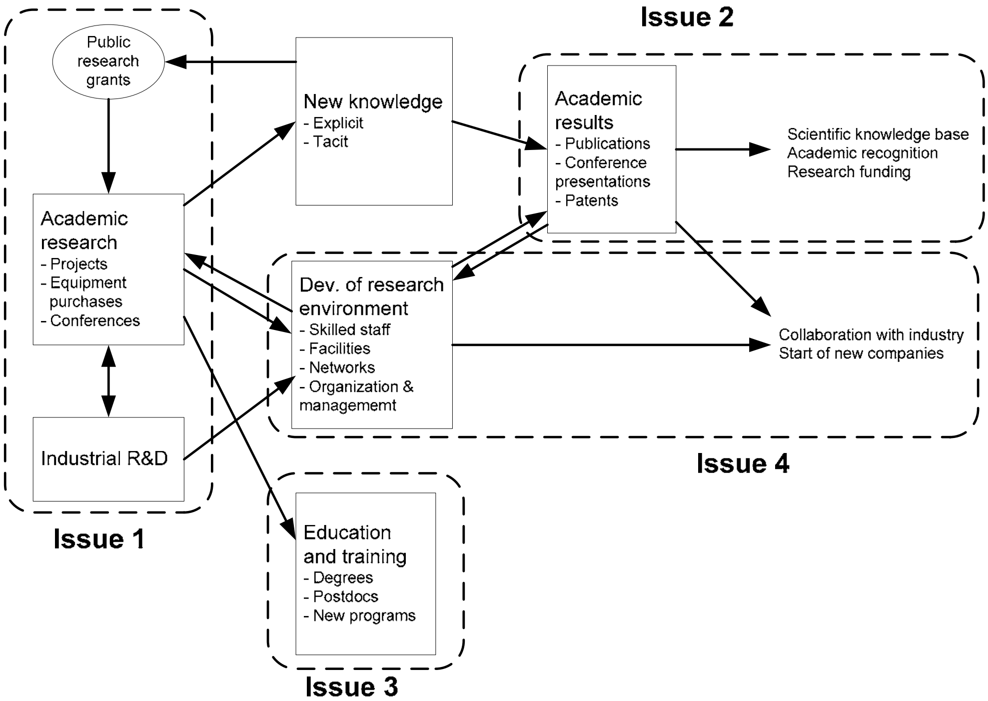
The fourth key issue is how the research environments have developed and what types of effect that these developments have had on the collaboration with industry. More precisely, the following questions can be raised:

- To what extent have the grants contributed to establishment of strong and viable research groups? In which particular fields?
- How important have the focal programs and projects been, as compared to additional financiers?
- To what extent have the grants contributed to network-building and collaboration between different research groups – within institutions and between institutions?
- To what extent have the grants contributed to network-building and collaboration with industry? How do these relationships look like?
- If they have occurred, how has the building of contacts and relationships with industry resulted in more long-term involvement of companies in the research?
- Has the development of the research environment stimulated the researchers to start up new companies for commercializing findings and ideas?

For designing additional studies, these issues and questions can easily be implemented into a research design. Each question must be matched with an appropriate method and data. Clearly, it is of essence to keep track of each project or program, as far as possible, to make sure that the correct (total) population has been identified and analyzed. A combination of methods is likely useful, as many question involve interpretative insights from policy-makers, researchers, industry representatives and stakeholders involved in the processes analyzed.

Figure 8.3 outlines these points visually. Note that even if the issue is circled around one specific phenomenon – such as issue 3 on education and training – our point is of course to include the arrows and how other steps in the process affect it.

Figure 8.3. research issues for chain-link effects of public policy on research



The numbers in Figure 8.3 correspond to the following key issues:
1) Development of research at universities and research institutes;
2) Long-term effects of academic research;
3) Effects of research on education and training;
4) Development of the research environment, including collaboration with industry.

8.2.2 Chain-linked effects of public policy on industry

In Figure 8.1, 'Academic Research' and 'Industrial R&D' have two-way arrows, as interactions amongst them are core for programs designed to stimulate competitiveness and growth through collaborative projects.

The tool-kit places 'Industrial R&D' as a key phenomenon, not least since one way of conceptualizing innovation policy is that it (positively) affects the innovative capabilities of firms. The focus is now upon the industrial perspective. Figure 8.4 therefore includes several steps related to research in Figures 8.2 and 8.3 into one step 'Research'.

Figure 8.4 outlines the principal mechanisms for the longer-term chain-linked effects of public policy on *industry*. To relate to competitiveness and growth, we are particularly interested in focusing on Industrial R&D, as linking the academic research with later production and sales (innovation).

Figure 8.4. Effects on industry

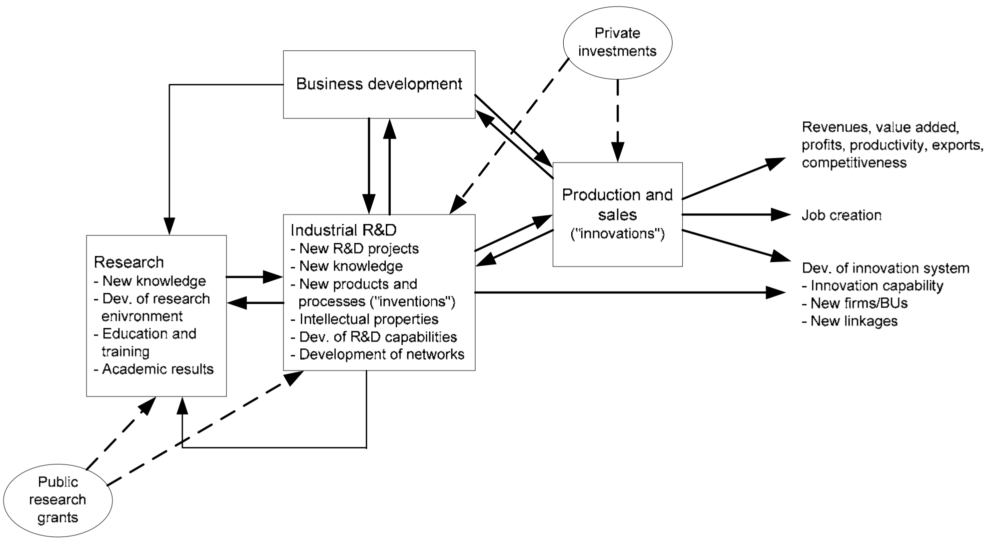


Figure 8.4 thus provides a more detailed model for the analysis of the effects on industry.

Industrial R&D is the main phenomenon which can be analyzed empirically – in addition to the chains of effects. The impact of funded research can be analyzed through a set of metrics, or aspects which can be analyzed. This includes whether new R&D projects were started, the development of inventions (products and processes), intellectual property rights, development of R&D capabilities, and development of networks. The network-linkages may be either with other companies or with universities and public research institutes. The arrows from Industrial R&D lead to research, business development, production and sales, and development of the innovation system.

Production and sales (of innovations) within existing firms doing the industrial R&D is one major way in which new fundamental knowledge for a sector is commercialized. These processes may be only internally in the firm, and not involve collaborative initiatives. In interaction with parallel processes of the company’s internal *business development* (aiming at new market offers[137]), these industrial R&D activities should lead to production and sales of new products (i.e. “innovations”). It should be noted, as indicated in Figure 8.4, that commercialization of research results always requires complementary private investments in industrial R&D as well as in start-up of production and sales. The amount of such investments can be seen as an indicator of the commercial value of the research.

In the final step, the company’s production and sales are in turn translated into financial and business effects on individual firms and the whole industry. For the firm internally, the effects are in terms of economic indicators such as revenues, value added, profits, productivity, exports, competitiveness and for employment. An interesting question is of course to what extent the realized growth can be traced back to effects coming from the specific research projects. Our assumption is that it is very difficult to trace back these effects. This report has not gone into detail about the company’s processes of commercialization.

Development of the innovation system can also be an effect of the phenomena and processes ongoing, from the industrial perspective. Figure 8.4 shows how these arrows are linked. There are arrows to firms’ commercialization and industrialization of new products, together with the industrial R&D activities (on the previous step in the chain). These also affect the structural development of the sectoral innovation system. First, resource development within existing companies, which constitute key actors in the innovation process, contribute to strengthen the innovation capability of the system (e.g. through recruitment of PhDs and interactive learning). Second, the innovation activities carried out in industry may lead to start up of new firms or new business units (within existing firms). These new actors may have a growth potential in themselves and/or provide other actors with valuable resources or services that were not available before. Third, the establishment of collaborative R&D relationships between firms and research institutions may lead to new linkages as well as more intensive linkages in the network. These developments – in terms of actors and networks – strengthen the capability and dynamic performance of the entire innovation system and its potential to generate further growth in the future.

We propose that there are three key research issues. They are: 1) Development of industrial R&D, especially as related to policy of interest; 2) Development of university-industry relations; and 3) Effects on the industrial competencies in the sectoral system of innovation.

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[137] Generally, new market offers may or may not require development of new products.

1) Development of industrial R&D, especially as related to policy initiatives of interest;

The first issue is concerned with how the industrial R&D has developed, and especially how this development has been affected by policy initiatives of interest. More specifically the following questions can be raised:

- To what extent have new R&D projects been triggered by the academic research in general, and the specified programs and projects in particular?
- To what extent have such projects resulted in new commercial products or processes? Are these outcomes protected by patents or other intellectual property (IP) rights? To what extent are these IPs generated in collaboration with research institutions?
- How is the companies' development of their R&D capability affected by the academic research?
- To what extent has the academic research contributed to develop the companies' network-linkages, with research institutions and with other firms – nationally as well as internationally?
- Have the six mechanisms for diffusion of research to industry been identified?

2) Development of university-industry relations;

The second issue focuses explicitly upon the development of university-industry relationships. The question is to what extent, and how, the research programs have affected the interaction between research institutions and industrial firms. For example:

- To what extent have new collaborative relationships been established? And what are the experiences of this "networking"?
- Have there been changes in the form of collaboration? For example, with regard to the actors' roles and contributions and the organization of the relationships. If so, what triggered these changes?
- To what extent does the collaboration involve more than two parties? That is, dyadic versus multi-actor collaborations.
- To what extent are the relationships regional versus national? How much matters geographical proximity?
- Does collaboration within the country also help firms to build relationships with foreign partners? Are geographically local linkages complements or substitutes to global linkages?

3) Effects on the industrial competencies in the sectoral system of innovation.

The third issue is about the effects on the sectoral innovation system as a whole. This includes research questions such as:

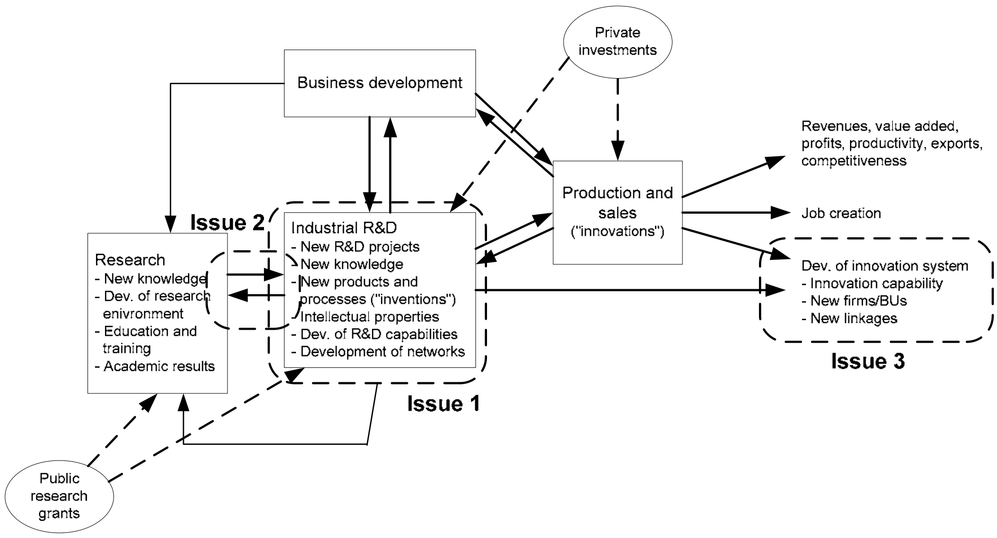
- Has the establishment of new collaborative relationships between researchers and companies contributed to increase the effectiveness and long-term potential of the innovation system?

Has the companies' involvement in R&D and innovation activities, triggered by the research programs, contributed to develop the innovation system by start of new firms/business units or by increasing the firms' innovation capability?

Figure 8.5 outlines these points visually. Hence, the numbers correspond to the following key issues:

1 Development of industrial R&D, especially as related to policy initiatives of interest;
2 Development of university-industry relations;
3 Effects on the industrial competencies in the sectoral system of innovation.

Figure 8.5. Key research issues for effects on industry



In summary, we propose that these are the crucial issues to understand, if one wants to better conceptualize, design and evaluate policy initiatives. These issues – and the related questions – are each specific and can be modified to become relevant to the specific program, technology, sector and so on. These questions were chosen as a way to make more concrete and to focus on the specific mechanisms of how public policy can shift a SSI.

8.3 Can Public Policy shift SSIs?

The final question then becomes, as to what role that public policy plays, within a larger national and sectoral innovation system. The analysis developed in this section is directly relevant to the components of the tool-kit proposed in Chapter 2, because we identify and discuss a series of specific, chain-linked effects across actors and phenomena.

On the one hand, public policy for science, technology and innovation have long promoted different mechanisms and forms for interactions and networking across organizations. This type of public policy has become more common in recent years, with one illustration being the publications and recommendations to be found on the website of the OECD (www.oecd.org). On the other hand, many studies demonstrate the difficulties of showing that public policy leads to long-term competitive impacts within regions (Braunerhjelm and Feldman 2007). This latter view is that public policy can facilitate growth, but is generally only one amongst many variables. We agree that public policy is one amongst many reasons for economic growth – and we have worked to nuance the understanding of causality and 'effect analysis' as proposed by VINNOVA to instead become an 'analysis of chain-linked effects'.

Hence, one could say that we pose a relatively simple – and yet complex – question namely Whether public policy can shift the SSI? Shift connotes a change of direction, which may help strengthen and influence the SSI to move in new directions. The concepts have been defined in Chapter 2 and applied to frame our empirical data and analysis. The question we pose is 'can', that is, is it possible at all, and if yes, in what ways and why.

The short answer is, Yes!

The longer answer to 'Yes' has many nuances. Those answers that we give below are by no means complete, but they do give insight into the complex ways in which public policy can cause effects upon research and industry, taken from a more long-term perspective, including multiple variables. Our answer to this question are based upon interpretations of the results, including the detailed descriptions from the research perspective (Ch 5) and from the industry perspective (Ch 6) as well as the comparison of key issues as they played out in innovative food and medical technology (Ch 7).

The cases of innovative food and medical technology illustrate that it is possible for public policy to shift sectoral systems of innovation. That shift is done through chain-linked effects, at different levels of analysis including actors and phenomena. The way in which public policy can shift SSI is related to more general points about public policy design, goals and implementation, in the modern knowledge economy. In other words, this way of conceptualizing the impact of policy upon research and industry for competitiveness and growth may also be applied to other sectors, industries and countries.

More broadly, we are proposing an explorative theoretical argumentation, which is focused around the idea of using public policy to shift the trajectory of an innovation system. 'Trajectory' refers to a general direction of research and industry development. The idea that the overall innovation system heads in a general direction is related to many micro-based decisions. Hence, the various directions are stimulated through a variety of actions by different types of firms, universities, public agencies and others, whom are linked in various feedback mechanisms across the SSI.

In our view, this places the idea of shifting the trajectory of a SSI through policy initiatives in relation to the role of a small, open economy within a globalised, linked, knowledge economy. A key issue for managing innovation in the connected world is the extent to which public policy can work with companies and public research labs, in order to stimulate connections locally and globally.

What does it mean, that public policy can shift the trajectories of SSIs?

Shifting the trajectory of a SSI could include many aspects. This report specifically focuses upon policy, upon how the interactions amongst university and industry occur, and upon how that interaction through research also affects the SSI and competencies of actors. Therefore, most of the more detailed answers below are restricted to the innovation system, as related to university-industry interaction and their respective perspectives on that interaction.

We propose that it is useful to analyze how the trajectory of the innovation system is altered in terms of:

- Changes in the fundamental knowledge base of the sector, in such a way as to support competitiveness through innovation
- Changes in the global orientation and competencies of actors involved in R&D, where actors include different types of firms as well as universities and research institutes
- Changes in the learning competencies of public policy actors
- Changes in the composition and types of actors involved in R&D and innovation within the SSI
- Changes in the existence and intensity of linkages between actors
- Changes in the flows of information, material, people
- Changes in the co-evolutionary pattern, due to aspects which change the selection mechanisms driving change, as explained below

These variables were derived from the answers to the key issues given in Chapters 5 to 7 as well as the concepts and framework about innovation and actors competencies in Chapter 2.

In terms of this report, we feel that thinking in terms of shifting the trajectory of the SSI also makes sense and it is therefore a valid approach, because it is congruent with policy initiatives at that time. In the national innovation system, Swedish public policy related to science, technology and innovation has worked for many years to promote connections and interactions between private actors like firms, between universities and between public actors like the respective Ministries of Education and Industry and like STU/Nutek/VINNOVA. Hence, for the government agencies in Sweden, the public policy initiatives analyzed here are types of experimentation, based on the idea of causing a change. Although few written policy documents are explicit on this point, there appears to be an implicit but fundamental idea that more public-private interactions about knowledge ought to lead to long-term economic growth for society.[138]

The discussion below outlines how we perceive that the trajectory of the SSI have been altered by the policy initiatives studied here – as well as by factors outside the control of these specific policies.

In what ways do the trajectories of SSIs in innovative food and medical technology shift?

To know whether something changed, one must remember where they started. So we just want to put in a reminder that the public policy programs that are studied here were implicitly (and sometimes explicitly) seen as responding to the needs of industry. In our terminology, the aim was therefore to help shift the innovation system, towards a more competitive regime and a higher growth rate.

In terms of the fundamental knowledge base of the sector, the project participants and results indicate that relevant knowledge for the sector has been developed through public policy. The notion of what is fundamental knowledge for the sector varies widely. On one end of the continuum, we have some projects focused upon improvements of products of existing companies and on the other end of the continuum, we have projects that explored new methodology, instruments and health benefits that were many years in the future. The fundamental knowledge in these cases refers less to blue-sky basic research than to fundamental aspects of applying knowledge to the specific business context of the industry.

This leads us to the issue of the role of public policy – and of whether, and how, industry is willing to pay the investment of costs of developing fundamental knowledge base.

[138] As in all countries, of course, one can argue that public policy is driven by some combination of more fundamental theoretical arguments about what 'ought' to happen as well as by power-struggles and by more experimentation with ways of tackling problems.

In innovative food, we can see that the companies are willing to be involved in collaborative research, financed primarily by the government, to develop more fundamental knowledge. However, the food industry is not so willing to pay full cost for academic research nor hire PhD students to continue specific projects – unless that knowledge is directly and specifically useful for their products and services. One reason may be that the food industry is often considered rather a traditional one with low R&D, as well as the upstream agricultural industry. This implies that they rely upon public policy taking more of the costs of investing into R&D than in other industries, which helps them accept the risk of failing in these projects. Note that some firms do spend significant percentages of turn-over on R&D – but these are usually university spin-offs from a previous period. Another reason is that the industry as a whole is one with low margins and relatively stable products and markets, even though many firms do develop new products, such as yoghurts containing beneficial bacteria. The Swedish public policy initiatives in innovative foods were in many cases directed to stimulating new knowledge, competencies, technologies and also products. So clearly in this case, public policy does help create interest and knowledge about products which differ from existing ones, and which may have significant demand in the future. This is another way in which public policy helps reduce risk for the company, here by opening up the horizons.

The medtech industry is more R&D-intensive than the food industry, although it is true that many of its products are relatively mature. The companies are very much focused on developing their existing product lines and may be interested in university collaboration to the extent that the projects clearly support the ongoing product developments activities. If there is public base-funding of academic research projects the firms may be prepared to provide co-funding of projects that are of direct interest to them. In other words, a prerequisite for active company participation is therefore that the government (or other research financiers) bears the main risk and cost.

In terms of the international orientation and competencies of the actors involved in R&D, these have developed during the decades studied here – but with different trajectories for national and for global actors.

Our results for both innovative food and for medical technology suggest that the large and medium-sized companies become increasingly global – either through international ownership and/or expansion abroad. They tend not to increase neither employment nor R&D in Sweden, although they continue to collaborate and be linked into the Swedish knowledge base. For the food industry, there is a clear decrease in employment by about 30 percent between 1985 and 2007, and with a much higher percentage of remaining jobs in companies owned abroad. Much of the employment in the food industry is in the companies owned internationally.

The medtech industry tends to be more stable over time, in Sweden. The small spin-offs are more linked to the geographically close universities. Only a few companies grow to medium size, and usually after a long initial phase. However, if we look at the industrial development within Sweden over a longer period of time (e.g. in terms of employment), it appears that growth comes mainly from new companies. And those that grow tend to have tight links to academia, either by being university spin-offs or by having other mechanisms to commercialize research. Large and medium-sized companies are often willing to buy up smaller companies to access specialized knowledge or new products and thereby increase their internal capabilities – but usually only after the idea has been thoroughly tested by the small company (which has thereby taken the costs and risks associated with development). Given the global character of the industries that we are studying these acquisitions are often cross-border (i.e. Swedish firms buy foreign firms or the other way around).

One aspect of competencies is how policy affects absorptive capacity. The ability of the companies to absorb knowledge from outside – whether from a supplier, customer or as of interest here, R&D and universities – is partly related to the education of employees and to resources spent on learning and innovative activities (which include but are not limited to R&D). The issue is that low R&D often implies that the company has few people with advanced degrees, and thereby also a non-redundancy in the communication channels needed to monitor, identify and bring in knowledge from the outside. In innovative food, our analysis of the LiFT PhD program suggests that many obtained jobs in industry, while in the interviews, many companies were skeptical to hiring PhDs, if the purpose was to continue with the collaborative project. This indicates that firms want the more general monitoring ability. In medical technology, the investigated programs and centers have resulted in a large number of doctoral theses. Many of the PhDs have moved on to industry and have thereby contributed to raise the scientific competence in companies – with positive effects on their ability to collaborate with universities and commercialize research findings.

For the universities, the suggested answer to this question of international orientation and cumulative competencies that we have is that the project leaders and the organizations rely upon multiple financers, and they may orient their research to obtain additional funding. The project leaders and the research environments vary in terms of their competencies, as measured through output indicators like patents, papers, and success in obtaining additional grants. Public policy money does lead to publications but less to patents. Still for those who patent, at level of individuals and research environments, there does not seem to be a trade-off between publications and patents nor between publications and working with companies.

Moreover, the idea of change over time requires more analysis, to understand the effects of policy for the future. A few project leaders manage to keep an even output over several years, but many fluctuate between years. One example is that they may one year have many publications and the next year none or that the research environment may be flooded with several parallel large grants for a period, followed by some years with no external financing. Companies rarely step in and pay for research projects which were previously collaborative, and financed with public money. This suggests that there is no automatic process. Research does not simply become consolidated into larger groups and thereby increase the quality, thereby obtaining more grants also from industry. Instead, fluctuations and variations are clearly part of the Swedish science policy context, especially after the reforms in the mid-1990s.

In terms of the learning competencies of the public policy actors involved, we have no results. This report has not studied the public policy actors involved.

We can see that the implicit assumptions about innovation policy and the linkages between innovation and growth have become more articulated and explicit in later decades. We also interpret that public policy has been willing to accept that government absorbs some of the risk of doing R&D and innovation, which encouraged companies to become involved. The reason is related to the objectives of VINNOVA and its predecessors. VINNOVA is funding needs-driven research and has a mission to develop effective innovation systems. This means, as illustrated above, that supporting research projects and the knowledge they generate should have industrial relevance and be applicable to industrial product development. Therefore, by definition the interaction between universities and research institutes on the one hand and industry on the other is of crucial importance from VINNOVA’s point of view. The medtech industry has always been driven by science to a large extent. This may be less true for the food industry, at least in a historical perspective. However, VINNOVA’s ambition is that modern bioscience should be more effectively used also in food-related research and product development. Therefore, public policy in that sector has been designed to extend existing, and develop new, types of capabilities and linkages at the firm level – but we have not studied whether and how VINNOVA and the Swedish state has learnt from these experiences.

In terms of composition and types of actors involved, the research programs and projects have included a broad range of firms, and a more narrow range of universities and research institutes.

In innovative food in industry, many medium and large firms in food located in Sweden are involved as Chapter 4 demonstrated, as well as many firms in related industries such as packaging and sensors. The co-operative organization Lantmännen and its subsidiaries are by far the most active participants. Many companies – which were previously part of large industrial groups, owned cooperatively or incorporated – were purchased during this period. The sense from some of the interviews was that Sweden has remained an interesting place to interact with universities and research institutes – but that is never a given for the future. We can call this a fragile system, whereby public knowledge producers must continually prove they are interesting and relevant partners for private companies ready to look elsewhere globally.

Also in the case of medical technology, we have large as well as medium-sized and small companies involved in the research programs and competence centers. Some of the larger ones such as Elekta, Siemens and St. Jude Medical appear relatively frequently as industrial partners. But this does not necessarily mean that they are deeply involved in the research projects.

In both sectors in research, the analysis shows that the large, established research environments tend to take a high proportion of the grants. Although this concentration is visible at the aggregate level, we can also see renewal. Especially in innovative food, the smaller grants from STU/Nutek/VINNOVA that went to the development of new research environments and centers were often used as a catalyst and later led to substantial grants from other financiers.

This is during decades where Swedish policy has been focused upon spreading science to regional colleges, which has been subject to a larger debate. We can see it, however, from an economics perspective. In these fields, there is clearly an advantage to the incumbent research environment, which also attracts young people. Likely, this is related to the fact that grants require skilled labor who can obtain grants. To get grants – especially large ones – you must already be established, you need track-record, access to capital equipment like specialized labs and also established networks with companies in order to access partners.

In terms of the existence and intensity of linkages between actors, they do exist but it is very hard to tell what is 'created' by policy and what 'exists' due to other mechanisms. We do see a number of 'repeat collaborators' in a series of projects, which may suggest that they maintain and possibly increase the intensity of linkages over time. In both sectors, the benefits obtained and mechanisms for explaining why many of these linkages exist are related to the next point.

In terms of the flows of information, material, people, these are crucial for understanding how public policy may shift a SSI in these cases. To understand this point, we must stress that our results differ from those of other studies that focus almost exclusively on start-up companies and patents. Many complex relationships can be identified, and companies are usually aware of the types and benefits of interactions with the universities and research institutes.

As mentioned in Chapter 2, Martin and Salter (2001) categorized the following six mechanisms for the diffusion of university research. We therefore wish to briefly highlight our key findings and ways of analyzing other SSIs, using their terminology:

- *Increasing the stock of useful knowledge*: The knowledge developed was often de facto 'useful' in that it should address relevant problems of industry, so that they might compete. This is usually visible in outputs like papers and patents.
- *Educating skilled graduates:* This remains a (if not the) key way for universities to diffuse knowledge to society, and has also been demonstrated as important here. This is visible in aspects like degrees granted, specializations and developing new areas.
- *Developing new scientific instrumentation/methodologies*: For innovative food, industry was primarily interested in this aspect.
- *Shaping networks and stimulating social interaction:* In our study, scientific papers, publications, conferences, networks, interactions and so on contributed to diffusing the fundamental knowledge in the sector.
- *Enhancing the capacity for scientific and technological problem-solving*: This mechanism is highly related to educating graduates and instrumentation. It should be visible in ways in which industrial R&D links into business development and production and sales.
- *Creating new firms*. This occurs in both cases, but is not the main mechanism. It is easier to identify and measure than the above mechanisms. Venture creation should be visible as academic spin-offs, as corporate spin-offs, and also as direct joint ventures from the collaborative projects.

We have found evidence that all six mechanisms are used in innovative food and medical technology. Moreover, they help us specify some of the chain-link feedback mechanisms, within the SSIs.

In terms of the selection mechanisms affecting the co-evolutionary pattern observed, this is a complex issue, but we can use the above findings to make some comments on evolution of the system, relative to policy. This is based upon the idea that one key aspect of innovation systems is the selection mechanisms whereby some activities and actors obtain more resources and become more dominant than others.

8.4 Looking towards the future

To conclude this chapter, we will discuss a few implications for later studies. Here, however, we restrict our remarks to whether policy choices affected the SSI in order to promote our initial premise of policy: Reasonable choices, not optimal ones; Stakeholder involvement; Policy learning, and Interlinked nature of the modern economy and policy worlds. These four variables are valid and can be applied to the projects and programs which are in some sense the 'start' of the overall analyses of broad effects within the SSIs of innovative food and medical technology in this report.

Firstly, the programs were proposed as a reasonable solution to identified problems – such as the need to increase competitiveness in the industries and encourage innovation for growth. No optimal solutions are possible in a global knowledge economy. One implication for this report is that developing an analysis of chain-linked effects requires a specification of some of the mechanisms and institutions whereby public policy may affect actors and processes, within a sectoral system of innovation. Another implication is the need to understand whether, and how, actors' competencies have developed, within a broader set of markets, institutions and scientific and technological knowledge.

Secondly, stakeholders were definitely involved, in that the research was to be 'needs-driven'. Stakeholders were primarily companies and universities, but with considerations of long-term effects upon society, such as increasing health benefits through innovative foods or better human healthcare. These public policy initiatives have also allowed for some experimentation, learning, and diversity of knowledge, actors and linkages.

Thirdly, the fact that VINNOVA has commissioned these reports (as described in Chapter 1) as part of a broader dialogue with the Ministry of Industry implies a commitment to policy learning.

Fourthly, the design and implementations of the programs and projects *de facto* involve public and private worlds, in that industrial collaboration is often an implicit prerequisite for involvement (and in later programs, a stated prerequisite).

Still, the issue of what is public in terms of knowledge and research needs more consideration, from a policy perspective. The research environments appear to be more vulnerable to swings in financing after the 1996 Swedish university reforms. Companies are not willing to finance this type of research. Therefore, once funding is finished, it is difficult to get new. Alternatively, we can say that many groups shift to new financiers when money dries up and they do so by shifting the focus of their research to match those opportunities or vice versa, they shift to new financiers, in order to keep the focus of their research objectives. It is hard to prove or to show decisively. One aspect is that VINNOVA (and others) have limited funding and make choices. Another impression from this study is that Swedish universities are becoming less and less able to take the costs and risks associated with projects that are not known to lead to results and additional financing.

Finally, a few words about the limitations to the approach here, as we develop well-grounded but more speculative remarks based on deep empirical knowledge. Of course, to design a specific study on how and why public policy changes the trajectory of a SSI requires more work but would be very useful. A very specific study would need to come much further and to take into consideration many questions. One is the breadth of analysis. Any of the questions posed above may be conceptualized and analyzed as regional, national or international linkages following previous work (McKelvey et al 2004). Another aspect is how one knows whether the changes are large or small and significant or not. These evaluations are always difficult. The methodology of ‘critical events’ in business studies could be a useful approach, so that rather than measuring the size of the change, to instead identify points which were critical for later developments. A final one is to find ways to analyze and discuss causality and impact of public policy, when there are complex feedbacks, across phenomena and levels in the overall SSI.

9 References

Affärsvärlden. (2005). Det nya blodiga Gambro. 3, 23 February, p. 16-19.

Action MedTech – Key Measures for Growing the Medical Device Industry in Sweden, 2007. A report jointly published by the Royal Institute of Technology, Karolinska Institutet and Karolinska University Hospital.

Asheim, B. and Coenen, L. (2005). Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research Policy*, Volume 34, Issue 8, October 2005, pp. 1173-1190. Regionalization of Innovation Policy.

Arrow, K. J. (1962). Economic Welfare and the Allocation of Resources for Invention, In Richard Nelson (ed.), *The Rate and Direction on Inventive Activity*. Princeton, N.J.: Princeton University Press.

Arvidsson, G., Bergström, H., Edquist, C., Högberg, D. and Jönsson, B. (2007). *Medicin för Sverige: Nytt liv i en framtidsbransch*. SNS Förlag: Stockholm.

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S. and Rickne, A. (2008). Analyzing the Functional Dynamics of Technological Innovation Systems, *Research Policy*, 37, pp. 407–429.

Buisseret TJ, Cameron H and Georghiou L. (1995). What difference does it make? Additionality in the public support of R&D in large firms. International. *Journal of Technology Management*, Vol.10, No. 4/5/6, pp. 587-600.

Braunerhjelm, P. and Feldman, M.P. (2007). *Cluster Genesis: Technology-based Industrial Development* (Paperback). Oxford, UK: Oxford Universiy Press

Cohen,W.M, Nelson, R.R and Walsh, J.P. (2002). Links and impacts: the influence of public research on industrial R&D. *Management Science*, 48 (1), 1–23pp

Coombs, R. and Metcalfe, S. (2000). Organizing for innovation: co-ordinating distributed innovation capabilities. In: Foss, N.J. Mahnke, V. (eds), *Competence, Governance and Entrepreneurship*. Oxford, UK: Oxford University Press, pp. 209-31.

Department of Industry and Department of Education, Sweden. (2004). Innovativa Sverige: en strategi för tillväxt genom förnyelse. (Innovative Sweden – A strategy for growth through renewal.). *Ds 2004:36*, www.regeringen.se.

Dodgson, M, Mathews, J, Kastelle, T, Mei-Chih Hu. (2008). The evolving nature of Taiwan's national innovation system: The case of biotechnology innovation networks. *Research Policy*, Volume 37, Issue 3, April 2008, pp. 430-445.

Edquist, C. (2001). Innovation Policy – A Systematic Approach. In: Archbugi, D. and Lundvall, B-Å. (eds). *The Globalizing Learning Economy*. Oxford, UK: Oxford University Press.

Edquist, C. and McKelvey, M. (2000). *Systems of Innovation: Growth, Competitiveness and Employment Volume 1*. Cheltenham, U.K: Edward Elgar.

Fagerberg, J.; D. Mowery and R. Nelson (2005). *The Oxford Handbook of Innovation*. Oxford, U.K: Oxford University Press.

Feldman, P. M. and Breznitz, S.M., (2008). The American Experience in University Technology Transfer. Forthcoming in Maureen McKelvey (ed.), *Mad as a Hatter: European Universities Learning to Compete*. Cheltenham, U.K: Edward Elgar.

Focus Medtech Agenda. (2005). A report jointly published by SwedenBio, SLF, ISA Sweden and Swedish Trade Council.

Formas. (2006). Nationellt forskningsprogram för livsmedel, Forskningsprogram 2004, Forskningsrådet för miljö, areella näringar och samhällsbyggande. *R5: 2006*.

Fransson C. (2005). Framgångsfaktorer för svensk livsmedelsexport, Tre fallstudier. Master thesis at SLU Sveriges Lantbruksuniversitet.

Freeman, C. (1991). Networks of innovators: a synthesis of research issues. *Research Policy*, 20, p. 499-514.

Georghiou, L.(2003). Evaluation of Behavioural Additionality. Concept Paper, Presented at the Meeting of the *TIP Working Group of the OECD*, June 2003.

Georghiou, L. (2002). Impact and Additionality of Innovation Policy. Paper presented at the Six Countries Programme on Innovation, Spring Conference 2002 on 'Innovation policy and sustainable development: Can pubic innovation incentives make a difference?. Conference held at Brussels, 28 February to 1 March.

Harvey, B. (1994). The relationship between science and technology. *Research Policy*. 23, pp. 477-486 .

Håkansson, H. (1989). *Corporate technological behaviour: co-operation and networks.* London: Routledge.

ITPS. (2007). Strukturstudie av näringslivet i Sverige 2004. Institutet för Tillväxtpolitiska Studier. *S2007:001*.

IVA. (1987). Den svenska medicintekniska industrin, sjukvården och samhället: en ansats till analys av samspelet mellan näringsliv och samhälle inom området medicintekniska produkter, *PM 9:1987*. Royal Academy of Engineering Sciences: Stockholm.

Jordbruksverket. (2006). Marknadsöversikt, Bearbetade jordbruksvaror, *Rapport 2006:13*.

Keith, P. (1998). The inevitable limits of EU R&D funding. *Research Policy*, Volume 27, Issue 6, September 1998, pp. 559-568

Kim, E-S. and Yong-Il S. (2007). Behavioural Additionality of R&D.Evaluation: Empirical Evidence from Korea Public R&D Program. *PICMET 2007 Proceedings*, 5-9 August 2007, Portland, Oregon.pp. 2247-2250.

Kline, S.J. and Rosenberg, N. (1986). An overview of innovation. In Landau, R. and Rosenberg, N. (eds), *The Positive Sum Strategy: Harnessing Technology for Economic Growth*. Washington, *DC:* National Academy Press, pp. 275-306.

Kuhlmann, S. (2001). Future governance of innovation policy in Europe – three scenarios. *Rseearch Policy*, 30, pp. 953-976.

Laage-Hellman, J. (1990). Utveckling av ny biomedicinsk teknik: en nätverksstudie. *STU-info 768-1990*. Stockholm: STU.

Laage-Hellman, J. (1993). Forskningsbaserat medicintekniskt företagande, *B 1993:12*. Stockholm: Nutek.

Laage-Hellman, J. (1998). Den biomedicinska industrin i Sverige, *B 1998:8.* Stockholm: Nutek.

Laage-Hellman, J., McKelvey, M. and Ljungberg, D. (2008). Pilot study: Analysis of effects on research and industry in life sciences (mimeo).

Laursen, K, Salter, A. (2004). Searching high and low: what types of firms use universities as a source of innovation? *Research Policy*, Volume 33, Issue 8, October 2004,1201-pp 1215.

Li. Livsmedelsindustrin i omvandling Livsmedelsföretagen, www.li.se

Li. (2007). Livsmedelsåret 2006. Livsmedelsföretagen. www.li.se.

Li. (2008). Livsmedelsåret 2007. Livsmedelsföretagen. www.li.se.

Lissoni, F., LIerena, P., McKelvey, M. and Sanditov, B. (2008). Academic patenting in Europe: Evidence from the KEINS database. In: McKelvey M. and Holmén M. (eds), *How European universities are learning to compete*. Cheltenham, UK: Edward Elgar.

Luukkonen, T. (2000). Additionality of EU Framework Programmes. *Research Policy*, 29 711-724.

Malerba, F. (2004). *Sectoral Systems of Innovation*. Cambridge, UK: Cambridge University Press.

Malerba, F (2002). Sectoral systems of innovation and production. *Research Policy*, Vol.31 2002, pp 247-264.

Mansfield, E. (1998). Academic research and industrial innovation: An update of empirical findings. *Research Policy*, Volume 26, Issues 7-8, April 1998, pp 773-776

Mark-Herbert Cecilia. (2002). Functional Foods for Added Value, Developing and marketing a new product category. Master thesis at SLU, Sveriges Lantbruksuniversitet.

McKelvey, M., Orsenigo, L. and Pammolli, F. (2004). Biotechnology as a Sectoral System of Innovation. In Malerba, F. (ed.), *Sectoral Systems of Innovation*, Cambridge, UK: Cambridge University Press.

McKelvey, M. and Orsenigo, L. (2006). Introduction in *The Economics of Biotechnology. Volume I and II, A two volume reference collection*. Cheltenham, U.K.: Edward Elgar.

McKelvey, M. (2005). Tensions in Co-Evolutionary Processes: Three Swedish Seed Organizations in the 20th Century. *Economics of Innovation and New Technology*, 14 (7).

McKelvey, M, Rickne, A and Laage-Hellman, J. (eds) (2005). *The Economic Dynamics of Modern Biotechnology*. Cheltenham, U.K.: Edward Elgar.

McKelvey, M. (1997). Using Evolutionary Theory to Delineate Innovation Systems. In Edquist, C. (1997). *Systems of Innovation: Technologies, Institutions and Organizations*. Pinter Publishers (now owned by Routledge).

McKinsey. (1995). Sweden's Economic Performance, *McKinsey Global Institute 1995*, www.mckinsey.com

Metcalfe, J.S. (2005). Systems Failure and the Case for Innovation Policy, in P. Llerena and M. Matt, *Innovation Policy in a Knowledge Based Economy*. Berlin: Springer.

Metcalfe, J.S. (2007). Innovation Systems, Innovation Policy and Restless Capitalism, pp. 441-454. In Malerba, F. and Brussoni, S. (eds), *Perspectives on Innovation.* Cambridge, UK: Cambridge University Press.

Metcalfe, S and Cooombs, R. (2000) Universities, the Science Base and the innovation Performance of the UK. CRIC, Breifing Paper No.5

MTF. (2007). Förslag till strategi of forskning inom medicinsk teknik i Sverige, Svensk förening för Medicinsk Teknik och Fysik.

Mål & Medel (2007). Det höll på att gå käpprätt åt helvete. Nr 2007/5.

Nelson, R. (1977). *The moon and the ghetto*. New York: WW Norton & Company.

Nilsson, M.; Svensson-Henning, M. and Wilkenson, O. (2002). *Skånska Kluster och Profilområden – En Kritisk Granskning*. Malmö: Region Skåne.

NRA. (2007). Nationell strategisk forskningsagenda för livsmedel. Arbetsgruppen för den Nationella plattformen för ETP – Food for Life.

Nutek. (1998). Forsknings-och utvecklingsstöd, Till industriella samverkansprojekt inom Livsmedelsområdet. Utlysning. Stockholm: Nutek.

Nutek. (1997). Medicinsk teknik och läkemedel: *Projektkatalog. Info nr 433-1997*, Stockholm: Nutek.

Nutek. (2000). *Nutek's FoU program Hälso- och sjukvårdsteknik: utvärdering 2000*. Stockholm: Nutek.

Nutek. (1992). Utredning rörande teknikutveckling för svensk livsmedelsindustri. *R1992:1*.

Nutek. (1996a). Teknologiska resurser inom livsmedelsområdet. Närings- och teknikutvecklingsverket. R 1996:46.

Nutek. (1996b). Biocompatible Materials Biocompatibility. Project reports from a research programme. *1996:25*. Stockholm: Nutek.

Nutek. (1996c). Utvärdering av NUTEKs medicintekniska satsningar. 1987-1996, *R 1996:60*. Stockholm: Nutek.

Paraskevolpoulou, E. (2008). Evolutionary Dynamics of Hidden Innovation policy: Regulation and innovation in the Detergents Indsutry. Phd thesis at University of Manchester, Faculty of Humanities.

Proposition 1996/97:5. *Forskning och Samhälle*.

Roberts, E.B., Levi, R.I., Finkelstein, S.N., Moskowitz, J. and Sondik, E.J. (1981). *Biomedical Innovation*. Cambridge, MA: The MIT Press.

Rosenberg, N and Nelson, RR. (1994). American universities and technical advance in industry. *Research Policy*, Volume 23, Issue 3, May 1994, pp. 323-348.

Salter,A.J. and Martin, B.R. (2001). The economic benefits of publicly funded basic research: a critical review. *Research Policy*, 30, 509–32.

SCB. (2006). Forskning och utveckling inom företagssektorn 2005. Statistiska meddelanden, UF 14 SM 0601.

Scherer, F.M. (2000). Chapter 25 The pharmaceutical industry. In: *Handbook of Health Economics*, Volume 1, Part 2, 2000, pp 1297-1336.

Schilling P. (2005). Research as a source of strategic opportunity, Re-thinking research policy developments in the late 20th century. Umeå Studies in Economic History, No. 32/2005.

Schumpeter, J. (1934). *The theory of economic development*. Boston: Harvard University Press.

Sharif, N. (2006). Emergence and development of the National Innovation Systems concept, *Research Policy*, V35 I5, Pages 745-766 june 2006.

Shaw, B. (1991). Developing Technological Innovations within Networks, *Entrepreneurship & Regional Development*. 3, pp. 111-128.

Sidén, L-K. (2003). Medical Devices in Sweden: Industrial structure, production and foreign trade 1985-2002, Royal Institute of Technology and Karolinska Institutet (licentiate thesis).

Smith, K. and West, J. (2005). Australia’s Innovation Challenges: The key policy Issues Submission to House of Representatives Standing Committee on Science and Innovation, Inquiry into Pathways for Technologial Innovation, April 2005. Available at http://www.utas.edu.au/.

SJFR (1986). Forskning för bättre mat. Skogs- och Jordbrukets Forskningsråd.

Smith, K. (2000). Innovation as a Systemic Phenomenon: Rethinking the Role of Policy. *Enterprise and Innovation Management Studies*, Vol.1, No.1, 73-102.

SOU. (1997a). En livsmedelsstrategi för Sverige. Näringsdepartementet. Statens offentliga Utredningar. *SOU 1997:167*.

SOU. (1997b). Svensk mat på EU-fat. Statens Offentliga Utredningar. *SOU 1997:25*.

Stokes, D. (1997). *Pasteur’s Quadrant: Basic Science and Technological Innovation*. Washington D.C.: Brookings Institution Press.

Swedish Research Council. (2006). International Evaluation of Swedish Research in Biomedical Engineering, *8:2006.* Stockholm: Swedish Research Council.

Ulmark P. (1996). Förändringsarbete, erfarenheter från att utveckla system och organisation. *338-1996*.

Vertova, G. (2006). *The Changing Economic Geography of Globalization: Reinventing Space*. London: Routledge.

VINNOVA. (2001). Innovativa livsmedel, Program för forskning, Utveckling och demonstration VINNOVA 2001-2005*, VI 2001:7*, maj 2001.

VINNOVA. (2003). Innovativa livsmedel, Utlysning inom VINNOVAs program för tillväxtområdet, Utlysning.

VINNOVA. (2004). Innovativa livsmedel, Utlysning inom VINNOVAs program för tillväxtområdet, Utlysning.

VINNOVA. (2006a). På spaning efter innovationssystem. *VP 2006:01*. Stockholm: VINNOVA.

VINNOVA. (2006b). Effektiv Produktframtagning. Projektkatalog 2006. VR 2006:19. Stockholm: VINNOVA.

VINNOVA. (2007a). VINNOVAs fokus på effekter, En samlad ansats för affektlogikprövning, Uppföljning, utvärdering och effektanalys. *VA 2007:14*. Stockholm: VINNOVA.

VINNOVA. (2007b). Effekter av den svenska trafikksikkerhetsforskningen 1971-2004: Hovedrapport. *VA 2007:07.* Stockholm: VINNOVA.

VINNOVA. (2007c). National and regional cluster profiles: companies in biotechnology, pharmaceuticals and medical technology in Sweden. *VA* 2007:04. Stockholm: VINNOVA.

Appendix 1

Biomedical engineering sub-fields used in the international evaluation of Swedish research in biomedical engineering (Swedish Research Council, 2006)

1 Biomaterials, tissue engineering
2 Imaging technologies (outside other headings)
3 Biomechanics
4 Biooptics
5 Biosensors, micro-nano(bio)technologies
6 Cardiovascular
7 Physiological measurement technology and modeling
8 Medical image and signal processing
9 Medical informatics
10 Medical radiation physics
11 Neuro (biology, engineering, informatics)
12 Technical audiology
13 Therapeutic technologies (various)
14 Ultrasound
15 Other

Appendix 2
Interviews

Interviews Medical technology sub-sector

VINNOVA:

Tomas Aronsson (2008-03-11)
Lars-Gunnar Larsson (2008-03-19)
Maj-Lis Ströman (2008-03-11)

Academia:

Chalmers University of Technology

Bengt Kasemo (2008-06-26)	Dept. of Applied Physics
Staffan Sjödin (2008-03-18)	Dept. of Applied Physics (previously Nobel Biocare)
Mikael Persson (2008-10-08)	Dept. of Signals and Systems

University College of Borås

Kaj Lindecrantz (2008-06-16)	Biomedical Engineering Group (previously Chalmers/Applied Electronics)

University of Gothenburg

Peter Thomsen (2008-12-22)	Dept. of Biomaterials
Jukka Lausmaa (2008-12-22)	BIOMATCELL

Karolinska Institutet

Anders Brahme (2008-10-24)	Research Center for Radiation Therapy

Linköping Institute of Technology

Per Ask (2006-09-17)	Dept. of Biomedical Engineering
Gert Nilsson (2006-09-15)	Dept. of Biomedical Engineering
Tomas Strömberg (2006-09-18)	Dept. of Biomedical Engineering
Hans Åhlfeldt (2006-09-17)	Dept. of Biomedical Engineering
Åke Öberg (2006-09-16)	Dept. of Biomedical Engineering
Ingemar Lundström (2006-09-18)	Dept. of Physics, Chemistry and Biology

Lund Institute of Technology

Thomas Laurell (2008-06-04)	Dept. of Electrical Measurements

Sune Svanberg (2008-06-23)	Lund Laser Center
Leif Sörnmo (2008-07-25)	Dept. of Electrical and Information technology

Lund University, Faculty of Medicine

Nils-Gunnar Holmer (2009-01-21)	Dept. of Clinical Science, Biomedical Engineering Group (by phone)

Royal Institute of Technology

Hans Hertz (2008-09-34)	Division of Biomedical X-Ray Physics
Lars-Åke Brodin (2008-11-08)	School of Technology and Health (by phone)

Umeå University and Luleå University of Technology

Olof Lindahl (2008-10-27)	Center for Biomedical Engineering and Physics (by phone)

Uppsala University and Swedish University of Agricultural Sciences

Ewert Bengtsson (2008-09-25)	Center for Image Analysis

Industry:

Personal interviews:

Björn Andersson (2008-10-21)	Elekta
Anders Eriksson (2008-09-11)	IBCT (previously Mölnlycke Health Care)
Erik Hedlund (2008-10-22)	C-RAD and RaySearch (previously Siemens –Elema)
Torbjörn Kronander (2008-09-18)	Sectra
Gösta Sjöholm (2008-10-21)	Karolinska Development and STING (previously Siemens-Elema)
Bengt-Arne Sjöqvist (2009-01-14)	Ortivus Medical

Telephone interviews:

Anonymous (2008-10-07)	Anonymous company
Jonas Andersson (2008-10-08)	Getinge Infection Conrol
Jörgen Hager (2008-10-10)	Becton Dickinson
Jan Hall (2008-09-23)	Nobel Biocare
Anne Helander Kenne (2008-10-15)	Q-Med
Stellan Lindberg (2008-10-22)	HemoCue

Arne Lindqvist (2008-10-28)	Attends Healthcare
Elisabet Lundqvist (2008-10-28)	Mölnlycke Health Care/Wound care Division
Per Matsson (2008-11-14)	PhaDia
Jan-Enar Mattsson (2008-10-14)	SCA Incontinence Care
Susanne Nilsson (2008-10-28)	St. Jude Medical
Göran Rydin (2008-10-09)	Maquet Critical Care
Leif Smeby(2008-10-22)	Gambro (previous R&D Director)
Tove Weigel (2008-10-21)	Mölnlycke Health Care//Surgical Division
Håkan Wernersson (2008-11-21)	ArjoHuntleigh

Interviews Innovative food sub-sector

VINNOVA:

Maria Landgren (2008-05-06)
Monica Ulin Carlsson (2008-05-06)

Academia:

Personal interviews:

Uppsala University and Swedish University of Agricultural Sciences

Bengt Vessby (2008-06-11)	Dept. of Pub. Health & Caring Sciences
Per Åman (2008-06-02)	Dept. of Food Science

Lunds University

Peter Rådström (2008-08-28)	Dept. of Applied Microbiology

SIK

Karin Wendin (2008-05-23)	SIK (Lund)

Telephone interviews:

Anne-Marie Hermansson (2008-05-20)	SIK
Hans Lingnert (2008-09-05)	SIK

Industry:

Personal interviews:

Kenneth Andersson (2008-06-09)	Skånemejerier
Ingemar Börjesson (2008-06-08)	Cerealia

Telephone interviews:

Ulla Svensson (2008-07-02)	Arla

Appendix 3
Databases

The 2 databases contains data for 53 Academic Authors who were financed and participated in VINNOVA projects. The data were collected from self reports and interviews from the Authors, from VINNOVA and from a bibliometrics research. Two different databases were created, containing the same information but differently constructed. The first is a panel dataset and the second a cross sectional dataset.

- THE PANEL DATASET

For every Author there was a research about his/her publications in the following databases. 1. Web of Science (ISI), 2. Scopus, 3. Science Direct, 4. Other (Linkedin, personal CVs, etc.). The main source was the “Web of Science” database.

After downloading all the articles found for every Author, they were separated by year. Therefore for every year there was aggregated the number of publications, the number of citations, the number of references and the number of total pages. The variable funding is also a time series variable and represents the financing of every year for VINNOVA projects.

The other variables were created from self reports or from information given from VINNOVA. They are used as binary variables, and have the same value during the years for every author.

The variable category was created according to the leydesdorff categorization. The Subject category which came out from the bibliometrics was transformed into a number according to the leydesdorff categorization which is given in different excel sheet.

The difference between the variable Number of Publications and Publications is that the first is the number of total publications while the second is a binary indicating if there were publications related to the project or not according to the reports.

- THE CROSS SECTIONAL DATASET

The cross sectional dataset contains the same info with the panel dataset but instead of following the authors year per year, contains only the total number of publications, citations, references and pages. Furthermore it does not contain the funding received during the years, but only the funding reported in relation to the last project. The variable lnfunding added is simply the natural logarithm of the variable funding. The variable category, in the case of the cross sectional data denotes what was the category with the highest frequency for every author.

idnr	Identification number for every Author
nr	Number of References
tc	Times cited
pg	Pages
py	Publication year
numberpublica~n	Number of Publications
category	Category
funding	Funding
relatedfunding	RelatedFunding
newmethodmodel	New Method/Model
newresearchne~k	NewResearchNetwork
publications	Related Publications
seminars	Seminars
workshops	Workshops
produdtv	Product development
prototyp	Prototypes
demonstration	Demonstrations
companynetworks	Company Networks
conference	Conferences
doktorander	Doctorates
licuppsatser	Licentiate uppsatser
examensarbete	Master theses
centrumbildning	Research centers
patentsVINNOVA	PatentsVINNOVA
pattentskeins	PattentsKeins
lnFunding	Logarithm of funding

Appendix 4
Interview guide for telephone survey

Företag:____

Intervjuperson:____

Befattning (eller dylikt): ____________________________________

Datum:__________

A. INLEDANDE FRÅGOR

Har företaget (under den senaste 20-årsperioden) haft samarbete kring **kliniska** tester och prövningar med universitetssjukhus?

Ja	Nej	Vet ej
☐	☐	☐

I vilken utsträckning har detta (kliniska) samarbete haft betydelse för företagets utveckling och kommersialisering av nya produkter?

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Har företaget (under den senaste 20-årsperioden) haft FoU-samarbete med **medicintekniska forskningsinstitutioner** (eller andra tekniskt/naturvetenskapligt inriktade universitets-institutioner som arbetar med medicinska tillämpningar)

Ja	Nej	Vet ej
☐	☐	☐

I vilken utsträckning har detta (medicintekniska) samarbete haft betydelse för företagets utveckling och kommersialisering av nya produkter?

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

OBS i fortsättningen fokuserar vi på detta, medicintekniska samarbete

Vilka olika **former** av FoU-samarbete har förekommit?

Vi skiljer på följande former:

- Uppdragsforskning
- Industridoktorander
- Deltagande i akademiska forskningsprojekt som drivs av universitetsforskarna med intern eller extern finansiering (t ex genom något program eller vid något centrum)
- Informella kontakter/samarbeten (individnivå)
- Kommersialisering av forskningsresultat utan att företaget varit med i själva forskningen
- Event. annat (öppen fråga)

Har företaget under den senaste 20-årsperioden (dvs sedan slutet av 1980-talet) haft forskningssamarbete med universitetsforskare i form av:

Uppdragsforskning (helt finansierat av företaget)

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Hur viktiga har svenska universitetsinstitutioner varit i jämförelse med utländska?

Mindre viktiga	Lika viktiga	Mer viktiga	Vet ej
☐	☐	☐	☐

Industridoktorander (som varit knutna till institution i Sverige)

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Deltagande i **akademiska forskningsprojekt** som huvudsakligen finansierats av universiteten själva eller genom externa forskningsanslag (t ex via något program)

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Hur viktiga har svenska universitetsinstitutioner varit i jämförelse med utländska?

Mindre viktiga	Lika viktiga	Mer viktiga	Vet ej
☐	☐	☐	☐

Informella kontakter/samarbeten med medicintekniska forskare

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Har företaget **andra typer av samarbeten** med medicintekniska institutioner?

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Har företaget **kommersialiserat** resultat från den akademiska, medicintekniska forskningen utan att ha varit involverad i själva forskningen? (t ex genom att köpa patent/licenser av forskare)

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Med **hur många** svenska (medicintekniska) institutioner har företaget haft FoU-samarbete

1	2-5	>5	Vet ej
☐	☐	☐	☐

Vilken/vilka har varit viktigast, historiskt sett?

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Ungefär hur stor andel av företagets FoU-budget används idag för att finansiera extern forskning (i form av uppdrag eller cash-bidrag till annan forskning)?

<5%	5-20%	>20%	Vet ej
☐	☐	☐	☐

I vilken utsträckning har denna andel förändrats under de senaste 20 åren?

Ökat	Varit konstant	Minskat	Vet ej
☐	☐	☐	☐

B. EFFEKTER AV FORSKNINGSSAMARBETE MED MEDICINTEKNISKA FORSKARE

Vilken typ av effekter har deltagandet FoU-samarbetet med de svenska (medicintekniska) universitetsinstitutionerna haft på företaget?

Lösning på tekniska problem relaterade till företagets egen FoU-verksamhet

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Tillgång till forskningsbaserade uppfinningar/idéer som kunnat kommersialiseras av företaget (dvs resulterat i nya produkter eller processer)

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Tillgång till nya kunskaper/kompetenser som har kunnat nyttiggöras i företagets egen FoU-verksamhet

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Ändring av företagets forskningsinriktning (t ex genom start av nya FoU-projekt)

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Bättre kunskap/insikter om trender inom vetenskap och teknologi (omvärlsbevakning)

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Rekrytering av kvalificerad FoU-personal (lic/doktor eller motsvarande)

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Etablering av kontakter/samarbeten (”nätverk”) med andra akademiska forskargrupper i Sverige

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Etablering av kontakter/samarbeten (”nätverk”) med andra akademiska forskargrupper utomlands

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Etablering av kontakter/samarbeten (”nätverk”) med andra företag

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Förbättrad/stärkt image

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Andra effekter?

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C. FÖRÄNDRINGAR AV SAMARBETSMÖNSTER (Issue 2)

(Hur har företagets samarbete med akademiska, medicintekniska forskargrupper i Sverige förändrats över tiden?)

Har omfattningen av företagets FoU-samarbete med (medicintekniska) institutioner förändrats under de senaste 20 åren?

Ökat	Varit konstant	Minskat	Vet ej
☐	☐	☐	☐

Om omfattningen ökat, i vilken utsträckning har denna utveckling påverkats av STU/Nutek/VINNOVAs forskningssatsningar? (t ex krav på industriell medverkan)

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Har samarbetet med akademiska forskare förändrats under de senaste 20 åren, med avseende på t ex samarbetets form/karaktär, samarbetspartners lokalisering (Sverige vs utlandet) eller effekterna (jfr olika slags effekter ovan):

Är <u>den geografiska närheten</u> till akademiska samarbetspartners viktig för resultatet av samarbetet?

Ej viktig Ganska viktig Mycket viktig Vet ej

☐ ☐ ☐ ☐

När är den viktig? (exempel på situationer)____

Har den geografiska närheten blivit mer eller mindre viktig under de senaste 20 åren?

Mindre viktig Lika viktig Mer viktig Vet ej

☐ ☐ ☐ ☐

Varför?____

Har andelen internationella forskningssamarbeten (jämfört med de svenska) ökat eller minskat under de senaste 20 åren?

Ökat Ungefär konstant Minskat Vet ej

☐ ☐ ☐ ☐

Vad är den viktigaste orsaken?

D. OM EFFEKTER PÅ INNOVATIONSSYSTEMET (Issue 3)

(be intervjupersonerna ge exempel i mån av tid)

I vilken utsträckning har företaget samarbetat med svenska ”start-up-företag” som avknoppats från medicintekniska forskningsmiljöer?

Inte alls ☐ I viss utsträckning ☐ I hög grad ☐ Vet ej ☐

Exempel?____

I vilken utsträckning har företaget samarbetat med utländska ”start-up-företag” som avknoppats från medicintekniska forskningsmiljöer?

Inte alls ☐ I viss utsträckning ☐ I hög grad ☐ Vet ej ☐

Exempel?____

Är dessa samarbeten (med svenska och utländska start-up-företag) viktigare idag än för 20 år sedan?

Inte alls ☐ I viss utsträckning ☐ I hög grad ☐ Vet ej ☐

I vilken utsträckning har företaget förvärvat svenska ”start-up-företag” som avknoppats från medicintekniska forskningsmiljöer?

Inte alls ☐ I viss utsträckning ☐ I hög grad ☐ Vet ej ☐

Exempel?____

I vilken utsträckning har företaget förvärvat utländska” start-up-företag” som avknoppats från medicintekniska forskningsmiljöer?

Inte alls ☐ I viss utsträckning ☐ I hög grad ☐ Vet ej ☐

Exempel?____

Är dessa förvärv (av svenska och utländska start-up-företag) viktigare idag än för 20 år sedan?

Inte alls ☐ I viss utsträckning ☐ I hög grad ☐ Vet ej ☐

AVSLUTANDE FRÅGOR

Har frågor kring IP-rättigheter, i samband med deltagande i akademiska forskningsprojekt, varit svåra att hantera?

Inte alls	I viss utsträckning	I hög grad	Vet ej
☐	☐	☐	☐

Kan du ge exempel på svårigheter som förekommit och hur man löst dessa?

(jfr bilaterala vs multilaterala samarbeten)

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VINNOVA´s mission is to promote sustainable growth
by funding needs-driven research
and developing effective innovation systems

VERKET FÖR INNOVATIONSSYSTEM – SWEDISH GOVERNMENTAL AGENCY FOR INNOVATION SYSTEMS

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