Pilot study

Analysis of Effects on Research and Industry in Life Sciences

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Analysis of Effects on Research and Industry in Life Sciences

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1 Introduction

This report presents the results of a pilot study carried out as preparation for a subsequent main study, where the long-term effects of Swedish government financing of research in the field of life sciences will be analyzed.

The principal purposes of this pilot study are:

1) To develop relevant concepts and analytical framework for the main study
2) To propose a methodology and research design for the main study
3) To collect empirical material on targeted research projects in life sciences (i.e., the two targeted areas medical technology and innovative food) and identify relevant interview persons and other sources of information.

This pilot study concerns the effects of Vinnova's efforts on *research* and *industry*. 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. There is a third effect area, that is, effects on *society* (including health-economic calculations). This analysis will be assigned to another contractor. The same applies to the task of writing a synthesizing report.

Our study will be delimited to two sub-sectors within life science: medical technology ("medtech") and innovative food. Vinnova has also specified which programs and projects within these two fields that the analysis should focus on.

This pilot study has been carried out from December 2007 to mid-February 2008. As an input to our work we have used reports and program-related documents provided by

Vinnova or obtained from other sources. We have also had discussions with key people at Vinnova and with some other experts involved in the two targeted sub-sectors.

In the present report we first present the background to the Effect Analysis (Section 2). In Section 3 we develop the analytical framework to be used in the main study. This is followed by a proposition of the research design, where we formulate tentative key research questions and discuss the methodology (Section 4). In section 5 we present a work plan for the main study. Hence, this pilot study leads to a proposal for a main study, to be discussed with Vinnova.

2 Background: Public Policy and Previous Effect Analysis

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 has been 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 "the old Nutek") over the years.

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.[1] The purpose is to use many-sided 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. Thus, it differs from other types of evaluations and effect studies that Vinnova carries out related to individual programs.[2]

So far, Vinnova has completed five Effect Analysis studies during the period 2002-2007, and these are useful for the current study. In addition, there are two ongoing studies. Generally, the experiences are very positive. Thus, the studies have generated valuable knowledge about the effects and also led to a methodological learning concerning the execution of Effect Analysis. One important lesson is that the completed analyses taken together 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. A second general lesson is that Effect Analysis studies covering a longer time perspective and more than one individual program can be successfully performed.

The methodology lessons are relevant to this pilot study. They indicate the importance of having evaluators with competence both in the subject field and in evaluation technique, the

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[1] The following text mainly builds on Vinnova (2007a).

[2] 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.

importance of written documentation about the programs, and the importance of anchoring the analysis work with 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, that it is advantageous to divide the work into a pilot study and sub-studies (i.e. different parts of the main study), and that the choice of theoretical and methodological approach has crucial importance for the results.

Based on these experiences with other fields, the planned 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). This is in line with the Triple Helix approach and reflects Vinnova's mission, which is to stimulate the interplay among academia, industry and society in effective innovation systems. 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. However, this pilot study only covers the first two effect areas, namely research and industry.

Another important and related starting point for the planned Effect Analysis 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 for the upcoming Effect Analysis is a stronger emphasis on current and future policy challenges.[3]

In the past, three main approaches have been used by the evaluators to varying degrees:[4]

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 first two approaches are relevant to the proposed main study, 'Analysis of Effects on Research and Industry in Life Sciences'.

Previous Effect Analysis studies have also proposed conceptual frameworks. Relevant ones are presented below, whereas the next section develops a model for the Effect Analysis on Research and Industry in Life Sciences.

In the study of the Swedish traffic safety research (Vinnova, 2007b), the analysis focused on so-called *effect chains* 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.

Figure 1 shows a simplified version of the analysis model used in that study. It is assumed that effects can take place at several levels. The building of research environments, individual researchers, and research networks that can develop and use the knowledge capital constitutes the first level – and is a prerequisite for all other effects.

[3] Vinnova (2007a, p. 35)
[4] Vinnova (2007a, p. 73-75)

Figure 1. Effects from publicly financed traffic safety research – a model of effect chains Source:Vinnova (2007b)

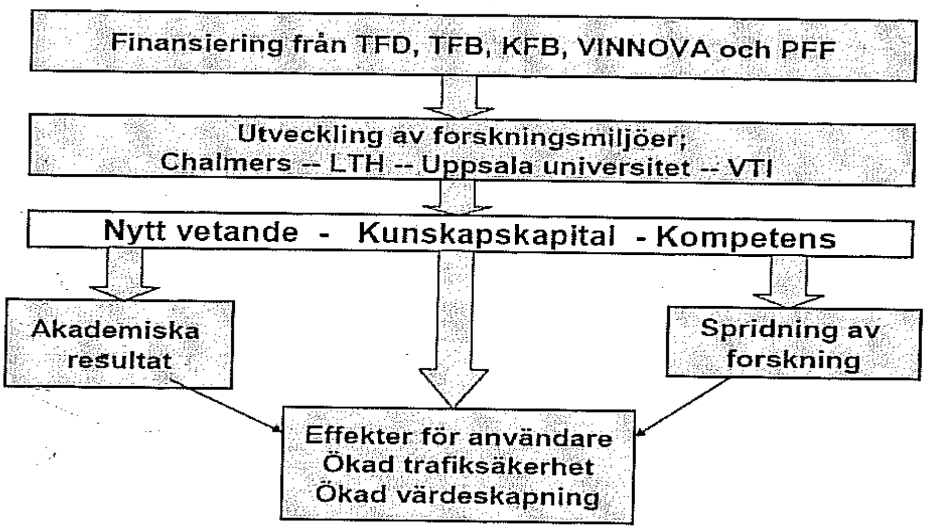


Figure 1 thus shows that financing of needs-oriented research through public policy leads to the development of research environments, at specific universities and technical universities. These in turn create new knowledge, knowledge capital and competencies, which lead to academic results, effects on users, and diffusion of research results.

The idea of using an effect chain approach constitutes a good starting point also for our study. During the pilot study, we have further developed this approach, and the next section therefore proposes a modified approach and two specific models.

3 Analytical Framework for Main Study

This pilot study makes a proposal for a main study – an Analysis of Effects on Research and Industry in Life Sciences. This section addresses the first purpose mentioned above, namely to develop relevant concepts and analytical framework for the main study.

Based on the background presented above, the main study will provide a broad picture of what has happened in research and industry in life sciences over a longer period of time, and try to relate these developments to efforts made by STU, Nutek and Vinnova. The two selected fields of life sciences are medical technology ("medtech") and innovative food.

Medical technology is often defined as a list of relevant technologies, which are applicable to medicine and medical practice. In a recent study, Vinnova defines the medical technology sector as companies that develop medical products that are not drugs.[5] 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".[6] This includes:

[5] Vinnova (2007c)
[6] Action MedTech (2007, p. 65)

- 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 health care professionals in their care of patients, e.g., (a) infection control, patient hygiene etc and (b) hospital beds, patient lifts etc.

The food sector is broad and comprises, for example, a large number of firms operating at different levels in the value chain and producing various types of food products. The planned main study shall not cover the whole food area, but it will instead focus on companies and research institutions involved in the development of “innovative food”, especially using life sciences. Given the consumers’ increasing interest in the importance of food for health, this is assumed to be a growth area – both nationally and internationally. It is at this stage not totally clear how this area should be delimited. This is something that needs to be further pursued during the main study. But basically, the analysis should focus on actors that perform R&D of relevance for the development of new food products with health-enhancing properties. This includes, for example, the field of functional food, but also parts of the agriculture sector, such as agricultural biotechnology.

In terms of longer effects, the main study will focus upon the effects of research support programs implemented by Vinnova (and its predecessors) [7] – in the medtech field since the late 1980s and in the case of food-related research since around 2000.

Tables 1 and 2 specify the relevant programs during this time period and give some basic data.[8] These programs will thus be taken as starting point for the effect analysis.

However, there may be other programs – run by Vinnova or other financiers – that are related in some way. Therefore, one result of the analysis in the main study will be to identify and discuss other, directly relevant research programs.

In addition, the pilot study has shown that major sources of support for innovative food may not be included in the initial list of research programs. This area was also supported by longer-term institutional support, especially to SIK. Discussions with Vinnova for the main study therefore need to specify whether specific instances of support to innovative food should be added to Table 2 or whether their role in the Swedish innovation system will be one result of our analysis.

[7] In the following, when we mention Vinnova this also includes its predecessors, STU and ”the old Nutek”, unless otherwise stated.

[8] It should be noted that the content of these tables is preliminary and so far incomplete. There are several questions that need to be sorted out during the main study.

Table 1. Research programs in medical technology to be covered by the main study

	Duration	No of projects	Funding, total (MSEK)	Purpose/aims
MEDIBILD	1987-96	38 ?	36, 4 7,8	- Support Swedish firms in the development of internationally competitive products and system solutions - Active firm interaction and clinical and commercial relevance
Biocompatible materials	1987- 93	25 ?	38,4 ? + 10,75	Establish an industrially relevant knowledge base
Biocompatibility	1992- 97 ?			- Est. of networks, knowledge transfer to industry, training industrially relevant researchers develop and est. biomaterial efforts in firms, - Long term: development of products with high potential for export.
Biomedical measure technique	1987-93	38 ?	45,3 ? + 7,5	- Develop new methods as a base for new high-tech industries - Improve medical diagnostics in order to render healthcare more effective
Minimal invasive medical technology	1993-96			- Strengthen the competiveness of the medtech industry, - Contribute to develop and produce new valuable products in new or est Swedish firms - Provide industry with new technology and examined researchers.
Mikronik	1991-07	?	47,4	- Encourage and support collaborations between physics, chemistry and biology to develop structures at the submicro-level - aim was functional and technical applications
KOFUMA	1997-99	?	31,8	-Create the conditions for development of new types of products and the establishment of new firms by strengthening the base of areas with high unfulfilled potential - Enhance and maintain Swedish industry's ability to take part in emerging and growing markets
Healthcare technology	1997-2001	76 granted applications ?	39,6 9,3	- Program covering the whole Medtech area - Aim to support growth and development of Swedish industry in Healthcare technology - Create interaction between Swedish healthcare, industry and academia - Support research that leads to new medtech products and develop national competence

Table 2. Research programs in innovative food to be covered by the main study

	Duration	No of projects	Funding, total (MSEK)	Purpose/aims
Industrial cooperative projects in the food area	1998-2001	?	24,9	- Strengthen food R&D and support exports - Give firms the opportunity to follow up on specific problems and put academia and industry in contact to strengthen the understanding of one another's problems
Innovative food	2001-2008	?	V call 2003: 20 V call 2004: 24 Tot 97	-To develop a knowledge base for development of food with health promoting characteristics, and connect it to techn development - Stimulate "need driven" cross disciplinary research - Strengthen the ability of Swedish industry to innovate in the area

3.1 Sectoral system of innovation and effect chain model

This pilot study has lead to a modified effect chain approach and two specific models for the effects on, respectively, research and industry.

This section concentrates on our proposed effect chain approach. Figure 1 in Section 2 was based on a previous study of traffic safety. However, we have made modifications, partly because they were needed in order to link public policy to developments within the Swedish innovation system and partly in order to suit the analysis of life sciences in general and the focal sub-sectors in particular. The text below points to some differences between medical technology and innovative food, but the model should be relevant for studying the general effect chains in both areas. Figure 2 below presents our proposed effect chain approach.

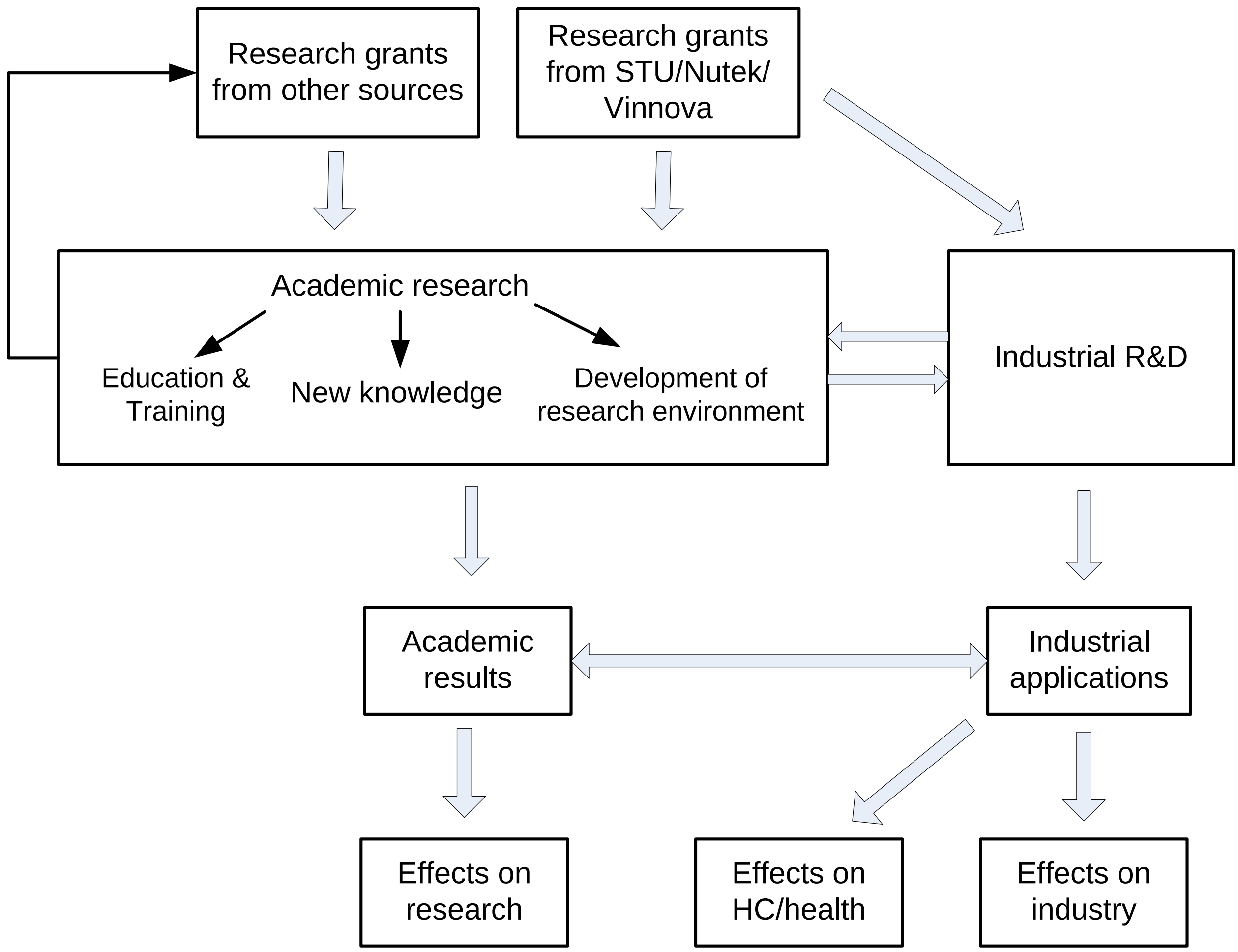
The first issue was to link public policy and the Swedish innovation system. In the main study, our proposed approach and models of the effect chains in life sciences will be used as a meta-analysis, in order to help us understand how specific public policy initiatives can affect the innovation system. In our view, the sectoral system of innovation includes its constituent actors, institutions and networks (Malerba, 2004). 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). While one can discuss the sectoral system of innovation (SSI) for biotechnology and life sciences (McKelvey et al 2004), we apply the SSI concept to the sub-sectors. The main study will thus analyze effects within two sub-sectors of life sciences, namely medical technology and innovative food. The focus of the main report will be on how and why public policy can induce changes over time in such an innovation system, in such a way as to affect both academia and industry.

To do so, the effect chain approach needed a better representation of causality, and how public policy affects the innovation system. For clarity, we agree that it is useful to start with a simplified figure, which represents the main chains of effect for medical technology and for innovative food. However, some developments are needed. Figure 1 above may give the impression that the research and innovation process is linear, e.g assuming that there is a simple cause and effect relationship between funding of academic research and economic growth. This is not the case. We suggest some additional elements and arrows in Figure 2 below, in order to account for major feedback loops.

A related modificationistherefore feedback loops within the effects chain. The innovation process is characterized by numerous feedback loops, between the different elements in the chain. Vital feedback loops occur when industry is involved in the research, such as when the needs and problems in industry trigger the start of new research projects 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 summarizes the model for analysis of effects that we propose to use in the main study.

Figure 2. Effect chains for life sciences



Our model of effect chains 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. 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.

This 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, the Foundation for Strategic Research and other public or private research 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.

The relevant research programs to be covered in the main study have already been listed in Tables 1 and 2 above.

These research grants from 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 results from the creation of new knowledge, which ultimately leads to effects on academia, healthcare and industry. This new knowledge 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. Tacit knowledge is more aligned with skills and competences, and "how to do things", and hence associated with developing the skills of individuals.

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 in the scientific community.

A third effect of the 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 Vinnova.

As indicated in the figure, an indirect effect of the research is that further research funding from other sources can be attracted. Hence, it is possible that 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 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. They may also benefit in other ways from the building of strong research environments. They may, for example, be able to 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 not necessarily linked to the specific results of the academic research.

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 in their own innovation activities leads to industrial applications, mainly in the form of new products (i.e. goods and/or services). In addition to applied R&D, this important step in the innovation process requires, normally, extensive investments in start-up of production and marketing.

On the last effect level in Figure 2, the academic achievements based on the 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. First, the development and commercialization of new products 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 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 other issue is whether and how the two sub-sectors of life sciences are similar or different. Figure 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 will not affect our work (since we will not study the effects on society). Medtech products are sold to healthcare providers (e.g. hospitals), which use them for carrying out medical services. In the case of medtech, however, the scientific knowledge may in some cases also be directly applied in healthcare. This is because some medical research is carried out by clinicians who are also working in the healthcare system, e.g. as physicians. It may be that some of the knowledge coming out of clinically oriented research projects can be applied directly without developing new 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. But on the other hand, this type of effect (on the healthcare system) will not be included in our part of Vinnova's Effect Analysis.

In summary, the pilot study has lead to this effect chain model illustrated in Figure 2, which constitutes the starting point for our analysis. In accordance with our assignment, the focus of the main study will be on the effects on research and industry respectively (but also including the previous levels in the chain). This effect chain model thus provides a broad model, which is used below to specify the specific models used to develop a framework of analysis and research design.

3.2 Framework for main study: Building actors' competencies and shifting the innovation system

Developed further from the effect chain model introduced above, this section proposes two specific models. These represent the analytical framework for the main study, which will lead us to propose a research design and data in Section 4. As stated above, the main study will address effects in terms of understanding and analyzing how specific public policy initiatives can affect the innovation system. Two key issues are how the research grants help build actors' competencies and how they help shift the innovation system, toward a more competitive regime and a higher growth rate.

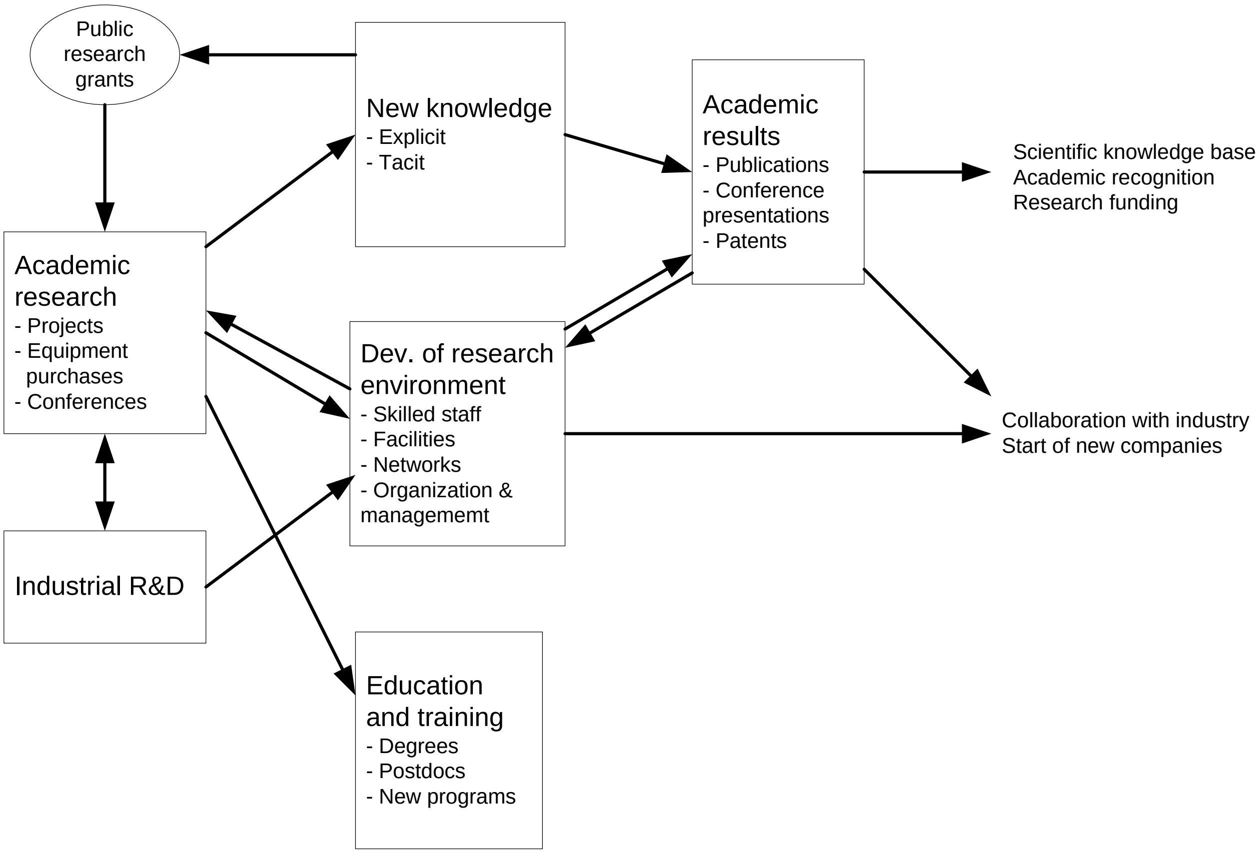
This section therefore focuses upon the specific mechanisms for the effects on, respectively, research and industry. These mechanisms represent ways in which the research grants by Vinnova have affected further developments through chain effects. They thereby form the basis for the specific research design proposed in the next section, including research questions, indicators and methodology.

Hence, this section provides more detailed models of the long-term effects on respectively, research and industry (compared to the overall model described above). These models are used to identify metrics and indicators, which can be useful for the main study. These metrics thus provide a way to analyze the building up of competencies within specific actors, as well as how public policy has shifted the sectoral system of innovation. They are useful both for making a broad analysis of the two fields, and for the specific case studies that we are planning to do (see Section 4).

Figure 3 outlines the main mechanisms for the longer-term effects on *research*. The main study will thus analyze this chain of events at the sub-sector level. For the case studies, we are particularly interested in the development of the research environment.[9]

[9] Research environment here refers to the resources, structures and processes built at universities (or at research institutes, the activities of which we for the sake of simplicity include in "academic research"). "Research and innovation environment" is a broader concept used by Vinnova. In our view, this 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 more narrow concept of "research environment". The important linkage between research and innovation is caught by studying the development of networks and university-industry interaction more broadly.

Figure 3. Effects on research



In the previous section, 'Academic Research was identified as a key intermediary chain in the effect model, and Figure 3 therefore specifies dimensions by which one can identify and specify metrics and indicators of the outcomes of the funded research. These metrics include especially the projects (title, amount of funding, co-financiers, project leaders), equipment purchases, and conferences organized or attended.

In turn, these research activities lead to three effects in the model, namely, New knowledge, Development of research environment, and Education and training. As explained in the previous section, 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 link in the chain. The metrics are thus primarily visible as outcomes, seen as academic results as discussed below. The second effect is Development of the research environment, which can be examined through metrics such as 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 third effect is Education and training for diffusing new knowledge, skills and techniques in society. Metrics which can be examined empirically include degrees granted (Masters, PhD), post-degree jobs for the graduates, and the development of new educational programs.

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 research. Firms may also be directly involved in the academic research through collaborative projects. In that way the industrial R&D may also have effects on how the research environment develops – in terms of competence development, network building and acquisition of new facilities.

The next link in the effect chain is Academic results, and 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. These 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.

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.

Figure 4 outlines the principal mechanisms for the longer-term effects on *industry*. The main study will analyze this chain of events at the sub-sector level. For the case studies, we are particularly interested in focusing on Industrial R&D, as linking the academic research with later production and sales (innovation).

Figure 4. Effects on industry

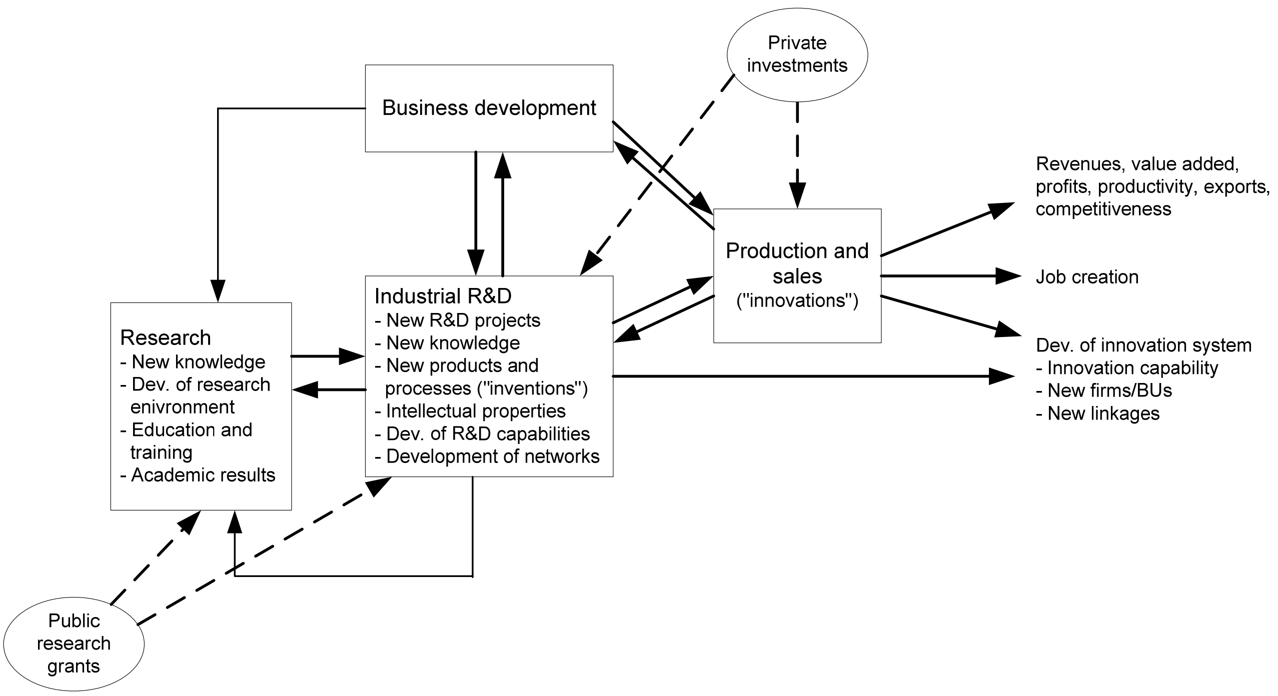


Figure 4 thus provides a more detailed model for the analysis. The main element which can be analyzed empirically – in addition to the chains of effects – is that of Industrial R&D. The impact of funded research can be analyzed through a set of metrics. This includes whether new R&D projects were started, the development of inventions (products and processes), intellectual property rights, development of R&D capabilities, and development of networks. These networks may be with either other companies or with universities and public research institutes.

In interaction with parallel processes of the company's internal business development (aiming at new market offers[10]), these industrial R&D activities should lead to production and sales of new products (i.e. "innovations"). It should be noted, as indicated in the figure, that commercialization of research results always requires complementary private investments in industrial R&D as well as in start-up 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, these efforts in turn are translated into effects on individual firms and the whole industry in terms of such economic indicators as revenues, value added, profits, productivity, exports, competitiveness and job creation (employment). An interesting question is of course to what extent the realized growth can be traced back to effects coming from the Vinnova-funded research projects.

As also indicated in the figure, firms' commercialization and industrialization of new products, together with the industrial R&D activities (on the previous level in the chain), also affect the structural development of the sectoral innovation system. First, resource development within existing companies, constituting 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 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. In other words, the model points to some possible long-term and indirect effects of Vinnova's efforts.

In summary, the pilot study has lead to two specific models of effects on, respectively, research and industry. These figures are used to specify issues and research questions. More broadly, they are developed as models which are relevant for understanding how public policy in the form of research grants can help shift the innovation system, towards better competitiveness and growth.

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 supported 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 at the firm level.

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[10] Generally, new market offers may or may not require development of new products.

4 Research Design for Main Study

This section discusses the results of second and third purposes of the pilot study, namely specifying methodology and research design as well as providing insight into the data collection processes of the pilot study and the main study.

This section links these two purposes to the concepts and analytical framework proposed above, in order to propose a research design for the main study. By that, we mean that this section includes a discussion of background overviews, research questions, indicators, methodology, and so forth, which will lead to the analysis of effects. Our proposal should be used as a basis for further discussion with Vinnova. Needless to say, after these discussions with Vinnova, we will continue to develop the more detailed methodology and data during the execution of the main study.

Depending on Vinnova's interest, the main study can be specified differently in terms of foci and work effort. If, for example, Vinnova is primarily interested in only a subset of issues, then of course a more limited study can be designed, In such a case, this has to be discussed before starting the main study. However, since we are interested in the long-term, overall effects of the efforts upon research and industry in these two sub-fields, this section proposes an ambitious, major study, including all the relevant aspects specified above.

The proposed main study (according to the more ambitious design) will use the conceptual framework developed above. The pilot study has used the two models in order to focus upon specific research questions and methodology, which are detailed below. Hence, the main study will have four fields in which to analyze the effects, as outlined in Table 3 below, and as specified in relation to the Figures 3 and 4 presented above.

Table 3. Effect fields

	Medtech	Innovative Food
Effects on Research	Figure 3	Figure 3
Effects on Industry	Figure 4	Figure 4

Naturally, comparisons across the two sub-fields as well as between the effects on research and industry will be made in the concluding section of the final report.

The research design discussion will be divided in several parts below. First, we will discuss the collection of some important background overview information. Second, we will discuss some methodological issues, before turning to how the methodological issues are used to answer research questions in the effect analysis per se.

4.1 Background information about the sub-sectors and public policy

As a background to the Effect Analysis, the main study will include overviews of the two sub-sectors and of the public policy to be analyzed. During the pilot study, we have performed some interviews with key informants and started to collect relevant data for the overviews.

First, the main study will include an *overview of the two sub-sectors*. This overview will provide insight into the characteristics of the sectoral systems of innovation in medical technology and innovative food. The main study will thus include a description of structural industrial characteristics and identification of key actors in Sweden (both firms and research units). We will primarily use secondary data for this purpose. Especially in the case of medtech there are recent studies that can be used as valuable sources, and for life sciences for food, more limited material is available.

A key issue for the main study is of course how Vinnova's financing of research, in the areas of medical technology and innovative food respectively, has affected the industrial development in Sweden. An important question necessary to highlight is therefore how these two industries have developed over time – that is, since the late 1980s in the case of medtech and since around 2000 for the food industry. An important purpose of the main study is to analyze how this development can be linked to Vinnova's efforts and draw conclusion from that. Therefore, the overview section will include a description of the industrial development over the relevant periods of analysis.

Second, there will be an *overview of relevant public policy*, specifically in terms of the research programs that the effect analysis should focus on. As shown in Table 1and 2 above, eight programs within medtech and two within life sciences for food will be analyzed. In the course of the main study we will investigate whether there are other relevant programs that we should take into consideration in the effect analysis – and which also might be included in the overview.

The overview will cover the main characteristics of these programs, specifically:

- duration
- amount of money
- research topics and objectives
- number of projects
- principal investigators
- researchers involved in the projects
- specific university, college or specialized institute
- industrial involvement in projects
- Additional variables: to be discussed with Vinnova

We assume that data for this part of the overview will be obtained mainly from Vinnova, but it cannot be excluded that other sources of information will prove to be useful.

In summary, these two overviews of the sub-sectors and of the relevant public policy will lead to two chapters in the final report of the main study.

4.2 Data and Methodology

During the pilot study, we have started to collect relevant secondary data, background reports, articles and identified some key informants. This work will be extended in the main study, to provide useful background overviews as well as material for the analysis.

An important purpose of the pilot study is to develop a methodology for the main study. We propose 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 have examined the relevance and the data constraints for each of the following methodologies:

- 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.
- Bibliometric studies. This means that we analyze publications and other quantitative data, primarily about academic results. These are primarily SCI data.
- Patent analysis. This means that we intend to use our Swedish part of the KEINS database on academic patents, in order to examine patents where academics (e.g. working at universities) are inventors.[11] Company involvement can be identified.
- Use of existing databases for specific analyses. In particular, we have been investigating the relevance of variables and terms of access to databases held by Vinnova.
- 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.
- Survey. This means a web-based or mail questionnaire distributed to a larger number of receivers.
- Case study. Data can be collected through interviews with complementary use of written documentation when available.

The main study will use most of these methodologies, as outlined below, in order to conduct a broad analysis related to specific issues.

Cases are of particular interest to this type of study. Hence, as a complement to this broader description and analysis of effects, pertaining to the entire fields of study (medtech and innovative food), we suggest the inclusion of case studies. These could focus on, for example:

- A specific research unit or research group
- A specific research project
- A specific technology
- A specific product commercialized by one company
- A specific company (established firm or start-up)

Our current proposal is that the case studies for the effects on research should focus upon the development of research units or groups. The case studies for the effects on industry should focus upon either a specific technology or product or a specific company.

The cases have two purposes, in the context of the main report. First, we envision a number of shorter cases (typically ½-2 pages), which can be used for the purpose of illustrating or

[11] 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.

exemplifying the patterns of effect that we have observed. These examples can provide a better understanding of the investigated effects, compared to the more aggregated data. Second, cases will be used as a main tool to address some of the research questions in more detail. These cases will tend to be somewhat longer. Cases may run across several key research issues and questions (as identified in next section).

During the pilot study, we have identified a number of potential cases, and important actors. In the main study, we will use this “list” and make choices in consultation with experts. How to select the objects for the case studies is of course a crucial question. Generally, valuable lessons can be obtained both by studying successful cases and failures. The former are usually easier to identify and collect data for, but some failures would be valuable to include, if possible. We suggest that the choice of cases is done during the main study, even though the interviews already done have offered opportunities to identify and discuss possible cases.

In summary, the pilot study has lead to the identification and assessment of the feasibility of a number of data and methodologies of relevance. Keeping in line with our proposal of an ambitious main study, we feel that most of these will be relevant, although some decisions require further discussion and specification during the main study.

4.3 Analysis of effects

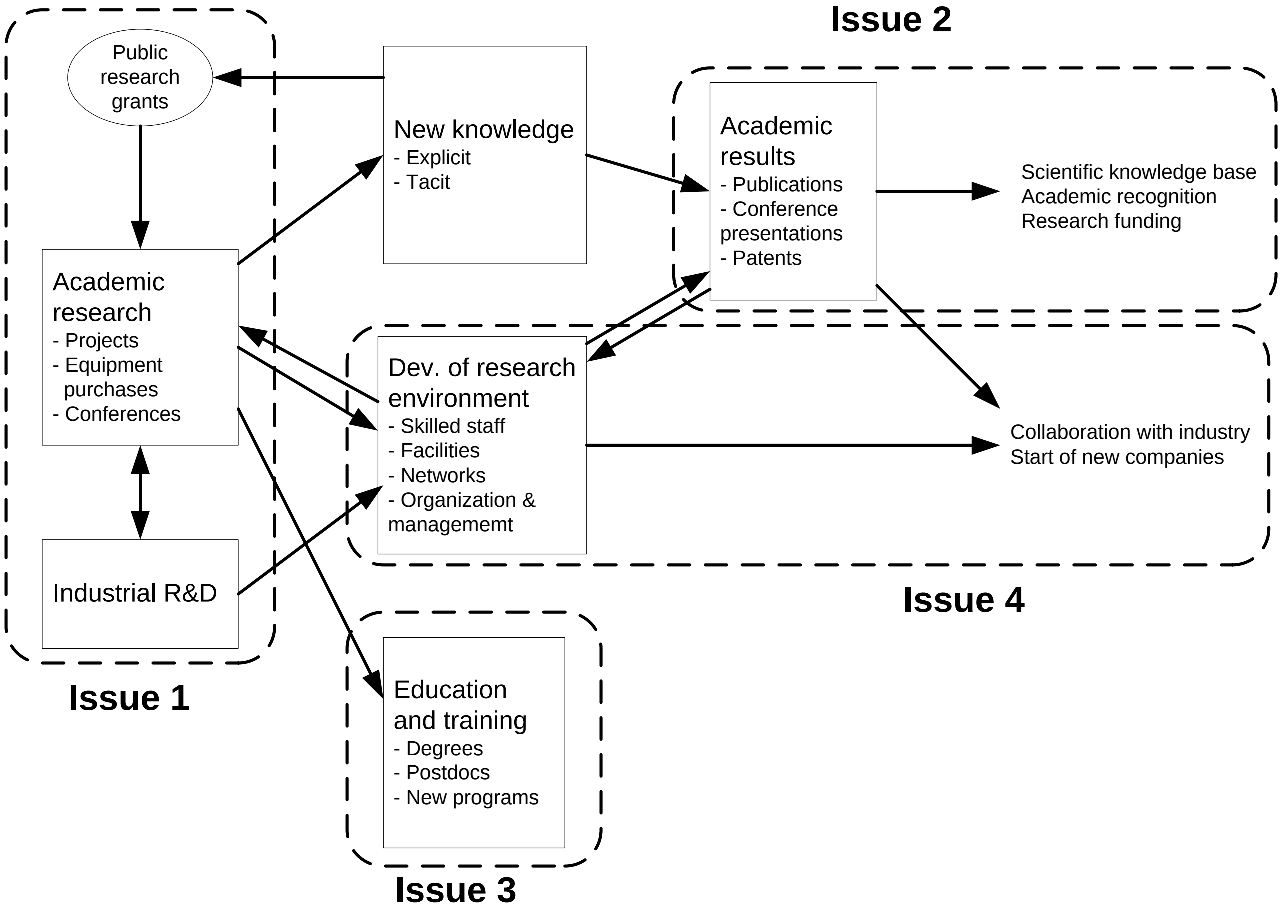
This section draws from the previous sections, in order to indicate how our proposed main study will use combinations of methods to answer specific research questions as related to effects on research and effects on industry respectively.

Our ambition is to conduct a broad analysis that covers the two research fields (medtech and innovative food) as completely as possible, with main focus on the 8+2 target programs. Departing from the key research issues (and research questions) identified below, we intend to collect data – e.g. through document analysis, interviews and surveys – that helps us to get answers that are valid for the entire fields. However, given the relative breadth of the two research fields, we must expect that there will be variation (different effect patterns) between different areas within the sub-sectors – for example, depending on what types of research activity that have been funded by Vinnova. We will try to capture these differences, if possible.

Effects on research

In terms of effects on research, we have identified four key research issues of effects over time, to be addressed in the main study. These key research issues are: 1) Development of research at universities and research institutes; 2) Long-term effects of academic research; 3) Effects of research on education and training; and 4) Development of the research environment, including collaboration with industry. Figure 5 illustrates how these focal issues relate to the effect chain model described previously.

Figure 5. Key research issues for effects on research



A first key issue is how the research at universities and research institutes has developed over the period covered by the study, that is, since the late 1980s in the case of medtech and since around 2000 for food-related research. 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 Vinnova?
- 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?

A second key issue has to do with the academic results of the research and their long-term effects:

- How have the academic publications developed over time?
- How have patenting activities developed over time?

- How has the academic results affected the research institutions, for example, with regard to academic recognition and future funding possibilities?

The third key issue concerns the effects on education and training:

- How many PhD degrees have been granted? Has this been a mechanism for diffusion of knowledge to industry or other societal actors?
- To what extent has the training of engineers been affected by the research programs?

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?
- 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?
- Has the (possible) 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?

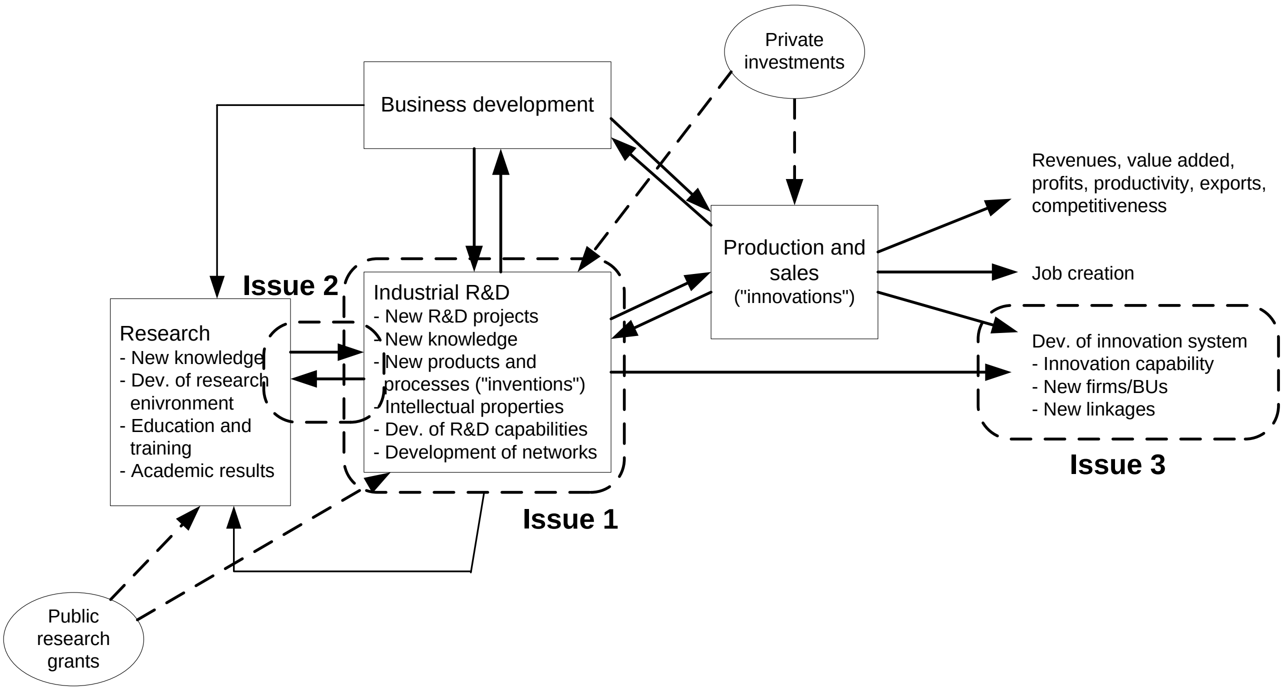
For effects on research, this longer list of questions have been synthesized and matched with proposed data and methods, in our internal-to-the-project work.

Hence, to answer these questions under the four key issues, we will use a combination of the methods mentioned above. For all questions, we will try to use existing documents (publications, reports, etc) and databases as much as possible. How far we can reach by using these sources of information is difficult to say, before starting to work actively with the material. To measure the academic results we will carry out bibliometric studies and patent analysis, where we will use well-established methods. However, we assume that much of the data we need for the analysis will have to be collected through interviews. The most important informants in this context are current and previous Vinnova officials who have been involved in the two fields (medtech and innovative food) and research leaders at key academic institutions (i.e. major receivers of grants). We believe that our interviews with industry representatives will also contribute to shed light on these issues. Case studies, based on interviews and/or existing documentation, will be used primarily related to the issue on research environments.

Effects on industry

With regard to the effects on industry, we have identified three key research issues, to be addressed in the main study. These key issues are: 1) Development of industrial R&D, especially as related to Vinnova and predecessors; 2) Development of university-industry relations; and 3) Effects on the sectoral system of innovation. Figure 6 illustrates which parts of the effect chain model that these issues mainly pertain to.

Figure 6. Key research issues for effects on industry



The first issue is concerned with how the industrial R&D has developed, and especially how this development has been affected by Vinnova's efforts. 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 Vinnova-supported 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?

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 Sweden help firms to build relationships with foreign partners?

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?

The methodological approach is basically the same as for the effects on research. However, the interviews for this part of the study will be carried out primarily with representatives of companies, for example, R&D managers and others who have been involved in commercialization of research during the relevant time periods. Needless to say, our interviews with research leaders will also be useful for this purpose (e.g., some of them may have worked in industry previously). Cases will be constructed based on data that we collect. In addition, there may be in the literature already published case stories that have relevance for our effect analysis. This remain to be verified.

5 Work plan for main study

A first step is to discuss the results of the pilot study with Vinnova, including a number of issues raised here as well as issues identified by Vinnova. Our first-hand proposal, as outlined in the preceding section, is to have an ambitious main study, covering the main effects in research and industry in the two sub-sectors.

When an agreement has been reached regarding the focus and ambition level of the main study, our work will be started during March (unless delayed by the discussions). A draft report is due 1 December 2008. The final report should be submitted by 31 January 2009.

As described above, the results from the main study will be reported under five headings, namely:

- Overview of the two sub-sectors (medtech and innovative food)
- Overview of policy/research programs
- Effects on research
- Effects on industry
- Comparisons

In addition, there will of course be a concluding chapter, including implications for public policy

The work on the five main parts of the study will require collection of primary and secondary data, analysis, and report writing. This work across the sub-sectors will to a large extent be carried out in parallel, but with emphasis on the two overviews at the beginning of the main study. This is also necessary in order to further proceed in terms of choosing case studies, sorting amongst relevant databases and interview persons, and so forth.

Like the pilot study, the main study will be carried out by the Institute for Management of Innovation and Technology (IMIT). Maureen McKelvey (project leader) and Jens Laage-Hellman will take the overall responsibility for the execution of the study. Other people will be engaged to carry out specific tasks, depending upon their specific expertise.

We propose that Vinnova organizes a reference group, with the aim of one meeting during Spring 2008 and one meeting in Fall 2008. Hence, they will give input and comments as well as help with contacts in the early and late stages of the main study. The group could consist of 4-5 persons with differing competencies, including one with a broad, historical overview of public policy in the area; one researcher with experience in commercialization; one person with a broad, historical overview of industry; and one with a current responsibility for biotechnology public policy. A balance between medical devices and innovative food needs to be found. We have developed a short list of persons meeting these criteria, as the basis for discussions with Vinnova.

This pilot study should thus be followed-up with a meeting with Vinnova, in order to discuss and specify the main study. The discussion with Vinnova about budget for the main study will of course influence the extent and coverage of the main study. This pilot study proposes a comprehensive main study covering the effect chain on research and industry, within two sub-sectors.

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