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The impacts
of research-based
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on the production
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Arend H. Zomer

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Dit proefschrift is goedgekeurd door de promotor en assistent-promotor:

Prof. Dr. J. Enders
Dr. B.W.A. Jongbloed

To Sushrut and my parents
Thank you for your love and support
You bring so much joy to my life

Overige leden van de promotiecommissie:

Prof. Dr. A.J. Groen
Prof. Dr. P. Groenewegen
Prof. Dr. A. Knie
Prof. Dr. S. Kuhlmann

Preface

Do spin-off companies make academics’ heads spin? Certainly, from time to time, the topic made my head spin. Nevertheless, I found writing this thesis a very rewarding experience and I am indebted to a lot of people that supported me in my efforts. In this preface I would like to take the opportunity to mention and thank those who provided me with new insights, practical advice, data or other kinds of support.

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Sushrut, thank you for all your patience with me, and coping with all the evening hours I did not spend with you but behind my laptop finishing this thesis.

The eagle has landed!

Arend Zomer
Enschede, December 2011

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No one should approach the temple of science with the soul of a money changer.

Thomas Browne (1605-1682)

Universities in many respects hold the key to the knowledge economy and society. It is vital that knowledge flows from universities into business and society.

European Commission (2003)

1 Introduction

For many centuries, scientific research has been the basis of many breakthroughs that have led to technological developments which benefit our society. As scientific research has become an activity funded by nation states in search of technological development for increased military potential, economic progress and social welfare, policymakers have increasingly encouraged scientific researchers to make tangible contributions to society. The general public, on its part, expects the vast amounts of public funding on scientific research to be used to benefit society. Concepts such as *'knowledge transfer'*, *'commercialisation'*, *'valorisation'*, *'academic capitalism'* (Slaughter & Leslie, 1997) and the so-called *'third mission'* of the university (Etzkowitz, 2003) have become part of the everyday paradigm of scientific researchers, university administrators and policymakers. The scientific community has become increasingly active in knowledge transfer and commercialisation, while knowledge production itself has taken on more interactive forms (Gibbons et al., 1994; Leydesdorff & Etzkowitz, 1996; Ziman, 2000). Nowadays, public research organisations, i.e., universities and non-university research organisations, engage in contract research for industry, conduct collaborative research projects with industry, apply for patents to protect and commercialise their knowledge and have started to engage in the creation of private enterprises in a systematic way. As a result, concerns have been voiced both inside and beyond the scientific community about the possible effects of these developments. Collaboration with industrial research partners might be beneficial for the research capacity of public research organisations but it could also lead to a forceful redirection of research agendas and delays in publication.

This study aims to contribute to the existing body of literature by investigating an activity which can be regarded as epitomising knowledge transfer from public research organisations to society and exemplifying innovative forms of knowledge production: the creation of private enterprises that originate from research departments of public research organisations.[1] While doing so, we focus on fields of research that have been particularly appropriate for knowledge transfer and commercialisation, and in which collaboration between scientific researchers and industry has become a mainstream phenomenon: biomedicine, computer science and nanoscience and technology (OECD, 2002). We investigate what relationships research departments maintain with their spin-off companies and whether these relationships have an effect on the research portfolios of research departments. Spin-off companies from public research organisations might yield benefits for the research departments they originate from. On the other hand, concerns are raised that activities, such as the creation of spin-off companies and collaboration with industry, could have negative repercussions.

1.1 Public sector research and the engagement in knowledge transfer

Scientific knowledge nowadays is regarded by policymakers as a key factor in contributing to wealth creation in our knowledge-driven economy (EC, 2003; OECD, 1998). In addition to the creation of novel insights of interest to the scientific community, it has become equally important for scientific researchers to create knowledge that is relevant and useful in order to address society's needs (Gibbons et al., 1994; Ziman, 2000). As a result, the value of scientific knowledge is increasingly viewed in economic and political terms (Salomon, 1985). In other words, the central questions have become: how can scientific research benefit our economy and society at large; what research should be funded, and what not; and how much research funding should be made available? In Europe, policymakers have referred to what they see as the European paradox: the inability of European countries to convert their top-level scientific output into wealth-generating technological innovations (Dosi et al., 2006; EC, 1995, 2003). As in the USA, both the European Union and its individual member states have introduced policies to promote and facilitate the transfer of knowledge between the scientific community and society. Public research organisations in OECD countries have been encouraged to engage in alliances with industry to both enhance the

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[1] Knie, A., Simon, D. (2005). PROKNOW Production of Knowledge Revisited: The Impact of Academic Spin-Offs on public research performance in Europe – Proposal No. 028577 for EU Sixth Framework Programme Priority 7; Citizens and Governance in a knowledge based society.

relevance of their research activities and to facilitate their use by industry (OECD, 2004c). In the same vein, national governments provide support specifically to small and medium-sized enterprises in the high-tech sector (Larédo & Mustar, 2004; Rothwell & Dodgson, 1992). These developments are indicative of the pressures that public research organisations are facing from their environment to expand their mission with economic and social goals (Häyrinen-Alestalo, 1999).

To encourage innovation, national governments around the globe have created programmes and organisations in order to foster knowledge transfer between science and society and to increase the commercialisation of scientific research. Examples in the USA include the Small Business Innovation Research programme, the Small Business Technology Transfer programme, the Advanced Technology Programme, the Industry/University Cooperative Research Centers and the Engineering Research Centers. The European Union supports research and knowledge transfer to society through its Framework Programmes for Research and Technological Development. On their side, many public research organisations in recent decades have set up technology incubators, technology transfer offices and science and technology parks (Djokovic & Souitaris, 2008). The USA and the UK for instance have witnessed a major increase in science parks, where companies are located close to a university, which indicates that universities and regional authorities have sought to create links with industry (Link & Scott, 2005; Monck et al., 1988). An early and well-known example of a science park is Silicon Valley in California. In addition, a major rise in the number of technology transfer offices, which facilitate patenting and licensing, has occurred in recent decades (Sampat & Nelson, 2002). Public research organisations have increasingly engaged in patenting and licensing, the creation of spin-off companies and knowledge transfer to industry (Link & Siegel, 2005; Mowery et al., 2004). Studies indicate that patenting and licensing by universities in the USA has increased significantly, almost tripling in the 1990s (Djokovic & Souitaris, 2008; Thursby & Kemp, 2002).

Several key scientific works have featured prominently in discussions about the increased engagement of public research organisations in knowledge transfer (Gibbons et al., 1994; Leydesdorff & Etzkowitz, 1996; Slaughter & Leslie, 1997; Ziman, 1994). These works claim that scientific knowledge production is increasingly motivated and steered by actors and organisations that call for economic relevance and solutions to societal problems. The New Production of Knowledge (Gibbons et al., 1994) and the Triple Helix Model (Leydesdorff & Etzkowitz, 1996) claim the collaboration between science and industry has increased, while the boundaries between the two are blurring. The Triple Helix Model expects public research organisations to retain their core research and teaching activities, and to supplement these 'core' activities with knowledge transfer and commercialisation activities. The New Production of Knowledge, on the other hand, expects boundaries to mostly disappear. A mode 2 type of knowledge production, in the New Production of Knowledge view, takes place in hybrid fora where knowledge production is application oriented. In addition, scientific autonomy and traditional ways of quality control through peer review are challenged by the need for public research organisations to be accountable to non-academic stakeholders. This may induce scientific researchers to adapt their activities and outputs to organisations they depend upon for their survival. Engagement in knowledge transfer can thus potentially have an impact on the activities and outputs of public research organisations. On these grounds, the increased engagement of public research organisations in knowledge transfer activities has led to a debate on the positive and negative effects of these activities on the research activities of scientific researchers. Policymakers have largely hailed the engagement of public research organisations in knowledge transfer and public research organisations are encouraged to engage in knowledge transfer with society. Internationally, knowledge transfer activities of public research organisations are regarded as beneficial for the economy and society at large (EC, 1995, 2003, 2005; OECD, 2001, 2004c). In the Netherlands, policymakers have voiced similar opinions. Public research organisations are expected to engage in knowledge transfer , and government bodies should encourage public research organisations to do so, according to the Ministry of Education, Culture and Science and advisory councils (AWT, 2007; Innovatieplatform, 2007; MOCW, 2005). However, researchers and public research organisations have been generally more cautious about engaging in knowledge transfer activities, fearing a decline in their traditional research and teaching roles (LERU, 2008).

1.2 Research-based spin-off companies as an entry point for empirical analysis

In this study, we focus on a specific form of knowledge transfer, spin-off companies that originate from public research organisations. For policymakers, spin-off companies are the epitomisation of knowledge transfer by public research organisations. These companies represent visible examples of commercialised scientific knowledge that contribute to the economy. Further, spin-off companies may engage in further knowledge transfer activities with public research organisations once they have been established. In the literature, the creation of spin-off companies by public research organisations is regarded as an important channel of knowledge transfer (DiGregorio & Shane, 2003;

Steffensen et al., 1999; Wright et al., 2004). Unfortunately, information about the numbers of spin-offs created within OECD countries is scattered, incomplete and in most cases not comparable because of different definitions of what constitutes a spin-off company from a public research organisation (Wintjes et al., 2002). Further, records of the creation of spin-off companies are dependent on the willingness of public research organisations to report them. Since knowledge transfer and commercialisation activities only began to become important activities for public research organisations from the late 1980s onwards, reports of the creation of spin-off companies only started to appear in the early 1990s. The number of spin-off companies created by public research organisations significantly increased in the 1990s, particularly in North America and Europe (OECD, 2001). However, there is enormous variation in the propensity to create spin-off companies among countries, and across public research organisations (OECD, 2001).

In order to give an impression of the size of the phenomenon of spin-off creation by public research organisations, we provide information from a few OECD countries. The AUTM (The Association for University Technology Managers) located in Canada and the USA conducts annual surveys on the number of spin-off companies created by public research organisations. Those reported include only spin -off companies that obtained licences from public research organisations. This means that companies founded by university staff without using technology licences are not included in the reports. We can therefore expect estimates from the AUTM to be significantly lower than the actual numbers (OECD, 2001). The AUTM reports the creation of approximately 83 spin-off companies annually from 1980 to 1993 in North America (AUTM, 2002). In the period 1994 to 1998, the number of spin-off companies created rose to an average of 281. During this period, the number of spin-off companies created per public research organisation rose from 0.6 to a little over 2. Between 1996 and 2001, the number of spin-off companies created by public research organisations in North America more than doubled (AUTM, 2002). Evidence from other countries also seems to point to an increasing number of spin-off companies being created over time, although the results are more mixed and less systematic. A study of nine public research organisations in Belgium shows that *"Belgium almost doubled its spin-off birth rate in the 1990s"* (OECD, 2001). A study of seven Finnish universities and the Technical Research Centre of Finland shows an increase in spin-off companies from 2000 to 2005 (Kankaala et al., 2007). Unfortunately the time span of this study is too short to assess any long-term shifts. Data from France shows an increase in the late 1980s and the early 1990s (OECD, 2001). In Germany, the number of spin-off companies appears to have risen from 1990 to 1997, with spin-off company creation rising from nearly 400 companies in 1991 to approximately 800 in 1995. Turning to the Netherlands, no historical information exists regarding the number of spin-off companies created by public research organisations. A study by van Tilburg and Kreijen (2003) estimated that 107 spin-off companies were created annually by public research organisations in the Netherlands, based on data from 1999 to 2001. This means that on average Dutch public research organisations created two to three spin-off companies annually.

The creation of spin-off companies by public research organisations, however, is only a small component of the total portfolio of public research organisations' knowledge transfer activities. Despite this, spin-off companies are a very visible and tangible form of knowledge transfer, and one that is popular with policymakers (Mustar et al., 2008; Rothwell & Dodgson, 1992). In the past 15 to 20 years, the creation of spin-off companies by public research organisations has received considerable attention from policymakers and the creation of spin-off companies is often associated with policies that aim to foster the creation of high-tech industries, and increase regional economic development and jobs (Bozeman, 2000; Rothwell & Dodgson, 1992). Spin-off companies exemplify how public research organisations transfer knowledge to society, and how they are engaging in new forms of scientific knowledge production by interacting with private enterprises. The creation of research-based spin-off companies can therefore be regarded as epitomising the engagement of public research organisations in knowledge transfer and commercialisation activities. This makes spin-off companies an attractive object for analysing the relationships between public research organisations and industry, and for studying the possible impacts of interactions with business on the production of scientific knowledge.

Studies looking into the impacts of knowledge transfer activities have so far focused on the effects of patenting (Geuna & Nesta, 2006; M. Meyer, 2006) and industrial funding of scientific research (Crespo & Dridi, 2007; Gulbrandsen & Smeby, 2005). The spin-off company phenomenon itself has received a great deal of attention from researchers (e.g. Djokovic & Souitaris, 2008; Mustar et al., 2006; O'Shea et al., 2007). In the literature, the concept of a spin-off company has been operationalised in several different ways and no fixed definition has been established as of yet. A literature review by Wintjes et al. (2002) has found at least ten different definitions for spin-off companies originating from public research organisations. In the broadest sense, spin-off companies can include enterprises that originate from staff and students from public research organisations or companies who use knowledge from a public research organisation . More strict definitions regard spin-off companies as private enterprises that are created based on intellectual property (IP) of a public research organisation, enterprises in which a public research organisation has made an investment or enterprises that were directly established by a public research organisation (Massing, 2001). In this study, we define a spin-off company as an organisation that has at least one of the two following characteristics: 1) its founders include employees or students from a research department and 2) its key technology originates from a research department. We take such a broad approach because we want to investigate relationships between research departments and spin-offs and the impacts of these relationships across the full spectrum of the spin-off company phenomenon. We do not want to exclude a sub-set of private enterprises emerging from public research organisations a priori.

To date, studies investigating the research-based spin-off company phenomenon, have focused on the conditions required for the initiation and development of research-based spin-off companies (Mustar, 1997; Wright et al., 2004), the role of support structures (DiGregorio & Shane, 2003; Link & Scott, 2005; Lockett et al., 2003) and the importance of research-based spin-off companies in relation to other forms of technology transfer (Rogers et al., 2001). The increased engagement of public research organisations in entrepreneurial activities has prompted a considerable number of studies that deal with the extent and the effectiveness of the commercialisation transfer process (e.g. Baldini, 2006; Bozeman, 2000; Djokovic & Souitaris, 2008; Rothaermel et al., 2007; Valentín, 2002). However, to date, no studies have looked at the effect of the relationships between spin-off companies and researchers from public research organisations on the production of scientific knowledge. Based on the New Production of Knowledge and the Triple Helix Model, one may expect relationships with spin-offs to affect the research agendas and research outputs of scientific researchers.

1.3 Research questions

Policymakers have been encouraging public research organisations to increase their knowledge transfer and commercialisation activities. At the same time, public research organisations have increasingly engaged in collaborations with industry and commercialisation of scientific research. The engagement in knowledge transfer and commercialisation is, on the one hand, hailed because such activities can increase the resource base of public research organisations. On the other hand, the engagement in knowledge transfer and commercialisation activities by public research organisations has been criticised for being detrimental to scientific research. Knowledge about the effects of knowledge transfer and commercialisation on the research portfolio of public research organisations is limited, especially with regard to spin-off companies from public research organisations. In this study, we are first of all interested in to what extent research departments within Dutch public research organisations engage in relationships with their spin-off companies. Additionally, this study aims to investigate the extent to which these relationships affect the resources that are available for research activities and how these relationships shape the research agenda and the research output of research departments. We label the combination of these three elements the research portfolio of a research department. The main research question of this thesis is:

When research departments engage in the creation of spin-off companies, do they maintain relationships with these spin-off companies and, if so, what effect do the relationships have on the research portfolios of the research departments?

In order to answer this question the following sub-questions will be addressed:

R1. What can the empirical literature tell us about the impact of knowledge transfer and commercialisation activities on the research portfolios of research departments?

This first sub-question aims to investigate what literature can teach us regarding the impact of knowledge transfer and commercialisation activities on scientific research. Numerous studies have focused on the effects of patenting, industrial funding and collaboration between scientific researchers and industry.

R2. What can we learn from organisational theory to conceptualise the relationships between spin-off companies and research departments, and the impacts of these relationships on the research portfolios of research departments?

Two organisational theories will be discussed: resource dependence theory and new institutional theory. We assume that public research organisations, as other organisations, can be characterised as open systems that support themselves by exchanging resources with their environment (J. W. Meyer & Scott, 1992) since public research organisations depend to a large extent on the system that provides them with the necessary funds and legitimacy to conduct research.

These theories will provide an interpretative framework with which we describe and analyse the relationships between spin-off companies and research departments, and the impact of these relationships on the research portfolio of research departments.

R3. What role does the environment of research departments play in shaping the relationships between spin-off companies and research departments?

An overview of processes that have occurred in the environment of research departments in the Netherlands will be provided. Such processes include rules, regulations and funding opportunities on a national level. The direct organisational environments of research departments, i.e., the research institutes and universities in which they reside, are taken into account as well since they may shape research departments' propensity to engage in relationships with spin-off companies

R4. Do research departments maintain relationships with the spin-off companies they helped to create and, if so, what is the type and intensity of these relationships?

The fourth sub-question will address empirically the extent to which research departments have engaged in relationships with their spin-off companies. We have selected eight research departments covering biomedicine, computer science and nanoscience and technology. These scientific fields have been the focus of attention of policymakers who believe that scientific research can contribute to the economy and societal problems in general.

R5. What impacts do the relationships between research departments and spin-off companies have on the research portfolios of the research departments?

This fifth sub-question will empirically investigate the impacts of the relationships on the research portfolios of research departments. We are interested in the impacts on the resources for research, the research agendas and the research output of research departments. Based on the theories we make use of, we do not expect research departments to be mere passive agents that cope with pressures from their environment, but also as agents that use these relationships to their own benefit.

R6. What differences can be observed across the relationships between research departments and their spin-off companies, and the impacts of such relationships on the research portfolios? Can the variations be explained by disciplinary and organisational backgrounds?

Based on the data that were gathered to answer sub-questions R3, R4 and R5, similarities and differences will be discussed regarding the relationships between research departments and spin-off companies, and the impacts of these relationships on the research portfolios of the research departments. The sixth sub-question seeks to compare the results of the eight case studies in terms of the different scientific fields and the organisational backgrounds of the research departments.

1.4 Relevance

This study seeks to contribute to ongoing scientific research as well as to current policy discussions. The engagement of public research organisations in knowledge transfer activities has attracted questions about the autonomy of science in contemporary society and the roles of public research organisations specifically. Among scientific researchers and policymakers, one of the main questions is whether these knowledge transfer activities influencing traditional research and teaching activities of academic researchers. Another point of interest is the extent to which researchers have engaged in knowledge transfer activities in relation to their total set of activities.

This study first of all seeks to contribute to our understanding of how the research portfolios of public research organisations evolve in response to the relationships they have with other societal actors. As we will show in Chapter 2, empirical literature is scarce on the question as to whether, and under which circumstances, research agendas, research activities and research output change when research departments engage in knowledge transfer. Second, studies concerned with the production of scientific knowledge, traditionally conducted within the Science and Technology Studies (STS) discourse, have mainly limited themselves to case study approaches without making use of sociological theory. This study attempts to employ resource dependence theory and new institutional theory to explain how research departments change as a result of pressure from their environment. In so doing, we hope to show that the behaviour of research departments can be described and explained by sociological theories not normally employed within the STS discourse, thereby promoting a more theory-driven approach to research questions with respect to the impacts of external organisations on the production of scientific knowledge. Third, the empirical analysis of public research organisations' engagement in relationships with spin-off companies can contribute to a discussion on the validity of views of the New Production of Knowledge (Gibbons et al., 1994) and the Triple Helix Model (Leydesdorff & Etzkowitz, 1996). Notions such as the New Production of Knowledge and the Triple Helix Model seek to describe the dynamics of contemporary knowledge production, focussing on the increasing collaboration between public research organisations and societal organisations. However, to date, only a few empirical studies have investigated the validity of their claims (e.g. Hessels & van Lente, 2008; Rip, 2000; Shinn, 2002). And so the question remains whether these generalised notions hold up under detailed investigation. To what extent are the boundaries of public research organisations actually blurring? Can scientific knowledge production be characterised as an activity in which multiple actors collaborate and that takes place in a context of application? These questions are also relevant to policy debates concerning the science system which have continued throughout the 1990s and the first decade of the twenty-first century. As the Triple Helix Model and the New Production of Knowledge have been used by policymakers to legitimise their efforts to increase knowledge transfer with society and commercialise scientific knowledge (e.g. Innovatieplatform, 2004), this study might be of interest to policymakers as well.

Additionally, this study hopes to show how public research organisations have responded to an environment that has become increasingly conducive to knowledge transfer and commercialisation. How do university-industry linkages develop, and to what extent are researchers responding to societal demands for relevant scientific knowledge? Further, this study may also increase our understanding of how relationships between spin-off companies and research departments shape the performance of public research organisations.

1.5 Outline

The structure of this study is a follows. Chapter 2 contains a review of the literature that discusses the current state of knowledge on the impacts of knowledge transfer and commercialisation activities on scientific research. Chapter 3 introduces resource dependency theory and new institutional theory, as the two sociological theories that form the basis of the theoretical framework for this study. This chapter concludes with a research model that will guide our empirical investigation. Subsequently, Chapter 4 presents an operationalisation of the research model and discusses methodological considerations. Chapter 5 describes the characteristics of the Dutch science system. The Dutch science system constitutes a significant part of the environment of our eight cases. The main actors, policies and developments are discussed. Further, we discuss why, and to what extent, Dutch public research organisations have started to engage in the support and creation of spin-off companies. Chapters 6 to 10 present the case studies of eight research departments that are part of five research institutes. In the case studies, we will seek to answer the third, fourth and fifth research questions. Chapter 11 proceeds with a comparison of the results of the case studies, answering whether differences can be observed in the relationships between research departments and spin-off companies, and in the impacts of the relationships on the research portfolios. Finally, Chapter 12 discusses and reflects upon the major results of the study. Here, we provide an answer to the main research question, discuss the validity of our propositions, present recommendations for further research and discuss policy implications.

2 The impacts of knowledge transfer and commercialisation activities on scientific research: a review of the literature

This chapter aims to provide an answer to the first sub-question by reviewing the empirical literature concerning the impacts of knowledge transfer and commercialisation activities on scientific research. Chapter 1 showed that public research organisations have increasingly engaged in knowledge transfer and the commercialisation of scientific knowledge. Especially in technology-oriented research fields, scientific researchers have increasingly engaged in knowledge transfer through collaborations with industry, patenting and the creation of spin-off companies. Academics have dedicated significant efforts to describing and analysing this trend. Empirical studies dealing with the effects of knowledge transfer and commercialisation on scientific research started to appear in the 1980s. Initially in the US, and later expanding to Europe and Australia, these studies have investigated the effects of patenting, industrial funding and other types of knowledge transfer between scientific researchers and industry. In this chapter, we have organised the empirical studies around three themes: resources for research (Section 2.1), research output (Section 2.2), and norms and preferences of scientific researchers (Section 2.3). The literature review in this chapter is based on a systematic review of articles in journals in higher education studies, science and technology studies (STS) and innovation studies over the past thirty years. Additional studies were identified by searching the reference lists of the found articles. After the review of the empirical literature, we take stock in the closing section, suggest topics for further research and answer our first sub-question.

2.1 Knowledge transfer, commercialisation, and resources for research

One of the most important reasons for scientific researchers to collaborate with industry and other societal organisations is to obtain monetary resources, thereby complementing institutional funding and research funding from research councils (Harman, 1999; Lee, 2000; Meyer-Krahmer & Schmoch, 1998; Slaughter & Leslie, 1997; Welsh et al., 2008). A study among Norwegian researchers showed that industry-funded researchers complement their existing funding in order to conduct expensive research projects (Gulbrandsen & Smeby, 2005). Seashore-Louis et al. (2001, p.243) report that there is a "*positive relationship between entrepreneurship and the size of [the] research budget…*". This could be the result of a 'star' scientist being able to be engaged in both excellent research and entrepreneurship, or a 'star' scientist who is able to bring in more research funding from industry than his or her less successful colleagues. A study by Geuna and Nesta (2006), which focused specifically on the effects of patenting, came to the tentative conclusion that there had been a growth in university patenting, but that patenting is not profitable for most public research organisations. There are some exceptions where substantial revenues are generated. Nelson (2001), estimates that many universities spend considerably more in operating their patenting and licensing offices than they bring in through license revenue.

In addition to monetary resources, knowledge transfer and commercialisation activities can provide access to information, research equipment and prestige. According to Welsh et al. (2008), contacts with industry can benefit scientific knowledge production not only through boosts in research funding but also by improving access to test data, equipment and facilities. Information from industry can be used to increase the understanding of research problems and their relevance for society as well as providing the ability to test hypotheses (Lee, 2000; Slaughter & Leslie, 1997). Furthermore, respondents in Lee's study mentioned that contributing to the university's mission, creating student jobs and internships, gaining practical knowledge and creating business opportunities were all motivations for scientific researchers engaging in relationships with industry. Contacts with industry help scientific researchers identify fundable basic research questions, introduce new research topics and gain access to unpublished data (Meyer-Krahmer & Schmoch, 1998; Senker & Senker, 1997). Overall, knowledge transfer with industry appears to be the second most important reason for engaging in exchange relationships with industry next to the acquisition of research funding (Meyer-Krahmer & Schmoch, 1998). Scientific researchers recognise that, in their relationships with industrial research partners, they are able to gain access to equipment and materials (Crespo & Dridi, 2007; Lee, 2000; Meyer-Krahmer & Schmoch, 1998; Slaughter & Leslie, 1997). This access to equipment is important to many scientific researchers in technical scientific fields since equipment is an expensive factor in scientific knowledge production in these fields. According to Slaughter and Leslie (1997), engagement in knowledge transfer activities and commercialisation increases the prestige of individuals and public research organisations as it shows they are able to produce knowledge that has a societal relevance and that is commercially exploitable.

2.2 Knowledge transfer, commercialisation, and research output

Studies investigating the effects of engagement in knowledge transfer and commercialisation activities by scientific researchers have also looked at how these activities affect research outputs such as peer-reviewed publications and patents. A significant number of studies report positive effects on scientific output: (Blumenthal, Gluck, Seashore-Louis, Stoto, et al., 1986; Gulbrandsen & Smeby, 2005; Harman, 1999; Lebeau et al., 2008; Ranga, 2003; Seashore-Louis et al., 2001; Senker & Senker, 1997; Zucker & Darby, 1996). Blumenthal, Gluck, Seashore-Louis, Stoto et al. (1986) conclude that biotechnology researchers who have industrial support publish at higher rates than their peers who lack industrial support. Their study was based on a survey of approximately 1200 researchers in US universities. The authors provide three possible explanations for this higher productivity: 1) industry might support researchers who are already highly productive; 2) the relationship might enhance the performance of researchers by adding research capacity; and 3) relationships with industry may provide new perspectives on scientific research. However, the results of this study have been challenged by Senker and Senker (1997) who find negative effects on scholarly output. Senker and Senker (1997) claim the conflicting findings stem from the fact that the sample of Blumenthal, Gluck, Seashore-Louis, Stoto et al. (1986) was biased towards cutting-edge scientific researchers, who are favoured by industry in biotechnology-related fields. A study by Harman (1999), found that scientific researchers who were funded by industry usually had better publication records, and in the preceding three years had published twice as much as their non-industry-funded colleagues. This study was based on a survey of 200 researchers in three Australian universities. Gulbrandsen and Smeby (2005) found a significant positive relationship between industrial funding and the number of scientific publications in a survey of 1967 researchers in four Norwegian universities. A case study centred on the Catholic University in Leuven comes to the conclusion that a positive relationship exists between high publication output and industrial funding (Ranga, 2003). The number of publications is positively correlated with the acquisition of contract research funding according to this study. Zucker and Darby (1996) concluded that commercial involvement by scientific researchers is associated with a higher scientific output as measured by citations. The authors hypothesise that resources from private companies lead to a higher research capacity and consequently more publications. Lebeau (2008) concludes that collaboration with industry is far from detrimental to scientific research and actually increases scholarly output significantly. Joint university-industry papers, on average, have higher impact scores than papers authored only by scientific researchers from public research organisations.

However, three publications report negative effects of industrial funding on scientific output (Gluck et al., 1987; Goldfarb, 2008; Senker & Senker, 1997). Based on a survey of 693 graduate students and post-doctoral fellows, Gluck, Blumenthal et al. (1987, p. 327) conclude that "*industry support is associated with fewer or delayed publications*…". The authors believe there are two possible explanations. First, industrial support may be directed towards applied projects that lead to fewer publications. Second, researchers who are more productive in scientific terms might acquire funding from other types of sources than those who are less productive. In another study, Senker and Senker (1997) found that there was a negative relationship between engagement in collaboration with industry and publication rates. According to them, the benefits of collaboration with industry appear to be closely associated with the interests of specific individuals, and the way in which they interpret their role in the university. A third study, conducted by Goldfarb (2008), focused specifically on universities in the USA collaborating with NASA. Goldfarb concludes that maintaining a relationship with a research sponsor reduces publication output. This suggests, according to Goldfarb, that pursuing goals that are not purely academic in nature reduces scientific output. The three studies by Senker and Senker (1997), by Gluck, Blumenthal et al. (1987) and by Goldfarb (2008) are the only three studies that come to the conclusion that interactions with industry lead to lower performance in terms of scientific output.

Three further studies paint a mixed picture with regard to the effects of industrial funding on scientific output. In an article following their 1986 publication, Blumenthal and colleagues add extra detail to their findings that biotechnology researchers with industrial support publish at higher rates than scientific researchers lacking such support (Blumenthal et al., 1996). Based on survey results from 2052 respondents, they concluded that scientific researchers in the life sciences who receive funding from industry published more peer-reviewed articles than those who did not. However, scientific researchers who received more than two-thirds of their research support from industry were less productive than those receiving a lower level of industrial support. Furthermore, their published articles were less influential than articles by scientific researchers with no industrial support. The authors have two explanations. The difference may be caused by the fact that the scientifically less successful researchers have more difficulty in acquiring research funding from federal and other non-industrial sources. Geuna and Nesta (2006) believe that the claim of Blumenthal et al. (1996), that industry funded researchers on average produce more journal articles, does not hold true for all scientific fields. According to Geuna and Nesta, the data of Blumenthal et al. (1996) show that, in certain fields, what matters is not industrial funding but external funding in general, which in turn is related to higher scientific output. Godin and Gingras (2000) report no negative effect on the number of publications of scientific researchers who collaborate with industry. Their study was based on publications by Canadian researchers contained in the science citation index over the period from 1980 to 1997. Further, the impact of articles written without involvement of non-university authors did not seem to be significantly higher than articles written in collaboration with non-academic partners. Another Canadian study finds that collaboration with industry does not negatively influence the number and quality of publications (Crespo & Dridi, 2007). On the contrary, most researchers benefit from these collaborations by increasing their volume of publications. A study by Seashore-Louis et al. (2001) concludes that scientific researchers who are engaged in entrepreneurial activities are highly productive in terms of scientific output. However, this is because of their research budget and position within the university, not the amount of industrial funding they receive. Here, entrepreneurial behaviour is defined as patenting, creating spin-off companies or receiving research support from industry.

Some studies have specifically focused on the impact of patenting and licensing on scholarly output. A study by Meyer (2006) focuses exclusively on patenting by nanotechnology researchers in Germany, the United Kingdom and Belgium. He compares the publication and citation performance of scientific researchers who patent to those who do not. He concludes that patenting is not related to lower publication and citation rankings. Moreover, "… *inventor-authors are prolific in terms of publication frequency and have achieved a position of considerable centrality in national networks. Inventor-authors are also over-proportionally represented among highly cited authors.*" (M. Meyer, 2006, p.1654) This corresponds with the findings of Azagra-Caro et al. (2006) who observe, in case studies of universities, that patenting activity tends to be associated with prestigious research departments and laboratories, and that scientific researchers who patent represent a small minority of their publishing peers. Another study by Buenstorf (2009) reports that inventors whose technologies had been licensed to the private sector had more publications and citations. According to Czarnitzki et al. (2009), there is a positive relationship between patenting and the quantity and quality of publications. However, when they distinguish between patents that are owned by industry and by public research organisations, they find that industry-owned patents correlate with a lower number of publications, whereas patents owned by a scientific researcher or a university correlate with a higher than average number of publications. These authors hypothesise that patents owned by researchers or universities correlate with higher than average publication volumes because *"the research projects are likely to be closer related to basic research than projects with business partners."* (Czarnitzki et al., 2009, p.33)

Empirical studies investigating the effects of knowledge transfer and commercialisation activities on other types of research output such as patents and commercial products are less common than studies investigating the impacts on publications. In total, three studies were found: Azagra-Caro et al. (2006), Blumenthal, Gluck, Seashore-Louis, Stoto et al. (1986) and Gulbrandsen and Smeby (2005). According to these studies, industrial funding correlates with a higher than average production of patents. In addition, Gulbrandsen and Smeby (2005) conclude that industrial funding correlates with a larger number of commercial products, spin-off companies and consultancy activities.

Finally, we discuss two empirical studies that report on the impact of spin-off company creation by scientific researchers on their research productivity. Lowe, et al. (2007) found that researchers at public research organisations who create spin-off companies are, on average, more productive researchers than their peers, even before they started a firm. They are also more likely to be high impact scientists. This implies that the creation and further development of a firm is rather disconnected from research output. Research output is largely dependent on the characteristics of the scientific researcher, not on the fact that a company created by the scientific researcher contributes to the research portfolio. A study by Buenstorf (2009) reports that there is no evidence to support the view that engagement in 'inventive activities' by scientific researchers is not incompatible with academic research. The study reports a weak but positive link between engagement in the creation of spin-off companies and research productivity. At the same time, the study indicates that the long-term effects of engagement in the creation of spin-off companies *"may be detrimental to the quantity and quality of a researcher's output"* (Buenstorf, 2009, p.290).

2.3 Knowledge transfer, commercialisation, and norms, preferences and open communication

One of the pivotal questions in empirical studies addressing the impacts of knowledge transfer and commercialisation activities by scientific researchers is whether these activities have an effect on the norms, preferences and open communication in the scientific community. In scientific journals, as well as in the mainstream media, cases have surfaced in the past 20 to 30 years in which industry-funded scientific researchers appeared to be forced by private companies to adjust their results or to exclude certain results from publication (e.g. Crumpton, 1999; Healy, 2002; Olivieri, 2003).

Studies focussing on the impact of knowledge transfer and commercialisation activities on openly communicating scientific results report that the more faculty members are involved in entrepreneurial activities the more likely they are to encounter secrecy (Seashore-Louis et al., 2001). Blumenthal, Gluck Seashore-Louis and Wise (1986) found that 40% of scientific researchers in the life sciences who receive support from industry perceive unreasonable delays in the publication of new findings as a possible risk. Fifty-three percent of their non-industry-funded colleagues recognised the same risk. Another publication by Blumenthal and colleagues reported that scientific researchers who collaborate with industry tend to be less open about sharing information, especially when commercial applications are anticipated (Blumenthal et al., 1997). The study also finds that scientific researchers are sometimes constrained by industry in sharing information with peers. Overall, scientific researchers sponsored by industry are more inclined to withhold information. Furthermore, scientific researchers supported by industry are less worried about the effects of this on the open communication of science than their non-sponsored colleagues.

Several empirical studies have investigated whether industrial funding and commercialisation activities have affected the norms and values of scientific researchers. Studies find that scientific researchers who are engaged in patenting or who receive funding from industry, remain committed to the scientific ideals of open communication of science and addressing basic research questions (Allen & Norling, 1990; Blumenthal, Gluck, Seashore-Louis, Stoto, et al., 1986; Crespo & Dridi, 2007; Harman, 1999; Lee, 2000; Seashore-Louis et al., 1989; Ylijoki, 2003). Engagement in knowledge transfer and commercialisation activities thus far does not seem to have destroyed traditional academic values as researchers are increasingly engaging in entrepreneurial activities (Ylijoki, 2003). Crespo and Dridi (2007) found that, in order to conduct basic research, scientific researchers would agree to pursue some intermediate applied research objectives which would provide industrial funding. They will do this to maintain their research capacity. In so doing, scientific researchers attempt to compromise in order to conduct basic research. A study by Senker and Senker (1997) found that scientific researchers involved in a scheme that promoted collaboration with industry, deemed it more important to apply academic knowledge than their colleagues not involved in the scheme. According to the authors, this does not imply that the scheme changed the norms and values of the scientific researchers involved. They suggest that scientific researchers chose to get involved in the scheme because their attitude towards the application of knowledge was more positive than that of their colleagues. Overall, there is no clear evidence in the literature that entrepreneurial activities by researchers are in principle incompatible with the traditional scientific values of open communication and the pursuit of basic research. On the contrary, most studies show that scientific researchers appear to be able conduct research into basic scientific problems while, at the same time, conducting research for industry (Ylijoki, 2003). Zucker and Darby (1996) however suggest that although commercialisation activity yields short-term growth, this may be offset in the future if the development of basic research is adversely affected. A study among life science researchers in the USA, funded by the National Institutes of Health, reported that although only 0.2 to 0.5% of the respondents in this study admitted *"falsifying or cooking research data"*, between 9.5 and 20.6% of the 3247 respondents admitted they had changed *"the design, methodology or the results of a study in response to pressure from a funding source"* (Martinson et al., 2005, p.737). These somewhat worrying findings imply that these scientific researchers are indeed susceptible to pressures from a source that funded their research, and found it acceptable that funding sources should influence their research activities.

We identified three studies that investigated whether there is a relationship between the funding source of a scientific study and its outcome. These studies investigated the outcomes of tests of medical treatments in clinical trials. A study conducted by Davidson (1986) investigated 107 journal papers that compared the performance of rival drugs in clinical trials. In each study, the drug produced by the sponsor of the research was found to be superior. This comparison raises doubts about the reliability of these studies and suggests that sponsors of clinical research can have an impact on the outcomes of scientific research. Another study, conducted by Friedberg, Saffran et al. (1999), found a statistically significant relationship between the funding source of medical trials and the reported conclusions. Five percent of the published reports on new drugs from industrial sponsors gave critical assessments, whereas 38% of independently funded reports were unfavourable to new drugs. A study by Stelfox, Chua et al. (1998) investigated 70 articles concerning the effectiveness of a drug for treating high blood pressure. The results of the study showed a strong association between the claimed safety of the treatment and financial ties with the producer of the treatment. In the articles investigated, the study found that 96 % of the authors of the favourable articles had financial ties with the manufacturer of the treatment, whereas 60% of the authors of neutral articles had such ties and only 37% of authors of critical articles had financial ties. The authors concluded that *"pharmaceutical industry has an important and constructive role in academic medicine"* and that medical professionals should be able to evaluate articles in the light of possible conflicts of interest, thus calling for a disclosure of funding sources and financial ties (Stelfox et al., 1998, p. 105). The results of these studies suggest a relationship between funding source and the outcomes of scientific research: scientific researchers appear to be susceptible to pressures from organisations that fund their research activities.

The large majority of studies concerned with the effects of industrial funding on the research agendas of scientific researchers suggest that scientific researchers who receive support from industry are more applied than their colleagues. According to Blumenthal, Gluck, Seashore-Louis, Stoto et al. (1986), university staff supported by industry are influenced four times as often by commercial considerations as other faculty members and there is a tendency to shift research in applied directions. Harman (1999) found it was twice as likely that industry-supported staff would select research topics based on commercialisation opportunities. Other studies, by Gulbrandsen and Smeby (2005), Godin and Gingras (2000) and Zucker and Darby (1996), also suggest that industrial funding is linked to applied research rather than to basic research. A study by Crespo and Dridi suggests that scientific researchers who are engaged in partnerships with industry are able to *"conduct basic research while doing applied research"* (Crespo & Dridi, 2007, p.72). This implies that, although the focus of research departments shifts to more applied research due to industrial funding, research departments are still able conduct basic research. Another study, by Senker and Senker (1997), found that even in research departments with high involvement in a government funding scheme to promote university-industry interaction, most individual academics continued to pursue their own research interests. However, one should note that this is the only study concerned with a government funding scheme promoting university-industry interaction to feature in our literature review. The two studies of Crespo and Dridi (2007) and of Senker and Senker (1997) that detected no shift towards applied research are based on interpretations of data from interviews and questionnaires. The other studies that found a shift towards more applied research employed larger datasets. Senker and Senker (1997) report that, in addition to monetary resources, industrial funded research provides scientific researchers with knowledge that helps them to identify new basic research questions. A study by Gulbrandsen and Smeby (2005) reported similar findings. Industry-funded researchers report that industrial funding brings in new and interesting research topics. However, these studies do not provide a definitive answer to the question as to what extent scientific researchers change their research themes due to their relationships with industrial research partners.

2.4 Conclusions

This chapter has provided a literature review presenting the evidence regarding the impact of knowledge transfer and commercialisation activities on scientific research. Most of the empirical studies we identified were interested in the impact of industrial funding, collaborative research with industry, and patenting and licensing. Empirical studies show that overall, collaboration with industry creates additional research capacity, provides access to test data and research agendas, and inspires research agendas. Patenting and licensing, on the other hand, do not generally lead to an increase in the resource base of public research organisations. While empirical studies find that collaboration with industry and engagement in commercialisation activities are not detrimental overall to the open communication of science, studies focussed on the life sciences provide less reassuring results. These studies indicate that scientific researchers are influenced by their research sponsors and may be willing to adjust their outputs. Further, a majority of the studies conclude that knowledge transfer and commercialisation activities are related to applied research conducted by scientific researchers. With regard to the output of scientific researchers, most studies come to a moderately positive conclusion: industrial funding and patenting are related to greater numbers of publications and citations. There are some exceptions among these studies with some reporting lower publication rates because of overdependence on industrial funding. Additionally, industrial funding is related to an increase in the development of commercial products, the creation of spin-off companies and consultancy activities. Based on this literature review, we expect relationships with spin-off companies to have an impact on the research portfolios of research departments. However, we still do not know under which circumstances, and to what extent, their research portfolios are affected. This knowledge would also benefit the broader discussion on the impacts of knowledge transfer and commercialisation activities. Given the fact that we did not find any empirical studies that examined the situation in the

Netherlands, our study could shed light on the impacts of knowledge transfer and commercialisation activities in a country that has been very active in supporting scientific researchers to engage in these types of activities.

Studies concerned with the impacts of spin-off company creation and collaboration with spin-off companies on scientific research are still scarce. The large body of literature on spin-off companies has focused on factors contributing to their success and failure, the role of support structures, the networks that spin-off companies have and the importance of spin-off company creation in relation to other forms of knowledge transfer by public research organisations (Djokovic & Souitaris, 2008; Mustar et al., 2006; O'Shea et al., 2007). The two studies that we did find that were concerned with the impacts of spin-off companies dealt with the effects on research output. Spin-off companies appear to be related with higher research productivity but it is unclear whether these spin-off companies actually contribute to the productivity of scientific researchers. Further, research concerning the impacts of spin-off companies would benefit from a broadening of the range of impacts considered. The impacts of relationships with companies spun off from public research organisations possibly also extend to the research agendas of research departments and the resources for research they have at their disposal.

We believe that studies on the impacts of knowledge transfer and commercialisation activities could benefit from the use of theoretical insights. The bulk of the existing empirical studies consist of quantitative analyses which have yielded valuable insights. However, the studies we identified only used theoretical concepts in a few instances to explain how knowledge transfer and commercialisation activities affected the research activities of scientific researchers. One of the goals of this research will therefore be to construct a theoretical framework that can be used as an interpretative framework for studying the impacts of knowledge transfer and commercialisation activities on the production of scientific knowledge. Such a framework will hopefully contribute to an understanding of the factors and the circumstances under which research departments are affected by their relationships with industrial research partners. This in turn might lead to a better understanding of how research departments accommodate knowledge transfer and commercialisation activities in their research portfolios. Are research and knowledge transfer complementary activities for research departments? Are knowledge transfer activities an integral part of their research portfolios, or do these activities take place in relative isolation in order not to disturb the research activities that the research departments are engaged in?

3 Theory, research model and propositions

In Chapter 2 we discussed the current body of literature investigating the impact of industrial funding and commercialisation activities on public research organisations and their activities. We concluded that the discussion would benefit from an interpretative theoretical framework to clarify under what conditions and in which ways research departments engage in relationships with their spin-off companies, and under what circumstances these relationships have an impact on their research portfolios. In this chapter, we aim to provide an answer to the third research question: what can we learn from organisational theory to conceptualise the establishment of relationships between spin-off companies and research departments, and the impact of these relationships on the research portfolios of research departments? Based on a discussion of two theories, resource dependence theory and new institutional theory, we develop our theoretical framework.

3.1 Conceptualising the behaviour of public research organisations

A major assumption in our approach is that scientific knowledge production is a social activity. The importance of social factors, including the context or environment in which knowledge production occurs, is widely acknowledged within the sociology of science (Knorr-Cetina, 1981; Latour & Woolgar, 1986; Pickering, 1992). We assume that public research organisations can be characterised as open systems that support themselves by exchanging resources with their environment (J. W. Meyer & Scott, 1992). Resource dependence theory (Pfeffer & Salancik, 1978) and new institutional theory (J. W. Meyer & Rowan, 1977) acknowledge the dependency of organisations on their environment since organisations regard the environment as providing critical resources for them. Organisations need to take into account demands from their environment if they are to secure these resources. Both resource dependence theory and new institutional theory see organisations as persistent structures that are constantly reinterpreted and negotiated. Resource dependence theory considers the survival of organisations as an activity of managing environmental requirements in order to acquire critical resources. New institutional theory focuses on external norms and rules which organisations are following in order to maintain their legitimacy and thereby secure critical resources. Organisations interact with an indeterminate and constantly changing environment that consists of a multitude of organisations, each with its own interests. Research departments as organisations exist under similar circumstances. Research departments need to take account of the demands of scientific peers, funding agencies, societal partners and the research organisation they are part of, in order to acquire vital resources that enable them to conduct their research activities. However, organisations are not simply imprisoned by their environment. Organisations can be interest-driven and base their behaviour also on internal conditions as well as demands from external organisations (Pfeffer & Salancik, 1978). Thus, we can expect the research portfolios of research departments to be shaped by the external conditions they are confronted with as well as by internal conditions. This study seeks to employ both resource dependence and new institutional perspectives as interpretative frameworks for the empirical observations that which will be made in Chapters 5 to 10.

3.2 Resource dependence theory: main concepts and critiques

Resource dependence theory considers the survival of organisations as an activity involving the management of environmental requirements in order to acquire critical resources (Pfeffer & Salancik, 1978). According to Pfeffer and Salancik, it is necessary to understand the context in which organisations operate in order to understand the behaviour of organisations because: *"the dominant problems of the organisation have become managing its exchanges and its relationships with the diverse interests affected by its actions"* (1978, p.94). The environment of an organisation is assumed to contain scarce and valued resources essential to organisational survival. The organisation is dependent on this environment for its survival since the environment supplies the organisation with the resources necessary to execute activities. Organisations which lack essential resources will seek to establish relationships with other organisations in their environment in order to obtain the needed resources (Pfeffer & Salancik, 1978).

Organisations strive to achieve two related objectives: 1) the acquisition of resources while minimising their dependence on other organisations, and 2) control over resources to maximise the dependence of other organisations on themselves (Pfeffer & Salancik, 1978). In both cases, organisations have an interest in reducing uncertainty in their dependencies on organisations in their environment. For any given organisation to be effective in securing resources, it will need to produce outcomes acceptable to the organisations it depends upon.

This will persuade organisations in the environment of the focal organisation to provide resources to the focal organisation. The assumption of resource dependence theory, that organisational survival depends on the environment of an organisation, implies that an organisation has to take account of the wishes of organisations in its environment. "*A variety of interest groups, individuals, and organisations have contact with a given focal organisation; each of these evaluates the organisation and reacts to its output and actions. Each has a particular set of criteria of preferences that it uses in this evaluation process …*" (Pfeffer & Salancik, 1978, p.32). So, different individuals, groups or organisations in the environment may have different preferences for evaluating an organisation (Pfeffer & Salancik, 1978). Organisations in the environment of the focal organisation might even have conflicting preferences, based on which they will evaluate the effectiveness of the focal organisation. For the focal organisation, it is therefore important to know which organisations hold power over the allocation of vital resources. In order to survive, organisations need to maintain a 'coalition of support', i.e., organisations willing to contribute resources to the focal organisation. Since organisations need to take account of several other organisations, individuals and institutions for their survival, the demands from one organisation in the environment are not translated routinely into changes in the behaviour of the focal organisation. As organisations often need to take into account several, maybe conflicting, demands, it is likely that they will not always be able to satisfy all the demands of organisations in their environment without acting strategically in their actions and communications to these organisations.

The dependence of a given organisation on other organisations is based on the amount of resources these organisations are willing to provide to the focal organisation and the number of alternative sources the focal organisation can turn to. The dependency relationships that arise allow organisations in the environment of the focal organisation to influence the behaviour of the focal organisation. However, these also allow the focal organisation, to some extent, to have an influence on organisations in its environment. In order to increase their chances of survival, organisations will attempt to limit their dependencies. If the dependence on a resource is low, resistance towards the criteria of any organisation offering only this type of resource to the focal organisation represents a minimal risk because it "*is no longer held captive by a single or limited number of sources of social support, resources or legitimacy*" (Oliver, 1991, p.164). Organisations will attempt to obtain power and autonomy[2], thereby limiting their

[2] We define autonomy as the capacity of an organisation to determine its own actions through independent choice within a system (Ballou, 1998). We define power as the ability of organisations to influence the behaviour of other organisations.

dependencies and reducing uncertainty regarding external pressures and demands (Pfeffer & Salancik, 1978). The dependency of organisations can vary due to a number of issues. According to Pfeffer and Salancik: "*Dependence can […] be defined as the product of the importance of a given input or output to the organisation and the extent to which it is controlled by a relatively few organisations. Also, regardless of how important the resource is, unless it is controlled by a relatively few organisations, the focal organisation will not be particularly dependent on any of them. When there are many sources of supply or potential customers, the power of any single one is correspondingly reduced*" (Pfeffer & Salancik, 1978, p.51).

According to Pfeffer and Salancik (1978) exchange relationships between organisations can involve monetary resources, physical resources, information and legitimacy. Monetary resources cover financial means such as currency and also stocks and bonds. Physical resources are composed of raw materials, production equipment and infrastructural assets. Information involves knowledge about the environment of the focal organisation based upon which an organisation can produce outputs desirable to organisations in its environment. Information also consists of knowledge, e.g., a patent or ideas that lead to new research questions. Legitimacy can be defined as the "*generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within a social system*" (Suchman, 1995, p. 574). A focal organisation that acquires legitimacy will find that organisations in its environment are willing to support the focal organisation by endorsing its activities or by contributing resources

Resource dependence theory assumes that the dependency of an organisation on its environment is shaped by its own preferences as well as the preferences of organisations in its environment. Thus, even though resource dependence theory predicts that the behaviour of an organisation is linked to external requirements, it is not necessarily the case that external requirements automatically dominate its behaviour or cause an organisation to change its behaviour. An organisation may make active choices to manage its dependencies on those parts of its environment which control vital resources. In so doing, an organisation aims to secure a steady flow of resources, anticipate developments in the environment, respond to threats and opportunities in its environment, expand its resource base and decrease uncertainty regarding the acquisition of resources (Pfeffer & Salancik, 1978). Organisations will select, from within its environment, other organisations from which to obtain resources. Often, an organisation will have several alternatives to choose from, and will choose the ones that best suit its interests (R. H. Hall, 1999). According to Pfeffer and Salancik (1978), an organisation can respond to demands by complying with them, by attempting to avoid these demands or by managing the conditions it is confronted with. While an organisation might comply with environmental demands, complying as a response mechanism might not be in the long-term interest of the organisation. According to Pfeffer and Salancik *"compliance is a loss of discretion, a constraint and an admission of limited autonomy"* (Pfeffer & Salancik, 1978, p.94). As a result, organisations often aim to avoid such a situation. An organisation can avoid undue influence by taking actions to reduce the probability of being subjected to external demands. Although it might not be possible to counter all demands from its environment, it may avoid the possibility of being influenced by one or more organisations in its environment. Managing those conditions which demand compliance in the first place can possibly be achieved by restricting information that will give insight into performance, controlling the performance, controlling the formation of demands or by controlling the information needed for performance assessments. Further, the focal organisation might present information about its performance in a way that suits itself best. A focal organisation may present information that is relevant to particular organisations in the environment, or the focal organisation can selectively present information that highlights its achievements and not its unachieved goals.

According to resource dependence theory, there are several types of constraints that limit the adaption to demands of other organisations in the environment. First of all, conflicting demands might limit the focal organisation's ability to adopt a behaviour that suits one or more of the organisations in its environment that it obtains resources from. According to Pfeffer and Salancik (1978), organisations in this situation will develop a strategy that will secure the largest amount of resources for the longest time possible and with the lowest risk. Internal preferences and external demands may also conflict, limiting adaptation to external demands.

Resource dependence theory has received a number of critiques. Resource dependence theory perceives organisations as rational actors that maximise their resources. By assuming this, resource dependence theory overlooks the unconscious imitation of behaviour by organisations and normatively-based conformity that mitigates or limits autonomous decision-making (Tolbert & Zucker, 1996). In a turbulent environment, in which unclear and competing demands are often present, organisations may imitate other organisations. In such an environment, organisations may also take into account norms and rules that are prevalent in their environment to retain legitimacy. Such actions are not well explained from the perspective of an organisation as a resource maximiser. Another critique, by Hall and Taylor (1996), pays attention to the fact that actions by organisations are not only dependent on external dependencies, but also on previous decisions by the organisation. Past choices which cannot be changed overnight, such as investments in physical resources and the employment of staff with a certain expertise, may make one option more appealing than another for an organisation.

3.3 New institutional theory: main concepts and critiques

New institutional theory, like resource dependence theory, assumes that organisations take account of their environment in order to survive (Oliver, 1991). Organisational responsiveness to demands from external organisations, and anticipating future demands from external organisations, is vital for organisational survival (J. W. Meyer & Rowan, 1977). According to new institutional theory, organisations are institutionalised, i.e., they adhere to norms and rules in their environment (DiMaggio & Powell, 1983; J. W. Meyer & Rowan, 1977; Scott, 1987b). A focal organisation will seek to attain legitimacy, which in turn will lead to the acquisition of vital resources from organisations in its environment.

According to new institutional theory, the environment of an organisation is dominated by rules, taken-for-granted assumptions, myths and routines about what constitutes appropriate or acceptable behaviour for the organisation (DiMaggio & Powell, 1991; J. W. Meyer & Rowan, 1977). Organisations are part of an organisational field, i.e., *"those organizations that, in the aggregate, constitute a recognized area of institutional life: key suppliers, resource and product consumers, regulatory agencies, and other organizations that produce similar services or products"* (DiMaggio & Powell, 1983, p.143). In every organisational field, beliefs exist regarding the way organisations should structure themselves and respond to changes in their environment. An organisation may be unaware of these rules and norms, or follow them blindly. Or, an organisation may comply consciously and strategically in anticipation of specific self-serving benefits (Scott, 1987b). If an organisation is effective in showing that it is acting in good faith, and complies with rules and norms in the environment, it will obtain legitimacy from organisations in its environment. In turn, this legitimacy allows the focal organisation to perform certain tasks and to obtain resources that are necessary for its survival. As such, the survival of an organisation is therefore linked to the extent of compliance to these institutional norms and rules. New institutional theory assumes that organisational behaviour is best explained by external pressures, and not by the preferences and actions of the focal organisation itself. An organisation will prefer to engage in conformist behaviour because non-conformist behaviour threatens the legitimacy of the organisation. As a consequence, new institutional theory expects organisations within a certain organisational field to develop a high degree of homogeneity over time since the same institutional pressures apply to them (DiMaggio & Powell, 1983).

The institutional environment imposes constraints on organisational change, and therefore, stability, inertia and the reproduction of externally produced norms will be the result (Tolbert & Zucker, 1983). DiMaggio and Powell (1983) argue that three types of reproductive processes exist that induce isomorphic behaviour within an organisational field. These are coercive, mimetic and normative forces that all lead to homogeneity in organisational fields. Coercive isomorphism results from the external pressures that are exerted on an organisation by other organisations upon which the focal organisation depends. Expectations from other organisations in the environment of the focal organisation are also viewed as coercive forces. Coercive forces involve political and legal pressures from, for instance, oversight and control of state agencies (Powell, 2007). Mimetic forces draw on habitual, taken-for-granted responses to circumstances of uncertainty. These forces originate from ambiguous goals or an uncertain environment (Powell, 2007). An organisation may be confronted with an environment in which it is not clear what is expected of it. In such an environment, an organisation may imitate the behaviour of other organisations in its environment. Normative forces are forces that originate from the professions, the role of education and evangelising efforts in which institutional entrepreneurs champion the adoption or influence of specific practices (Powell, 2007).[3]

Under conditions of uncertainty, organisations may choose to imitate the behaviour of other organisations in their environment that they know, trust and regard as successful (Galaskiewicz & Wasserman, 1989; Oliver, 1991). This does not mean that organisations will simply adhere to the demands and expectations of organisations in their environment. Organisations often have to cope with incompatible demands originating both internally as well as externally. This increases the likelihood that organisations will opt for a response that is other than simple adherence to environmental rules and norms (Oliver, 1991). Organisations can decouple their formal structure from their task core, and respond symbolically to changes in their environment while leaving their core

[3] Entrepreneurs in this sense are not individuals leading a private business but persons who spread a new practice or philosophy.

activities untouched (J. W. Meyer & Rowan, 1983; Powell, 1988). In so doing, organisations are able to decouple organisational practice from organisational structure, thereby retaining their legitimacy as well as their core activities (J. W. Meyer & Rowan, 1977). This implies that, in addition to mimicking institutional norms and rules, an organisation might be able to avoid pressures from the environment by symbolically complying with demands from the environment, by communicating that it is adhering to dominant norms and rules, while at the same time not changing its core activities. This strategy is especially useful when conflicting norms need to be addressed and responded to. New institutional theory thus assumes that a changing institutional environment does not necessarily lead to organisational change, but that it is likely that organisations will try to maintain stability in their core activities (DiMaggio & Powell, 1983; Dowling & Pfeffer, 1975; J. W. Meyer & Rowan, 1983).

New institutional theory received some criticism. First of all, critics point to its dominant focus on how organisations follow institutional rules, with less attention paid to forces that explain organisational change (Oliver, 1991; Perrow, 1986). The role of the organisation as an active agent within a larger structure that attempts to counter influences and to maximise its power is neglected. A second criticism follows from the first critique: new institutional theory is weak in explaining why certain organisations display different behaviour in the context of a similar institutional environment (Greenwood & Hinings, 1996). The underlying factors that can explain why some organisations resist pressures from their environment, while others comply with these pressures in the same organisational field, are difficult to explain using new institutional theory.

3.4 Towards a research model

This section compares resource dependence theory and new institutional theory as the next step in building our research model. The aim is to come to a description of the strong points of both theories, and discuss under which circumstances either one, or a combination of both theories, can explain the behaviour of public research organisations. The intention is not to integrate the two perspectives (c.f. Greenwood & Hinings, 1996; Oliver, 1991; Tolbert, 1985).

According to both new institutional theory and resource dependence theory, organisations need to be responsive to the demands of organisations in their environment if they want to maintain legitimacy and survive (J. W. Meyer &

Rowan, 1977; Pfeffer & Salancik, 1978). This implies that when an organisation engages in exchange relationships with other organisations it will need to take into account the demands and expectations of the organisations it is dealing with. It is undesirable for an organisation that a certain exchange relationship leads to activities and outcomes that do not conform to the habits and conventions of organisations in its environment. New institutional theory expects organisations to pay attention to the norms and rules of organisations in their environment in order to maintain their credibility (Huisman & Meek, 1999). Resource dependence theory tends to emphasise the task and the technical environment of organisations (Oliver, 1991; Tolbert, 1985). In so doing, resource dependence theory is interested in the activities of an organisation, the concrete demands from organisations in its environment and the exchange relationships between the focal organisation and other organisations in its environment. New institutional theory is interested in less tangible pressures from the environment that affect organisational behaviour.

When engaging in exchange relationships with other organisations, the focal organisation will attempt to act according to what is in its own best interest (1991). This interest, according to new institutional theory, is institutionally defined (Hinings & Greenwood, 1988; Scott, 1987a). Organisations will follow the habits and conventions in the institutional environment. These routines are often implicit, or so generally accepted that organisations automatically shape their behaviour on these premises. Organisations that conform to habits and conventions, obtain legitimacy and hence are able to secure vital resources that ensure their survival. Resource dependence theory, on the other hand, expects organisations to be first and foremost interested in mobilising resources to ensure their survival. Resource dependence theory assumes that the interests of an organisation are at the epicentre of its engagement in exchange relationships, and that the exchange relationships have the goal of furthering the agenda of the focal organisation. Actions of organisations according to resource dependence theory are political and calculating (Oliver, 1991). An organisation may attempt to control those external criteria that give it legitimacy and access to vital resources. Resource dependence theory offers insights into environments where exchange relationships with organisations, resource flows and power positions in networks are of central concern (Oliver, 1991). However, new institutional theory argues that gaining resources is not the first thing that is on the mind of an organisation. *"Organizations may act ethically or responsibly not because of any direct link to a positive organizational outcome (e.g., greater prestige or more resources) but merely because it would be unthinkable to do otherwise"* (Oliver, 1991, p.148). In other words, the behaviour of a focal organisation may be driven not by processes of self-serving resource mobilisation (DiMaggio, 1988), but by subconscious acceptance of values or practices in its environment.

Both new institutional theory and resource dependence theory assume that organisations seek stability and predictability in their exchanges of resources with other organisations in their environment (DiMaggio & Powell, 1983; J. W. Meyer & Rowan, 1977; Pfeffer & Salancik, 1978). Resource dependence theory argues that organisations will try to obtain a stable flow of resources by using their own powers to control or negotiate interdependencies with their environment. By so doing, organisations are able to counter influences and achieve a predictable stream of resources, thus reducing uncertainty. Organisations have to cope with uncertainty, manage resource flows, handle interdependencies and, most importantly, external criteria need to be controlled as much as possible (Child & Kieser, 1981; Pfeffer, 1981). According to resource dependence theory, an organisation can exercise some degree of influence over its environment. It is not only adaptation which characterises the organisation's relationships with its environment: *"rather than taking the environment as a given to which the organisation then adapts, it is considerably more realistic to consider the environment as an outcome of a process that involves both adaptation to the environment and attempts to change that environment"* (Pfeffer & Salancik, 1978, p.222). In contrast to the reduction of uncertainty by using power, institutionalists focus on the reproduction of external norms and rules (DiMaggio & Powell, 1983; Zucker, 1977). New institutional theory views reproduction as a strategy to conform to habits and conventions since this contributes to organisational stability. Power is centred in the institutional environment, not the focal organisation itself. Institutionalists emphasise how organisations follow collective norms and beliefs. New institutional theory provides insights into environments with a high level of institutionalised beliefs about how organisations should function. Organisations need to conform to external criteria if they want to retain legitimacy.

The type and the intensity of exchange relationships can be explained by the environment that the focal organisation is part of on the one hand, and by the preferences, and the level of power of the focal organisation over, and dependency on, certain resources (Pfeffer & Salancik, 1978). These aspects shape how a focal organisation engages in exchange relationships with other organisations, the type and intensity of these exchange relationships, and what impact these exchange relationships have on the activities and the products of the focal organisation. An organisation engages in relationships with other organisations to acquire resources that are vital to its survival. According to new institutional theory, resources may be acquired if an organisation presents itself to organisations in its environment as conforming to habits and conventions. Consequently, an organisation will likely follow the dominant rules and norms in its environment, since not doing so will lead to a decrease in legitimacy. However, one can also expect that an organisation engaging in exchange relationships with other organisations, will attempt to counter the demands of other organisations if these demands conflict with its own interests. An organisation might first wish to engage in an exchange relationship that provides vital resources while, at the same time, this relationship could constrain behaviour in a way that is detrimental to its legitimacy. We might also expect an organisation to attempt to change the criteria under which the exchange relationship takes place, effectively eliminating or diminishing the control by organisations in the environment. Resource dependence theory and new institutional theory have different expectations with regard to the basis on which organisations engage in exchange relationships and their effects on organisational behaviour. According to Oliver (1991, p.148): "t*hese differences … reflect divergent assumptions about the degree of choice, awareness, and self-interest that organizations possess for handling external constraints."* A study by Huisman and Meek (1999) concludes that resource dependence theory is more applicable in situations where the organisation has a clear understanding of the tasks it should perform according to its environment; in which the pressures are visible and in which the management of scarce resources is crucial. New institutional theory, according to Huisman and Meek, is more applicable in situations where invisible pressures are more dominant, and where the primary goal is to attain social worthiness rather than the acquisition of resources. Both resource dependence theory and new institutional theory have suggested a variety of strategies that organisations may employ to deal with demands from their environment, and these strategies reflect their diverging assumptions. The strategies range from acquiescence and compromise, to avoidance, defiance and manipulation (Oliver, 1991). Resource dependence theory has proposed organisational strategies to counter demands from the environment that reflect the active choice of organisations. Such strategies aim to resist and manipulate external dependencies or exert influence over the allocation or source of critical resources (Oliver, 1991; Pfeffer & Salancik, 1978; Scott, 1987b). New institutional theory has produced a variety of strategies that reflect the non-choice behaviour of organisations, such as acquiescence and mimicking the dominant behaviour in the organisational field (Oliver, 1991).

3.5 Relationships and their impact on organisational behaviour

So far, we have discussed resource dependence theory and new institutional theory, their critiques, and their similarities and differences. We now discuss how both resource dependence theory and new institutional theory can contribute to the understanding of how research departments engage in relationships with spin-off companies and how, as a result of these relationships, the research portfolios of research departments may be affected. Subsequently, we present the research model that is based on this discussion.

Resource dependence theory is useful in our research for the following reasons. First, according to resource dependence theory, the environment of an organisation is assumed to contain scarce and valuable resources essential to its survival. Resource dependence theory assumes that an organisation is rational and adaptive in responding to its environment, seeking to manage the resource relationships it maintains with organisations in its environment. The need to acquire resources from organisations in the environment gives rise to the dependence of the focal organisation on these organisations in the environment (Donaldson, 1995). An organisation can exert power over other those organisations in its environment that are in need of certain types of resources, thereby influencing the behaviour of these organisations. This approach is helpful for our research since we seek to examine how exchange relationships between research departments and spin-off companies shape the behaviour of research departments. Second, resource dependence theory assumes that the environment of an organisation consists of other organisations, and that this environment is indeterminate, perpetually changing and consisting of a multitude of competing interests. Resource dependence theory is therefore useful in examining how the environment plays a role in the engagement of research departments in exchange relationships with their spin-off companies. In this environment, a multitude of interests will be present, which potentially impede or support the research departments' relationships with their spin-off companies. Third, demands from the environment need not necessarily lead to changes in the activities of the focal organisation. Organisations might attempt to counter pressures, negotiate and influence their environment. Fourth, the preferences and the resources of the focal organisation shape the relationships it maintains with other organisations and the extent to which the focal organisation is influenced by other organisations in the environment. New institutional theory is valuable in our research since it assumes that organisational survival is based on the legitimacy of the organisation in its environment. Legitimacy is earned by adhering to institutional norms and rules. Since the environment of an organisation consists of multiple and conflicting demands, new institutional theory expects an organisation to be unlikely to change its activities if a limited number of relatively unimportant organisations in its environment ask it to, since this would jeopardise organisational legitimacy with other, more dominant, organisations in the environment. New institutional theory, in this sense, is more suitable for describing the stability of the technical core, the inertia of organisations, as well as the reproduction of externally-produced norms (Tolbert & Zucker, 1983). In situations where competing demands exist, an organisation might symbolically comply with organisations in its environment to maintain its legitimacy while, at the same time, avoiding changes to its core activities. For instance, research departments are part of an environment in which a multitude of competing demands exist. For example, academic peers expect peer-reviewed publications whereas policymakers may expect research departments to show that they produce knowledge that can be used by industry to innovate.

Our discussion of resource dependence theory and new institutional theory has helped us to identify the main building blocks for our research model. From these theories, we have learnt that organisations in the environment of a research department, as well as the preferences and resources of the research department itself, shape the relationships with spin-off companies and the research portfolio of the research department. Figure 3.1 presents the research model. The research model distinguishes between the preferences and resources of a research department (box I), the potential resources and demands of organisations in its environment (boxes II and III), the relationships that a research department engages in with its spin-off companies (box IV) and the research portfolio of the research department (box V). In box III and IV we specifically talk about potential resources since a research department will never be able to acquire all resources that an organisation in the environment holds. A research department has the potential to acquire a subset of the resources of an organisation in its environment. The type and the intensity of the relationships a research department maintains with its spin-off companies is the first dependent variable. The research portfolio constitutes the second dependent variable.

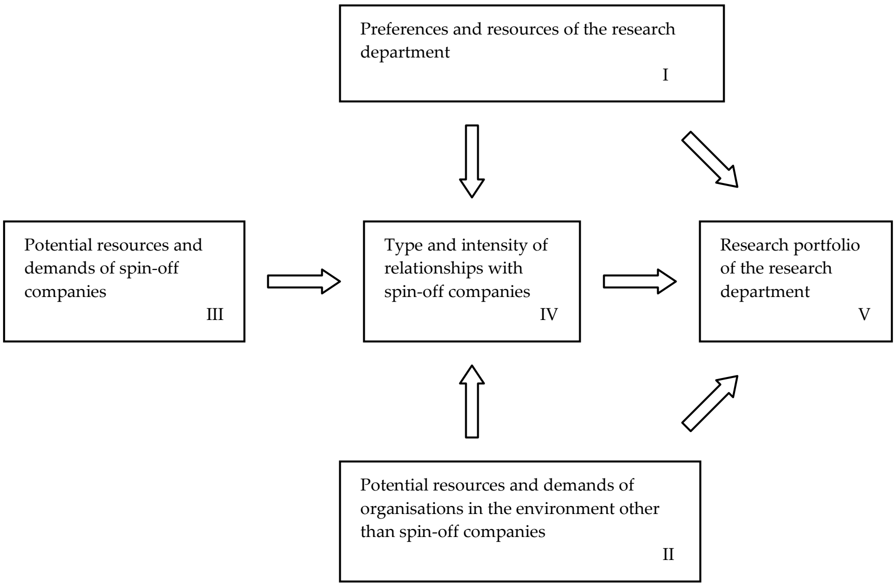

Figure 3.1. The research model

3.5.1 Preferences and resources of the research department

Our research model considers the preferences and resources of a research department to be one of the explanatory factors in shaping its engagement in relationships with spin-off companies and for changes in the research portfolio. In doing so, the research model takes into account the assumption of resource dependency theory that research departments do not merely follow the demands, norms and rules of its institutional environment but are able make deliberate choices based on their own interests concerning the mobilisation of resources (Oliver, 1991). Each organisation *"has a particular set of criteria or preferences"* which affect how it deals with demands and expectations from its environment (Pfeffer & Salancik, 1978, p.32). According to new institutional theory, the preferences of organisations are shaped by the dominant habits and conventions in the institutional environment. One of the most important features of the environment of a research department is the scientific communities that it is part of. Scientific communities have their own logic and cultures (Becher & Trowler, 2001) which affect the research portfolios of scientific researchers. According to Becher and Kogan (2000, p.153): *"both the organisational stability and the academic status of basic units are therefore to a significant extent dependent on the existence of peer groups* *outside the institution itself."* While Rip (1981, p.307) asserts that: *"the cognitive state of a discipline and the nature of its internal regulatives are independent variables determining the attitudes of scientists towards external orientation."* Thus, the scientific community is a key component in driving the preferences of the research departments. Finally, research departments can be constrained in their choices because of past investments (Pfeffer & Salancik, 1978). Research departments may own physical resources such as research equipment that is expensive and not easily replaceable. The expertise of personnel employed by a research department is another constraint on research departments in their ability to adapt to external demands for particular research themes and outputs.

3.5.2 Potential resources and demands of spin-off companies and other organisations in the environment

Based on resource dependence theory and new institutional theory, we can expect that the survival of a research department will depend on its responsiveness to external demands from multiple organisations within its environment. One of the principal organisations for the research department to take into account is the organisation it is part of, i.e., the university and research institute. The university and research institute, in which a research department resides, can impede or facilitate behaviour by introducing monetary incentives and penalties, structures or policy measures that either support or obstruct the behaviour of a research department. Organisations in the environment of a research department also consist of government agencies, charities, non-profit organisations, private enterprises and spin-off companies. Since we are specifically interested in the impact of the relationships with spin-off companies, the research model makes a distinction between the spin-off companies that a research department has helped to create and other organisations in its environment. Government agencies include research councils and other government agencies that allocate research funding as well as quality assurance agencies that are crucial in providing assessments of the quality and performance of a department's research portfolio. Charities, such as the Dutch Cancer Society, also provide research funding. Non-profit organisations and private enterprises may be clients of a research department. These organisations may consist of industrial research partners, but could also include public organisations that are interested in the research outputs of the research department. Examples are the Ministry of Defence or academic research partners that contract out part of their research and development activities.

The organisations in the environment all possess resources that may be vital for the survival of a research department. They can provide monetary resources, physical resources, information and legitimacy (Pfeffer & Salancik, 1978). New institutional theory places particular emphasis on legitimacy since it enables the acquisition monetary resources, physical resources and information. Since organisations in the environment of a research department are interest driven as well, we expect that, in exchange for the resources that organisations provide to a research department, they will expect something in return. Different types of organisations will have different preferences for resources, outputs and behaviour that the research department displays. Although resource dependence theory expects organisations to learn about the preferences and the potential resources of organisations in the environment, the preferences and potential resources may not be completely clear. New institutional theory expects a research department to follow habits and conventions in the environment; implying that in addition to explicit demands, it also takes into account less explicit preferences of organisations in its environment. Some organisations, in the environment of a research department, will be crucial for the survival of a research department while other organisations may be perceived by a research department as peripheral.

3.5.3 Type and intensity of the relationships with spin-off companies

Organisations will identify, in their environment, organisations from which they expect to acquire resources. As discussed in the previous section, organisations can contribute four types of resources to an exchange relationship: monetary resources, physical resources, information and legitimacy. Given the fact that the environment of an organisation can consist of multiple and conflicting demands, the engagement in exchange relationships with external organisations is not merely a matter of selecting the providers with the largest amounts of potential resources. Engaging in a specific exchange relationship that requires the research department to produce certain outputs may negatively affect another external organisation from providing the research department with additional resources. A research department can be expected to engage in relationships with multiple organisations, ranging from academic organisations to government agencies, charities and industrial research partners. Spin-off companies are only one type of candidate. The relationships with spin-off companies will exist alongside the relationships the research department maintains with other organisations in its environment. When engaging in a relationship with spin-off companies, a research department will take account of the demands of organisations in its environment, the resources they potentially provide, to what extent the demands of external organisations conflict with each other, and whether demands of external organisations are in line with the preferences of the research department.

3.5.4 Research portfolio of the research department

In Chapter 1, we decided that we would study the effects of relationships with spin-off companies on the resources that are available, the research agendas and the research output of research departments. We labelled these as the effects on the research portfolios of research departments. The research portfolio of a research department is partially financed by the larger organisational unit which it belongs to, i.e., a research institute or university. In addition, research departments are dependent upon other organisations in their environment, such as spin-off companies, to provide them with resources. The activities that a research department undertakes and the outputs it produces are essential to legitimise its existence and to mobilise resources from organisations in its environment. This does not imply that a research department will automatically adhere to norms and rules in its environment. Researchers in a research department will have certain beliefs about what the research portfolio of their research department should consist of, i.e., what research themes the research department should select, who the research partners should be, whether the research department should engage in basic or applied research projects and the extent to which industrial research partners should be involved in the research projects. We therefore assume that stability, as well as change, in the research portfolio of a research department are not caused simply by an adherence to the demands of spin-off companies and other organisations in its environment. The research portfolio of a research department will be, to some extent, dependent upon its own preferences and the resources it possesses.

3.6 Propositions

Based on the insights from both resource dependence theory and new institutional theory, we assume that research departments are open systems that support themselves by exchanging resources with their environment. A research department is constrained by multiple external pressures and its survival depends on the responsiveness to external demands and expectations. A research department will seek stability, predictability and legitimacy, since this will enable the research department to obtain vital resources. The environment of a research department shapes the conditions under which dependency relations will have effects on the research portfolio. Both resource dependence theory and new institutional theory claim that organisations are capable of choosing strategies in response to external demands and expectations. Based on these insights we have formulated a number of propositions.

The first proposition addresses the research institute and university that a research department is part of. Both resource dependence theory and new institutional theory state that organisational survival depends on responsiveness to external demands and expectations. New institutional theory stresses that organisations follow the dominant rules and norms in their environment in order to acquire legitimacy. If the environment of a public research organisation stresses the importance of engagement in knowledge transfer, new institutional theory expects a public research organisation to conform to these norms and rules in order to maintain its legitimacy, thereby securing its survival. Resource dependence theory, on the other hand, expects a public research organisation to be mainly interested in managing its resource exchanges in order to mobilise vital resources. We therefore construct two different propositions. Proposition Ia expects public research organisations to follow a new institutional logic, whereas Proposition Ib expects public research organisations to behave according to a resource-based logic.

Proposition Ia:

A public research organisation that is situated in an environment that values knowledge transfer will support the creation of spin-off companies in order to adhere to the dominant rules and norms in its environment.

Proposition Ib:

A public research organisation that is situated in an environment that values knowledge transfer will support the creation of spin-off companies in order to mobilise resources from its environment.

Proposition II addresses the level of the research department and concerns the exchange relationships between research departments and their spin-off companies. The proposition deals with the consequences of attempts by government agencies to encourage scientific researchers to engage in relationships with industry. Will research departments operate independently from monetary incentives in engaging in relationships with their spin-off companies? Or will research departments positively respond to such encouragements and engage in relationships with their spin-off companies in order to acquire additional resources? Resource dependence theory expects a research department to engage in relationships with organisations in its environment to the extent that it will not conflict with its own preferences or other relationships it maintains with external organisations. By engaging in relationships with its spin-off companies, a research department can legitimise the acquisition of resources from research funding organisations that prefer scientific researchers to engage in relationships with industry. We therefore choose to pose the following proposition.

Proposition II:

A research department that resides in a funding environment which makes resources available to encourage science-industry relationships will employ the relationships with its spin-off companies to mobilise such resources from its environment.

When engaging in relationships with external organisations, research departments will need to deal with the demands and expectations of these organisations. Whereas resource dependence theory expects organisations to be mainly concerned with the mobilisation of resources from their environment, new institutional theory expects organisations to be inclined to conform to external criteria since this will enable them to retain their legitimacy. Resource dependence theory expects that, when a research department engages in exchange relationships with external organisations, it will attempt to buffer the demands of these organisations when the demands are not in line with its own preferences. This allows the research department to retain its autonomy, and thereby protect its legitimacy with other organisations in its environment. Thus, we expect the research department to limit the influence of spin-off companies on its research portfolio, especially in situations where the preferences of the research department and the spin-off companies are not compatible. Based on these arguments, our third proposition states the following.

Proposition III:

When engaging in relationships with its spin-off companies, a research department will seek to avoid influences on its research portfolio if the demands of the spin-off companies are not in line with its own preferences.

Our fourth proposition is based on assumptions of both resource dependence theory and new institutional theory. Resource dependence theory expects that a research department will attempt to control the external criteria it is confronted with when mobilising resources. However, in circumstances where this is not possible, and the potential resources are important for a research department, a research department will change its behaviour in order to acquire these resources. In line with new institutional theory, research departments would prefer to persist in their behaviour since the rules and norms in their environment prefer departments to display particular behaviour. Organisations seek stability and predictability, especially in an uncertain environment. Therefore, we can expect that, in a situation where spin-off companies that hold vital resources demand changes in the research portfolio of a research department, this department will change its research portfolio but will remain as close as possible to its preferences.

Proposition IV:

A research department will only allow changes to its research portfolio in response to a relationship with a spin-off company if this relationship will provide the research department with access to a significant amount of resources, but the research department will change in a way that is closest to its own preferences.

Based on resource dependence theory and new institutional theory we have conceptualised the establishment of relationships between spin-off companies and research departments in this chapter. We also conceptualised the impacts of these relationships on the research portfolios of research departments. We concluded that research departments may choose to engage in relationships with their spin-off companies based on their own preferences and the resources they hold, as well as the demands and resources of spin-off companies and other organisations in their environment. The relationships with the spin-off companies may affect the research portfolios of the research departments while research departments may also be able to avoid influences on their research portfolios. The discussion of both theories has subsequently been used to develop our research model and a set of propositions that will be tested in the empirical part of this thesis.

4 Methodology and operationalisation

This chapter discusses the methodological considerations of this study and presents the operationalisations of the main concepts in the research model. We present the case selection, methods of data collection and data analysis, as well as some limitations of this study.

4.1 Research design

Our study focuses on the relationships of research departments with their spin-off companies and the impact of these relationships on the research portfolios of the research departments. We employ a multiple case study design (Yin, 2003) as this allows us to collect in-depth information on the research activities of research departments while, at the same time, allowing us to investigate to what extent the environments of research departments play a role in shaping their relationships with spin-off companies. Are there differences across scientific fields and organisations that can be identified? One could argue that disciplinary differences will shape the relationships between departments and their spin-offs as well as the impacts on the research portfolio of a research department.

Chapter 5 will present the national context of our cases. The chapter deals with the main organisations in the Dutch science system and the developments over time with respect to research funding and policy initiatives to encourage knowledge transfer and commercialisation by public research organisations. Chapter 5 also shows how public research organisations in the Dutch science system have reacted to the increased emphasis on knowledge transfer and the commercialisation of their research results, including the creation and support of spin-off companies. The case studies as such are included in Chapters 6 to 10. We investigate to what extent the research portfolios of research departments have changed in the period after the spin-off companies were created and discuss, on the basis of opinions of interviewees, financial data, output data and documents, whether changes in the research portfolios are caused by the relationships that the research departments have maintained with their spin-off companies. In Chapter 11, we compare our case study results to learn about the impacts of the relationships on the research portfolios and whether disciplinary and organisational backgrounds matter.

4.2 Operationalisation

In this section, we will operationalise the main concepts of the research model introduced in Section 3.5. A research department may engage in relationships with spin-off companies based on its own preferences and resources, as well as the potential resources and demands from spin-off companies and other organisations in the environment of the research department (Figure 4.1). In turn, these relationships may affect the research portfolio of the research department. In the following sub-sections, the various components of the research model will be elaborated and operationalised.

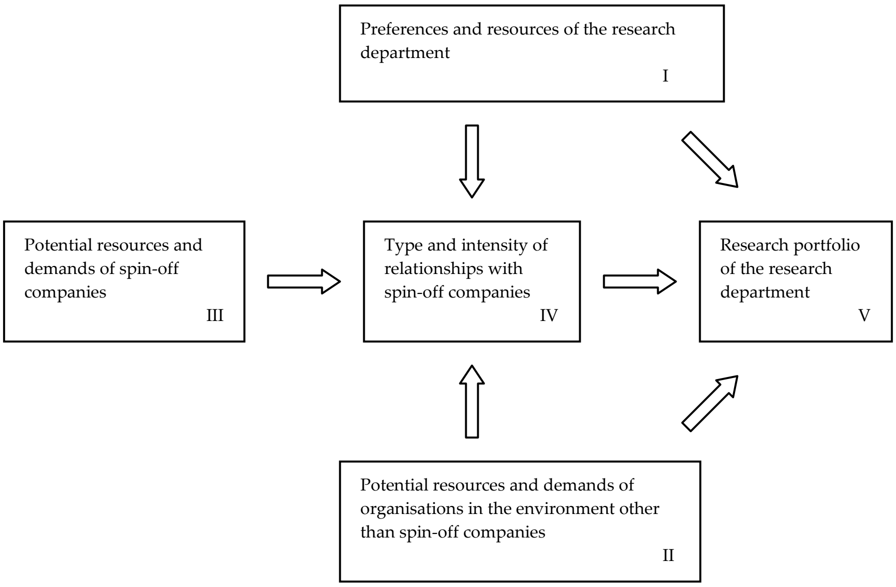

Figure 4.1. The research model restated

4.2.1 Preferences and resources of the research department

The first set of explanatory variables in our research model concerns the characteristics of a research department. Research departments are organisational units in a university or a research institute that have their own administrative, physical, and academic existence (Leisyte, 2007, p.19). We consider a research department to have its own interests and to have certain resources in its possession. We selected five indicators to operationalise the preferences and resources of a research department (Table 4.1). The preferences of a research department are expressed in its mission statement. The mission of a research department will be stated in terms of basic research, applied research, and research networks. It also states the broad research themes and the propensity of the research department to engage in commercial activities and collaboration with industry. In Chapter 3 we argued that the preferences of a research department are profoundly influenced by its peers in the disciplinary community. We therefore look at the norms of the scientific community that the research department is part of, as expressed in peer reviews and research assessments. Some of the criteria deal with the issue of whether it is expected (or customary) for a research department to collaborate with industry.

Available resources, alongside preferences, shape the choices of a research department. A research department's decisions and research portfolio will depend on financial resources, human capital resources, as well as fixed resources in the shape of research equipment and facilities. Choices are constrained due to the composition of the academic staff in place (their expertise and embodied knowledge). Equally, the available research equipment and facilities might constrain the research questions that can be addressed (Thagaard, 1987). We take into account the size of the research department, the number of tenured and non-tenured researchers, including professorial chairs.

Table 4.1. Operationalisation of Box I: preferences and resources of the research department

Variables	**Indicators**
Preferences	Mission statement
	Norms of the scientific community the research department is part of
Resources	Staff of the research department
	Institutional budget allocated by the research institute or university
	Research equipment/facilities owned by the research department

4.2.2 Potential resources and demands of spin-off companies and other organisations in the environment of a research department

In the environment of a research department, different types of organisations may be distinguished. Organisations in the environment of a research department consist of the university and research institute that it is part of, government agencies, charities, and public and private enterprises. We pay particular attention to the spin-off companies since these are central to our research. Each type of organisation in the environment of a research department holds a different set of resources for a research department and may place different demands on the department. Resources may be provided in return for particular services, and different organisations will have different demands in terms of the services a research department should produce. Table 4.2 presents the operationalisations of the demands and the potential resources of organisations in the environment of a research department. Legitimacy, based on resource dependence theory and new institutional theory, is not a directly observable variable and therefore is not explicitly included in the table. We take the transfer of resources as an approximation of legitimacy. The financial resources, physical resources and information that may be obtained from external organisations are an expression of the appreciation and the legitimacy that such organisations award to a research department. Legitimacy can be provided to a research department by all the organisations its environment, including the larger organisation of which the department is part.

Regarding the demands and potential resources, we pay attention to the type of organisation the research department is part of, the mission of the organisation, its internal policies, regulations and structures that affect the research department's engagement in knowledge transfer and the internal resource allocation mechanism in place for funding research departments. In terms of the type of organisation, we distinguish between a university and a public non-university research institute. Universities in the Netherlands receive their recurrent funding from the Ministry of Education, Culture and Science, while non-university public research organisations receive their recurrent funding from NWO (the Netherlands Organisation for Scientific Research) or other organisations. We are interested in the mission of the research institute and university the research departments are part of since this will provide information about the norms of the organisation towards research and knowledge transfer activities. The mission of research institutes and universities can be regarded as a proxy for their attitude towards research and outreach activities. Additionally, the internal resource allocation mechanism that research departments are confronted with may affect the propensity of these research departments to mobilise resources from certain organisations in their environment. We are therefore interested in monetary incentives given for the acquisition of research projects funded by national research councils, the EU, and industrial research partners. For instance, research departments might be encouraged by their research institute or university to attract funding from research councils since this may be more prestigious from an academic point of view than industrial funding. Conversely, a research department may also be encouraged by its research institute to engage in collaboration with industry since this shows that the institute is conducting societally relevant research. Internal policies, regulations and structures that affect the research department's engagement in knowledge transfer are indications of the willingness of the larger organisational unit that the research department is part of to support knowledge transfer and commercialisation activities. The specific regulations and policies that are in place with regard to creating spin-off companies, applying for and licensing of patents or collaborating in research partnerships with industry will affect the degree to which research departments will engage in research commercialisation.

Government agencies include research councils, government ministries and intermediary agencies that all hold potential monetary resources that can be allocated to research departments through research funding, such as recurrent funding, project funding, subsidies and grants to individual researchers. Government agencies do not provide research departments with physical resources or information. Government agencies can of course provide subsidies for the acquisition of research equipment, but we regard such subsidies as monetary resources that departments can convert into physical resources. Research programmes are often targeted at a scientific field or a theme within a scientific field. Government agencies, which fund scientific research, may have preferences for certain research areas or themes and certain types of output, such as peer-reviewed publications, patents or prototypes. Some government agencies may demand departments collaborate with public or private organisations. And government agencies may also have a preference for either applied research or basic research.

Table 4.2. Operationalisation of Boxes II and III: potential resources and demands of spin-off companies and other organisations in the environment of a research department

Variables	Indicators
Potential resources	Monetary resources (research funding, subsidies etc.)
	Physical resources (equipment, materials etc.)
	Information (test data, know how, design criteria etc.)
Demands	Research themes
	Types of output (peer-reviewed articles, prototypes, patents, spin-offs etc.)

Research departments can also apply to private non-profit organisations such as charities for research funding. Some of these charities aim to provide research funding to develop treatments for cancer, cardiovascular diseases or neurological disorders, and can be an important funding source for research departments in the life sciences. Like government agencies, charities also may have a preference for certain research themes and types of output. They may be particularly interested in outcomes that directly lead to clinical applications, and clinical trials that lead to the treatment of a disease.

Private and public organisations that collaborate with research departments can hold monetary resources as well as physical resources and information. These organisations can provide research departments with research funding, materials, research equipment, prototypes, test data, know-how and design criteria. Private and public organisations that maintain a relationship with a research department are directly interested in the outputs of a research department. Rather than contributing to the advancement of our understanding of the world, public and private organisations that collaborate with a research department principally hope to benefit directly from the relationship they maintain with a research department. These organisations will demand that a department conducts research on certain themes that are directly relevant to their interests and help solve their (sometimes very practical) questions. They may therefore demand certain types of output, such as peer-reviewed articles or they may be more interested in seeing the research department create patents or perhaps particular applied outputs such as prototypes.

Spin-off companies that have originated from a research department fit within the category of private organisations that a research department can interact with. Since spin-off companies are the focus of our research, we pay particular attention to the potential resources and demands of spin-off companies. Spin-off companies can provide research departments with monetary resources as compensation for the knowledge they obtain from them. The potential monetary resources of a spin-off company depend on its research budget, indicated by the size of the spin-off company in terms of turnover and personnel. Regarding physical resources and information, we take as indicators the products and services that spin-off companies produce and whether spin-off companies are knowledge-intensive companies. This is indicative of the type of resources they hold, i.e., research equipment, materials and know-how including personnel. The products and services, as well as the high-tech or low-tech nature of the spin-off company, may also be indicative of the demands they will have in terms of knowledge needs. Finally, whether spin-off companies have already developed a product or service that is available on the market, is an indicator of the extent to which they are in need of additional knowledge from the research department they originated from.

4.2.3 Type and intensity of the relationships with spin-off companies

The type and intensity of the relationships between a research department and spin-off companies is the first dependent variable in this study. It concerns the actual flow of resources between spin-off companies and a research department. A relationship may result from the interplay of demand and supply, in other words, the actual relationship that may emerge depends on the potential resources and preferences of the research department, as well as the demands and potential resources of the spin-off company and other organisations in the environment of the research department. From Chapter 3, we learned that spin-off companies can provide three types of resources to research departments: monetary resources, physical resources and information. A fourth resource, legitimacy is a resource that is not directly observable. The operationalisations are presented in Table 4.3.

In Table 4.3 we distinguish between monetary resources and non-monetary resources, i.e., information and physical resources. Non-monetary resources are operationalised using six main categories: joint publications; joint patent applications; former research staff of the research department employed by the spin-off company; personnel simultaneously affiliated to the spin-off company and the research department; bachelor and master theses supported by the spin-off company; and exchanges of test data, facilities, instruments and prototypes between the spin-off company and the research department. Research staff that have left the research department for a position in the spin-off company are indicative of embodied knowledge and expertise being acquired from the research department. Simultaneous affiliations of personnel with a research department and a spin-off company are indicative of the commitment of such people to both the spin-off company and the research department. They represent a linking pin between the research department and the spin-off company and may act as an enabler and promoter of exchanges between the two organisations. We include the support of students' bachelor and master theses by spin-off companies since knowledge flows between spin-off companies and departments need not only occur through personnel and formalised research projects, but also through student internships and projects. Test data, facilities, instruments and prototypes exchanged between the spin-off company and the research department are indicative of informal exchanges of information and equipment.

Table 4.3. Operationalisation of Box IV: type and intensity of the relationships with spin-off companies

Variables	**Indicators**
Non-monetary resources	Joint publications with spin-off company
	Joint patent applications with spin-off company
	Former research staff of the research department employed by spin-off company
	Personnel simultaneously affiliated to spin-off company and research department
	Bachelor and master theses supported by spin-off company
	Test data, facilities, instruments and prototypes obtained from spin-off company
Monetary resources	Contract research commissioned by spin-off company
	Jointly acquired government-funded research projects

	Financial support of PhD research projects
	Spin-off company’s capital stock owned by the research institute or its staff
	Funds from spin-off company in exchange for knowledge from research department
	Donations received from spin-off company

Monetary resources are accounted for using the following operationalisations: contract research projects acquired from spin-off companies, joint acquisition of government-funded research projects, financial support of PhD projects by a spin-off company, spin-off company’s capital stock owned by the research institute or its staff, funds from a spin-off company in exchange for knowledge and donations received from a spin-off company. Contract research projects signify direct monetary contributions by spin-off companies to the research department in return for research outputs. Jointly acquired government-funded research projects are research projects that a research department and a spin-off company jointly carry out for organisations such as research councils, national ministries and the EU. We also measure the financial support that spin-off companies provide specifically for PhD research projects. Such support would indicate that spin-off companies are interested in long-term research projects. For research departments, financial support for PhD research projects is very valuable since it signifies long-term support of their research activities. A research institute or its staff members may hold capital stock in a spin-off company. Possession of capital stock may allow a research institute or its members to acquire resources from the spin-offs by receiving dividends from the stock ownership or by selling the stocks. Ownership of capital stock may also affect decision-making processes in spin-off companies. Another form of monetary exchange is when a research department sells knowledge it has in exchange for monetary resources. The knowledge in this exchange can be intellectual property but it may also lack a legally protected form. We would emphasise that, we do not account for capital stock in this indicator. In addition to commissioned contract research, spin-off companies may donate monetary resources to research departments. Such monetary donations should be regarded as a kind of philanthropy and as distinct from contract research projects in which an organisation that commissions a research project will expect outputs.

Legitimacy as a resource is not directly observable. It is created by the actions of the research department, its relationships and the services it delivers. The scientific credibility of a research department, as described by Latour and Woolgar (1986), is part of the legitimacy a department possesses. A research department can employ its legitimacy to mobilise resources from organisations in the environment. Increasingly, government agencies provide research funding on the condition that industry and scientific researchers collaborate with each other. Research departments, when creating, or collaborating, with spin-off companies will probably be viewed by these research funding organisations as legitimate organisations that are worthy of receiving research funding.

To indicate the intensity of the relationships and exchanges between research departments and spin-off companies, the data on the resources will be translated into an ordinal measure scale for each indicator. The scale represents the intensity of the relationships: none, minor, significant and major. We choose this approach to condense the large volume of information on the exchange relationships. 'None' indicates there are no exchanges of resources at all. 'Minor' indicates that the exchange of resources is of limited size in relation to the research portfolio of a research department. 'Significant' indicates that the exchange of resources is considerable in relation to the research portfolios of the research departments. 'Major' indicates that the exchange of resources is a key part of the research portfolio.

4.2.4 Research portfolio of the research department

The second dependent variable in the research model concerns the research portfolio of the research department. The research portfolio consists of three items: resources for research, the research agenda and the research output. Their operationalisations are presented in Table 4.4.

Resources for research are operationalised in terms of the number of contacts with industrial research partners other than spin-off companies, the share of income from industry, and the share of income from national government agencies and international funding agencies. A research department may expand its network with other research partners through its contacts with spin-off companies. Relationships with spin-off companies potentially lead to new opportunities to collaborate in research with other public and private organisations. If the composition of a research project changes due to the research department's collaboration with spin-off companies, this may lead to a reorientation of the department's research projects and where it acquires its funding from.

Table 4.4. Operationalisation of Box V: research portfolio of the research department

Variables	Indicators
Resources for research	Number of contacts with industrial research partners other than spin-off companies
	Share of income from industry
	Share of income from national government agencies and international funding agencies
Research agenda	Shifts in research themes
	Balance between basic and applied research
Research output	
Scientific publications	Number of articles published in peer-reviewed journals
Other research outputs	Number of prototypes, demonstrators and clinical applications created
	Number of patent applications
Research quality	Ratings in research evaluations by VSNU/QANU
	Quality of peer-reviewed journal publications

The research agenda is operationalised on the basis of information on the research themes of a research department and its balance in terms of basic research and applied research. The research themes chosen as well as the balance between applied and basic research may change due to relationships between a research department and its spin-off companies. Exchange relationships with spin-off companies may lead to researchers shifting their research themes towards issues that concern problems faced by industry. Conversely, one could argue that working with, or starting, a spin-off company could be a way of outsourcing research and development activities that no longer fit into the research portfolio of the research department or have become routine activities. This would allow research departments to continue to work on more basic research. In terms of research outputs, the scientific publications concern the number of publications in peer-reviewed journals. Other research outputs include prototypes, demonstrators, clinical applications and the number of patent applications a research department has filed. Depending on the scientific field, research departments may engage in the creation of such outputs. Increased resources for research, due to exchange relationships with spin-off companies, may contribute to the output of a research department. On the other hand, demands from spin-off companies may lead to a greater emphasis on outputs other than scientific publications. The research quality of a research department is operationalised using the ratings a department has received in research evaluations carried out under the auspices of VSNU and QANU, as well as by the opinions expressed by respondents on the quality of peer-reviewed journal publications the department has produced.[4] As far as the ratings in research evaluations are concerned, we are interested in seeing how the quality of a research department increased or declined as a result of relationships with spin-off companies.

4.3 Case selection

In order to test empirically whether the research portfolios of research departments are affected by their relationships with spin-off companies, we employ a multiple case study design. The research institutes and research departments we selected are all part of the Dutch science system. Policymakers and government agencies in the Dutch science system have increasingly encouraged researchers to engage in knowledge transfer with industry, and we are interested to learn what the effects have been on research departments. To set the stage, Chapter 5 will discuss the main features and developments in the Dutch science system in more detail. We will focus on eight research departments in three different scientific fields: biomedicine, computer science, and nanoscience and technology. Within these scientific fields, many opportunities exist for scientific researchers to engage in knowledge transfer and the commercialisation of their research results. This makes these scientific fields particularly relevant for investigating whether a funding environment that encourages university-industry relationships and commercialisation will affect knowledge transfer activities and ultimately the research portfolios of research departments.

[4] Before 2003 research evaluations of research departments were facilitated by VSNU (Association of Universities in the Netherlands). From 2003 onwards, research evaluations are conducted by QANU (Quality Assurance Netherlands Universities).

4.3.1 *Selection of the research institutes*

In order to investigate whether the larger organisation of which a research department forms part, i.e., the research institute or university, affects the research department's engagement in relationships with spin-off companies, we selected five research institutes. Two of these institutes are situated in a comprehensive research university, two research institutes are part of a technical university and one research institute is a non-university public research organisation. We investigate whether institutional missions influence the propensity of research departments to engage in relationships with their spin-off companies. In Table 4.5 the main characteristics of the five research institutes are presented. We have anonymised the research institutes and universities, and provided acronyms for them.

Table 4.5. Main characteristics of the selected research institutes

	MedLab	PharmLab	ICTInstitute	ICTLab	NanoLab
Part of:	Comprehensive Research University		Non-university public research organisation	Technical University	
Scientific field(s)	Biomedicine	Biomedicine	Computer science	Computer science	Nanoscience & technology
Mission	Basic research with clinical relevance.	Basic research with clinical relevance.	Basic research is primary goal. Technology transfer plays a role but not prominent.	Design, application and integration of technology. Technology transfer is important part of mission.	Basic as well as applied research. Technology transfer is an important part of mission.
Size of the research institute	715 FTE in research and education (2006)	111 FTE in research (2007)	156 researchers (2006)	475 researchers (2006)	300 researchers (2006)
Number of spin-offs created[5]	at least 8 (1990-2006)	6 (1990-2006)	14 (1990-2006)	36 (1994-2006)	35 (1988-2006)

[5] Source: Annual reports and interviews conducted by the author.

4.3.2 Selection of the research departments and their spin-off companies

Within the five research institutes, we selected eight research departments. Table 4.6 presents the eight departments and the scientific fields they are part of. Further details of the research departments can be found in Chapters 6 to 10. The research departments have all helped to create a number of spin-off companies. We expect that if any impact of a spin-off company is to be detected, it is most likely to be in the research department that helped to create it. We only selected research departments that have spin-off companies because we are interested in the relationships that research departments have with their spin-off companies, how they make use of them and what impacts the relationships have on the research portfolio of research departments. In selecting the research departments, we looked for research departments with a high density of spin-off companies. In the literature, a variety of definitions of what constitutes a spin-off company exist. A study by Wintjes et al. (2002) found ten different definitions for spin-off companies originating from universities and non-university public research organisations. We define a spin-off company as an organisation that has at least one of the two following characteristics: 1) its founders include employees or students from a research department; and 2) its key technology originates from a research department. The selection of the research departments and their spin-off companies was not based on the intensity of their relationships with the research departments nor on the characteristics of the spin-off companies. In so doing, we avoided a sampling bias in which large spin-off companies, and spin-off companies with an intense relationship with their research departments, would have been overrepresented.

Table 4.6. Number of created and investigated spin-off companies per research department[6]

	Biomedicine	Computer science	Nanoscience and technology
Research department :	**MedLab 1**	**ICTLab 1**	**NanoLab 1**
Number of spin-off companies created	2	2	4
Spin-off companies investigated:	BIO1	ICT3, 4	NANO1, 2, 3, 4
Research department:	**MedLab 2**	**ICTLab 2**	**NanoLab 2**
Number of spin-off companies created	5	2	2
Spin-off companies investigated:	BIO2	ICT 5, 6	NANO4, 5
Research department:	**PharmLab 1**	**ICTInstitute 1**	
Number of spin-off companies created	2	2	
Spin-off companies investigated:	BIO3, 4	ICT1, 2	

In selecting cases, we made sure we selected at least two research departments in each scientific field. In total, we investigated 15 spin-off companies originating from 8 research departments.[7] Table 4.7 presents an overview of the spin-off companies. The table indicates the research department the spin-off companies originated from, the acronyms of the spin-off companies, in what year they were founded, the size of the companies and the products and services they offer. We investigated four biomedical spin-off companies, six computer science spin-off companies and five nanoscience and technology spin-off companies. The size of the spin-off companies ranges from 3 FTEs to 150 FTEs. The oldest enterprise was founded in 1992 while the youngest company was founded in 2006.

[6] The NanoLab 1 case and the MedLab 2 case form exceptions in terms of the number of spin-off companies that have originated from these research departments. NanoLab 1 helped to create four spin-off companies and MedLab 2 helped to create five spin-off companies. The spin-off companies of NanoLab 1 still exist, while only one spin-off company of MedLab 2 still exists, explaining the differences in the number of investigated spin-off companies.

[7] One spin-off company created by the NanoLab research institute originated from both the NanoLab 1 and 2 research departments, which explains why 16 spin-off companies are listed in Table 4.6 while we only mention that 15 spin-off companies have been investigated. The spin-off company that originated from both research departments is dealt with in the investigations of both NanoLab 1 and NanoLab 2.

Table 4.7. Main characteristics of the investigated spin-off companies[8]

Spin-off company	Research department	Founded in:	Size in FTE	Technology area
BIO1	MedLab 1	2000	140	Antibody-based vaccines
BIO2	MedLab 2	2000	20	Anti-inflammatory drugs
BIO3	PharmLab 1	2004	5	Anti-inflammatory drugs
BIO4	PharmLab 1	1995	150	Drug delivery systems
ICT1	ICTInstitute 1	1998	12	Software for web-based multimedia
ICT2	ICTInstitute 1	2000	20	Software assessment and re-engineering
ICT3	ICTLab 1	1996	10	Speech analysis
ICT4	ICTLab 1	1999	8	Visualisation software for simulators
ICT5	ICTLab 2	2004	15	Wireless sensory networks
ICT6	ICTLab 2	2005	12	Energy efficient microchips
NANO1	NanoLab 1	1995	25	Mems and integrated optics
NANO2	NanoLab 1	1998	10	Particle velocity sensors
NANO3	NanoLab 1	1992	4	Membranes for microfiltration
NANO4	NanoLab 1&2	1999	25	Glass-based microchips
NANO5	NanoLab 2	2006	3	Diagnostic medical systems

4.4 Data collection and analysis

The data for this study were collected in the course of the EU sixth framework programme ProKnow project, in which the author was involved. The ProKnow project aimed to investigate "*the interactions between public research institutions and academic spin-offs focusing on the impact of entrepreneurial activities on the academic research system.*"[9] As such, this thesis largely makes use of the ProKnow data collection protocols.[10] We used multiple sources of data, thereby triangulating the collected information (Yin, 2003, p.97). In the data collection process, we relied on semi-structured interviews with staff members of the research departments, with spin-off company personnel, with technology transfer officers and with directors

[8] Size in FTE indicates the size of the companies at the time the interviews were conducted. Since BIO2 and ICT1 had ceased to exist prior to data collection, we report the maximum size they achieved during their lifetime.

[9] http://www.proknow-eu.de/about.htm Accessed on 15 January 2009.

[10] Interview data from two respondents were collected by Liudvika Leisyte in the framework of a comparative study on management and self-governance models (2006-2009) funded by the German Research Foundation (DFG).

of the research institutes. Additionally, financial reports and strategic plans, as well as research evaluations, were collected. Appendix III contains examples of the interview protocols used in this study. Overall, the data that were collected covers the period from 1990 to 2007. Research departments were asked to provide data about their portfolios in the years that relationships existed between them and their spin-off companies and also data from the period before the relationships with the spin-off companies had started.

In the first step of the data collection process, we identified and interviewed technology transfer officers and scientific directors from the five selected research institutes. These people were interviewed using a semi-structured questionnaire. Using the interviews we obtained access to strategic plans and reports, as well as information about research departments and their spin-off companies. This information allowed us to identify research departments that had helped to create spin-off companies. In a second step, we interviewed the leaders of research departments in order to obtain permission to collect data about the research departments and to identify key persons within the research departments and the spin-off companies. Subsequently, a first round of interviews was conducted with representatives of the spin-off companies. Again, a semi-structured questionnaire was used. A second round of interviews was held with researchers of the research departments. We selected only senior staff members as they had held a position in the research department for a longer period of time. Their seniority gave them a better understanding the developments their research departments and the environment of their research departments had gone through over time. Interviews were conducted with at least two staff members of each research department.[11]

In total, 39 semi-structured interviews were conducted with representatives from spin-off companies, research departments and research institutes. A list of the people interviewed can be found in Appendix II. The interviews were recorded with the consent of the respondents and notes were made during the interviews. During and after the interviews, financial data, strategic reports and other documents were collected. Occasionally, respondents were approached for a second time by phone or electronic mail to provide additional information. The bulk of the data collection occurred between July 2006 and October 2007. In 2008 some additional interviews were conducted to complement the existing material.

[11] MedLab 2 is the only exception in this respect where one senior researcher of the research department was interviewed.

The collected data were analysed as follows. Interview data were analysed and categorised using the concepts and operationalisations of the research model. Interview data from different respondents were combined in order to come to a general conclusion about a research department, while we retained dissimilar opinions wherever they occurred. Financial data from reports and administrative systems, strategic reports and research evaluations were used to check the findings from the interviews. Interview data and financial data were compared with each other in order to check whether the financial data corroborated the interview data. Based on the statements of the respondents and the financial reports, we were able to determine the relative size of the exchanges with the spin-off companies compared to the total research portfolios of the research departments. Based on the extent of the relationships over time, in relation to the overall research portfolios, the intensity of the relationships were categorised using the scores 'none', 'minor', 'significant' or 'major'. Similarly, we grouped interview data with financial reports and other strategic documents to assess changes in the research portfolios and the impact of the interactions with the spin-off companies in this respect.

4.5 Limitations

In this final section, we discuss the limitations of this study. Limitations concern difficulties in attributing causality when measuring impacts, and the generalisability of the empirical results.

4.5.1 Attributing causality

While this study aims to investigate the impact of relationships between research departments and spin-off companies on the research portfolio of the departments, we are aware that it is difficult to determine causality between relationships with spin-offs and changes in the research portfolios of departments. Attributing causality is one of the most challenging endeavours in the social sciences. In an ideal situation, the case selection would have included pairs of similar research departments in which one of each pair had created spin-off companies while the other had not. In such a controlled approach, which limits the differences in independent variables which are not of central concern to the study, causality is easier to attribute. In our study this was not feasible since the research departments we came across were unique in their research activities as well as in their connections with organisations in their environment. Therefore, we decided to triangulate the interview data by interviewing multiple senior researchers within individual research departments, technology transfer officers, directors of the research institutes and representatives from the spin-off companies. At the same time, we did not only collect data from interviews but also collected data from annual reports, strategic plans, research evaluations and financial reports. In doing so, it was possible to check the opinions of the respondents concerning the impact of the relationships between research departments and spin-off companies on the research portfolio.

4.5.2 Generalisability

In this study we empirically investigate eight research departments within three scientific fields in the Netherlands. Given that it is limited to a single research system and a relatively small number of research departments, the results of this study may be difficult to generalise to other countries. The comparative case study methodology, however, does provide the ability to investigate which mechanisms play an important role and to test propositions. The investigations in this study provide an understanding of the mechanisms that affect the engagement of research departments in relationships with their spin-off companies. The study also provides insights into the mechanisms that underlie the changes in the research portfolios of the research departments due to their relationships with spin-off companies. Since research departments in the three selected scientific fields in the Netherlands have been increasingly encouraged by policymakers to engage in knowledge transfer and commercialisation activities, this study will show how the environment of research departments, as well as their own characteristics, shape their relationships with spin-off companies and their research portfolios. We believe these findings could be useful for other researchers interested in the impacts of knowledge transfer and commercialisation activities on the production of scientific knowledge.

5 National context: the Dutch science system

This chapter has two aims. First of all, it describes the national context for the case studies. We describe the main actors in the Dutch science system and how the environment of research departments in the Netherlands has become increasingly supportive to the engagement in science-industry collaboration and commercialisation of research results. In the second part of this chapter, we describe how public research organisations in the Netherlands have responded to these pressures in their environment in the light of their engagement in supporting spin-off company creation.

5.1 Main actors in the Dutch science system

In the Dutch science system one can distinguish between three levels (OECD, 2003a) as presented in Figure 5.1. The first level consists of organisations concerned with high-level policymaking. This level is occupied by the Dutch government, ministries that fund education and research, as well as advisory councils. The Ministry of Education, Culture and Science is responsible for higher education and research. The Ministry of Economic Affairs is responsible for technology and innovation policy. Other ministries also contribute to the governance and funding of public research organisations. In addition to the ministries, the first level includes two advisory bodies: the Advisory Council for Science and Technology (AWT) and the Scientific Council for Government Policy (WRR). In 2003, the Innovation Platform, a think tank, was set up by the government with the aim of developing plans to increase the innovative capacity of the Netherlands. The Innovation Platform included key figures from the worlds of government, business, science and education.

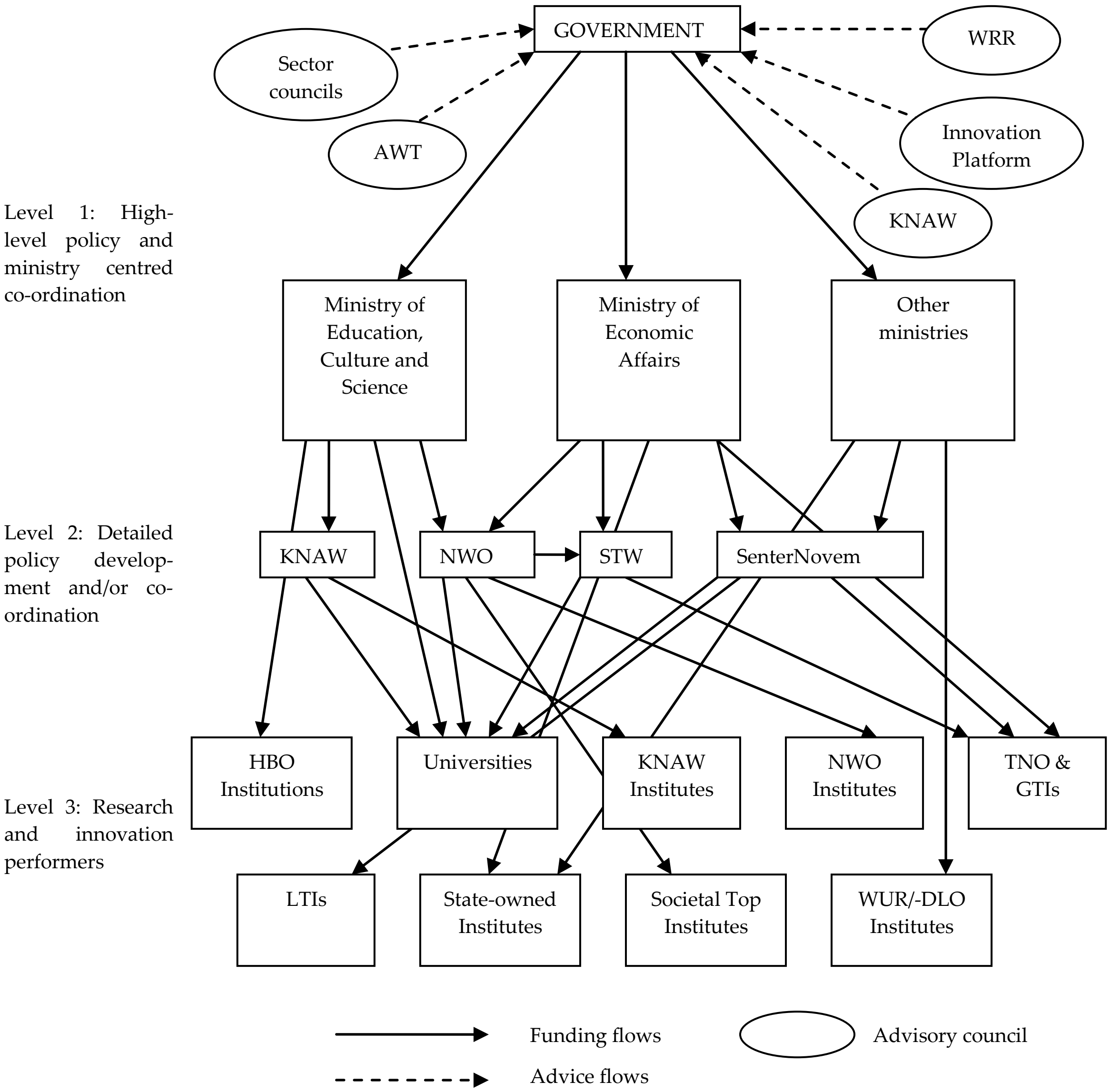

Figure 5.1. Organisations in the Dutch science system[12]

The second level in the science system is an intermediary level. A characteristic of the Dutch research system is that the system has a relatively large number of organisations on this intermediary level, such as research councils and

[12] Adapted from OECD (2003a) and Jongbloed (2010).

representative bodies (van der Meulen & Rip, 1998). The Netherlands Organisation for Scientific Research (NWO) and the Foundation for Applied Sciences (STW) are the two main research councils in terms of providing research funding to universities and other non-university public research organisations. SenterNovem and the Royal Netherlands Academy of Arts and Science (KNAW) also provide research funding. NWO is the most important research council. Its mission is to promote high quality scientific research, as well as initiating and fostering new developments in scientific research. NWO is responsible for the allocation of project-based research funding. Its funding originates mostly from the Ministry of Education, Culture and Science. NWO funds research projects while also administering nine research institutes. In 2007, NWO had a budget of €567 million; €466 million was provided by the Ministry of Education, Culture and Science and €101 million originated from other sources. STW is another important provider of research funding and receives its funding from the Ministry of Economic Affairs and the Ministry of Education, Culture and Science. Its mission is to fund excellent and application-oriented technology research in universities and other non-university public research organisations in the Netherlands. In 2007, the budget of STW amounted to approximately €61 million. SenterNovem is an agency of the Ministry of Economic Affairs and promotes sustainable development and innovation in the business sector. In this role, SenterNovem finances public, private and public-private research and innovation projects.[13] In 2007, the agency allocated a budget of 848 million Euros to projects that supported research and innovation in the Netherlands. In comparison to NWO, SenterNovem and STW are focused on fostering the utilisation of scientific knowledge by business and the dissemination of scientific knowledge to societal partners. KNAW advises the government and universities on science policy matters and acts as an unofficial representative of academic researchers. It also acts as an umbrella organisation for 18 research institutes. In addition to these organisations, the Association of Research Universities in the Netherlands (VSNU) and the Netherlands Association of Universities of Applied Sciences (HBO-raad) also represent the interests of Dutch universities and the universities of applied sciences respectively. The VSNU and the HBO-raad represent their member organisations in policy discussions.

The organisations that actually carry out research and development constitute the third level in the Dutch science system. On this level, there are nine general research universities, three technical and one agricultural university. The Netherlands also has 40 universities of applied sciences. Eight universities are

[13] In 2010 SenterNovem became a part of the newly created AgentschapNL.

allied with academic hospitals. There are several non-university research institutes and laboratories: the Netherlands Organisation for Applied Research (TNO), six Large Technological Institutes (GTIs), nine Leading Technological Institutes (LTIs), agricultural research institutes (DLOs), three Societal Top Institutes and several state-owned research centres.

5.2 Research funding and knowledge transfer policies

In recent decades, the environment of universities and other public research organisations in the Netherlands has become increasingly conducive to engagement in knowledge transfer and commercialisation activities. Section 5.2.1 describes the rise of knowledge transfer policies and the associated policy instruments. Section 5.2.2 discusses trends in research funding in the Netherlands.

5.2.1 The rise of knowledge transfer policies and instruments

The Dutch government and government ministries and agencies in the Dutch research system have encouraged universities and other public research organisations to engage in knowledge transfer with other societal organisations and to commercialise their research results. In the Netherlands, engagement in knowledge transfer and commercialisation activities by public research organisations is often labelled as ‘valorisation’. Over the years, numerous policies and regulations have been introduced to promote science-industry interaction. This has profoundly changed the environment in which public research organisations operate. An early example of this was a white paper by the Ministry of Economic Affairs that called, among other things, for the establishment of ‘transferpunten’, i.e., industrial liaison offices, to support knowledge transfer between public research organisations and the business sector (MEZ, 1979). During the 1980s and 1990s, several other policy instruments were introduced to encourage public research organisations to engage in knowledge transfer with industry and to create patents, spin-off companies and other commercial outputs. Numerous reports and advice were issued by organisations in the first and second layers of the Dutch science system (e.g. AWT, 1992, 1994, 1995, 1998, 1999, 2001, 2003, 2005; MOCW et al., 1995; NWO, 2004; VSNU, 2005; WRR, 1990) Internationally, similar developments took place. Organisations in other countries and supra-national bodies, such as the OECD and the EU, stressed the role of public research organisations in contributing to the knowledge economy (e.g. EC, 1995, 2003; OECD, 1997, 2000, 2003a, 2004a, 2004b). Illustrative of the importance attached to innovation-oriented research in the Netherlands was the establishment of the Innovation Platform in 2003. The Innovation Platform consisted of a number of representatives from the government, the business sector and academia, and developed plans to stimulate innovativeness in the Dutch knowledge economy. The Ministry of Education, Culture and Science explicitly stated that outreach activities, such as the pursuance of intellectual property and the creation of spin-off companies, are part of the mission of Dutch universities (MOCW, 2003, 2005). In the eyes of the Ministry, the mission of universities should be complemented with activities such as knowledge transfer with organisations outside of academia. Further, advisory councils, research councils and the Innovation Platform have stressed the importance of knowledge transfer and the creation of research-based spin-off companies (Innovatieplatform, 2007). In 2004, the VSNU, in collaboration with the Dutch Federation of University Medical Centres (NFU) and the Confederation of Netherlands Industry and Employers (VNO-NCW), signed a charter to promote university-industry knowledge transfer (NFU et al., 2004).

Several concrete initiatives have sought to steer academic research towards more economically relevant problems, to promote knowledge transfer and to involve academia in the commercialisation of their research results. An overview of the key policy instruments and programmes is presented in Table 5.1. From the 1980s onwards, the Dutch science system has witnessed a steady growth of instruments that promote public-private partnerships (PPPs) in research and the commercialisation of scientific knowledge. All but one of the listed instruments are administered by STW and SenterNovem. Only the Casimir project is administered by NWO. In addition to the listed policy instruments, the Ministry of Economic Affairs and other ministries provide competitive research funding and link the funding to a pre-condition that research institutes collaborate with industry. This type of research funding often has a more incidental character.

Table 5.1. Policy instruments that encourage science-industry knowledge transfer[14]

Instrument	Description	Budget in Euros	Years of operation
Innovation-Oriented Research Programme (IOP)	Competitive grants for innovative research projects in public-private cooperation	66 million (2006 – 2009)*	1980 - present
Open Technology Programme (OTP)	Competitive grants to stimulate projects in universities with a potential for application and commercialisation	Average of 43 million annually (2000–2008)**	1981 - present
Economic Reinforcement Fund (ICES/KIS 1)	Subsidies for cooperative research alliances involving public research institutions and private companies	113 million	1994 - 1998
Leading Technological Institutes	Public-private partnerships in which scientific researchers and business collaborate in research projects	29 million in 2003****	1997- present
Economic Reinforcement Fund (ICES/KIS 2)	Subsidies for cooperative research alliances involving public research institutions and private companies	211 million	1998 - 2002
ICES/KIS 3 - Bsik	Subsidies to set up public-private research consortia	802 million	2003 - 2009
Smartmix	Subsidies for cooperative research alliances between scientific researchers and business	100 million annually	2007 - 2010
Innovation vouchers	Subsidies for SMEs to commission contract research at universities and other public research institutions	25 million annually*	2004 - present
Technopartner	Subsidies and venture capital for high-tech start-ups	21.2 million (2006-2009)*	2004 - present
Biopartner	Subsidies, seed funding and venture capital for start-up companies in the life sciences	See above	2000 - 2004
Valorisation Grant – SBIR	Subsidies for feasibility studies and seed funding	Approximately 1.5 million annually**	2004 - present
Casimir	Incidental grants to foster staff mobility between universities and private companies	2,8 million in 2007***	2005 - 2007

One of the first initiatives to encourage scientific researchers to increase the societal relevance of their research was the creation of the Advisory Councils on Research (van der Meulen & Rip, 2001).[15] In the 1980s, Innovation Oriented

[14] This table was adapted from (Jongbloed, 2004). Other sources: ICES/KIS budgets are from SenterNovem.nl; * TOF-overzicht 2006, 2007, 2008, 2009, Ministry of Education, Culture and Science; ** Annual reports STW; *** NWO; **** OECD (2003a).
[15] In Dutch the Councils of Research are called Sectorraden.

Research Programmes (IOPs) were set up by the then Ministry of Education and Sciences in cooperation with the Ministry of Economic Affairs. In the late 1980s these programmes were supplemented with Priority Programmes, aimed to link basic research to socioeconomic objectives, and Stimulation Programmes (van der Meulen & Rip, 2001). According to van der Meulen and Rip (2001), these programmes had a threefold goal. First of all the programmes were set up to develop new knowledge relevant for specific socioeconomic fields. Second, the programmes were aimed at enhancing the research capacity within public research organisations and private enterprises. And third, the programmes aimed to facilitate knowledge transfer that would lead to concrete innovations in the private sector. In 1981, STW was established with the goal of stimulating excellent application-oriented research in technology areas. Its main activity to date is to supervise the Open Technology Programme (OTP), which had an annual budget of €43 million between 2000 and 2008. In the 1990s, other programmes were initiated including ICES/KIS, the Leading Technological Institutes (LTIs), Technopartner and Smartmix. These programmes provide monetary resources to scientific researchers to encourage them to engage in relationships with private companies or to engage in the commercialisation of research. So far, three rounds of ICES/KIS tendering have taken place. The first ICES/KIS call for proposals occurred in 1994, another in 1998 and the most recent was honoured in 2004. In total, the ICES/KIS programmes invested over €1.1 billion in university-industry research consortia. In 2000, the Ministry of Economic Affairs created the Biopartner support programme specifically for the creation of high-tech start-up companies in the biotechnology sector. This programme provided a stimulation grant to encourage the development of a business plan and seed-money to start a company. A follow-up programme, Technopartner, was introduced in 2004. It provides support for start-up companies in a broad range of technology sectors.

This overview shows that the beliefs and norms of the environment of public research organisations in the Netherlands have changed. Engagement in knowledge transfer and commercialisation activities by universities and other public research organisations have become important activities in the eyes of science policymakers. Beliefs and norms were supplemented with a conviction that public sector research should engage in knowledge transfer and commercialisation activities so as to contribute to the innovative capacity of the Dutch business sector. In addition to normative pressures from the environment, public research organisations were encouraged by directed funding. Today, substantial amounts of research funding are awarded to university-industry partnerships and application-oriented research programmes.

5.2.2 Developments in research funding

We will now discuss developments in recurrent and non-recurrent research funding. We do so in order to demonstrate that although availability of recurrent and non-recurrent research funding in the Netherlands has increased overall, research departments have been confronted with increased external steering of their research agendas. Increasing amounts of monetary resources are tied to external funding that has been oriented towards certain research themes and/or science-industry collaboration. Research universities receive recurrent funding, i.e., a more-or-less fixed annual budget for research, also known as first stream income from the Ministry of Education, Culture and Science. In addition, university researchers can compete for project funding and contract research, i.e., non-recurrent funding. Project funding, also known as second stream funding, comes from NWO, KNAW and STW. Further, there is funding from contract research conducted for SenterNovem, industry, non-profit organisations, and for national and international governments, which is referred to as third stream funding. Non-university public research organisations receive recurrent funding either from the Ministry of Education, Culture and Science, the Ministry of Economic Affairs or organisations such as NWO and KNAW.

A study by the Rathenau Institute found that first stream research funding for universities rose from approximately €493 million in 1975 to almost €1750 million in 2005, an increase of 355% (Versleijen et al., 2007). Corrected for inflation, recurrent research funding for Dutch universities was relatively stable until 1990. Thereafter, between 1990 and 2005, the recurrent budget for the universities almost doubled in real terms. The data that are available on the ratio of recurrent funding to project funding indicate that recurrent funding is in decline relative to project funding and contract research. The Association of Research Universities in the Netherlands (VSNU) estimates that, in 1990, approximately 58% of university personnel allocated to research were funded through recurrent funding from the Ministry of Education, Culture and Science, while in 2006 recurrent funding accounted for just 48% (Versleijen et al., 2007).

Non-recurrent research funding has witnessed a shift from academically-oriented research programmes to research programmes that are specifically targeted at technology sectors and innovation (Lepori et al., 2007). While in 1970 about 50% of project funding research instruments in the Netherlands were academic-oriented, in 2002 the share of academic-oriented instruments was down to about 18%. The remainder of the funding instruments in 2002 were either thematically-oriented or innovation-oriented. These funding instruments provided funding to projects in specific technology research areas such as genomics, micro- and nanotechnology and ICT. Project and contract research funding from the Ministries of Education, Culture and Science and of Economic Affairs rose significantly from less than €200 million in 1975 to almost €1 billion in 2005 (Versleijen et al., 2007).[16] Research programmes that encourage university-industry collaboration and application-oriented research benefitted most from the increase. NWO, the principal provider of project funding, saw its budget rise from less than €50 million in 1975, to €300 million in 2005 (Versleijen et al., 2007).[17] Research funding from NWO is supposed to support basic research. However, over time, NWO has also started to increasingly support application-oriented research. In the same period, the Ministry of Economic Affairs has significantly increased its funding of scientific research through programmes that the stressed commercialisation of scientific knowledge and university-industry collaboration (see Table 5.1). During the 1990s, research funding from third stream sources began to exceed NWO project funding. Figure 5.2.2 shows the composition of third stream research funding in the university sector.[18] The data illustrate that, from 1990 onwards, there was a steady increase in contract research funding, from approximately €231 million to €616 million in 2006. The share of industrial funding was 22% in 1990 and this rose to 27% in 2003, rising from approximately €50 million to €160 million (Figure 5.2). Private non-profit organisations (PNPs), including charities, contributed almost €70 million in 1990 and €184 million in 2003. International grants, originating predominantly from the European Union, saw an even larger increase, international grants tripling from €25 million to almost €90 million. National government agencies almost doubled their contract research budgets from €85 million to €160 million annually. Even corrected for inflation, these increases indicate a significant rise in market-oriented activities by universities.

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[16] This study is based on the budgets of the Ministry of Education, Culture and Science and the Ministry of Economic Affairs, and in some cases, NWO. It does not include contributions from non-governmental organisations such as industry, nor does it include funding from international governments such as the European Union.
[17] Not corrected for inflation.
[18] Source: (CBS, 2004, 2006). The figures are based on the annual reports of universities and concern third stream funding coming from education as well.

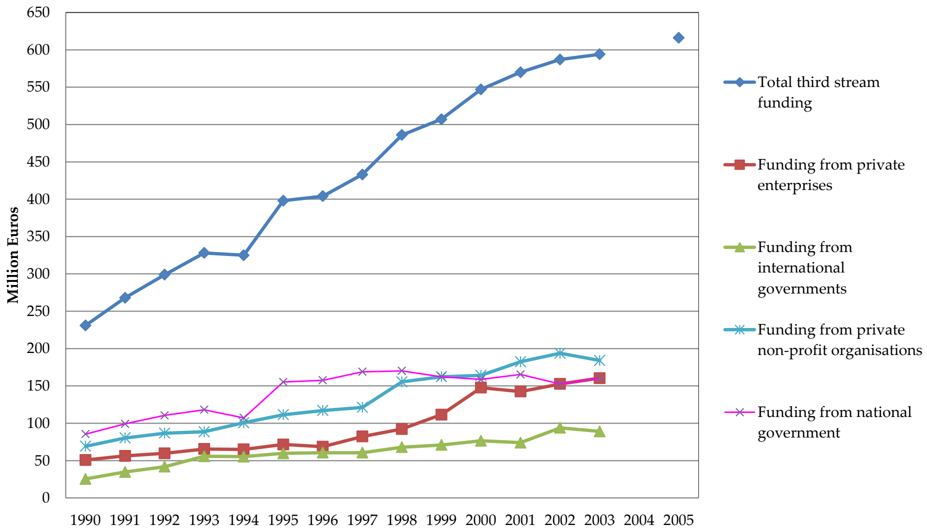

Figure 5.2. Third stream research funding of Dutch universities, 1990 to 2005

The increase in project funding and contract research has contributed significantly to the research capacity of public research organisations in the Netherlands. Most of this increase has been driven by research programmes that are focused on application-oriented research and require university-industry collaboration. In many cases, scientific researchers are required to co-finance research projects using funds from their own resources. This is known as matching. It is not uncommon for research funding organisations such as NWO, STW, SenterNovem, the European Union, and charities to expect universities to contribute about 50% of the research costs from the universities' own resources. Such project funding and contract research activities therefore limit the way in which universities can spend their recurrent research budgets. According to the Dutch universities, the obligatory contributions to externally acquired research projects have limited their abilities to protect and enforce parts of their research portfolios (MOCW, 2003). In other words, the room to set their own research agendas has come under pressure by the obligatory matching of external funding. There is an ongoing debate about whether matching of project funding has remained stable or has increased, and whether the extent of the matching problem has increased in recent decades (cf. AWT, 2004a, 2004b; CPB, 2004; Versleijen et al., 2007; VSNU, 2006). Nevertheless, it is clear that, as scientific researchers increasingly acquire external funding, more institutional resources, which formerly could be spent outside the confines of externally-acquired research projects, are now tied to such research projects.

5.3 Research assessments

Research assessments are an important feature in the environment of public research organisations. In the Dutch science system, research assessments are nowadays conducted by QANU (the organisation for Quality Assurance Netherlands Universities) from 2003 onwards. Before 2003, VSNU conducted these research assessments. The aim of the assessments is to evaluate the quality of scientific research programmes. Until 2004, assessments were conducted every five years and simultaneously in all research departments active in the same research field. From 2004 onwards, the research assessments follow a different procedure. Individual universities have greater autonomy over the assessments. Universities are able to choose when assessments take place, which departments are reviewed and whether or not the review will be conducted in collaboration with departments in other universities active in the same research field. The Standard Evaluation Protocol 2003-2009 evaluates public research organisations on the basis of four criteria (QANU, 2003):

- Quality (international recognition and innovative potential)
- Productivity (scientific output)
- Relevance (scientific and socioeconomic impact)
- Vitality and feasibility (flexibility, management and leadership).

The evaluation protocol leaves room for the review committee to focus on selected aspects of the research institutes or research departments. For instance, the review committee can devote substantial attention to research commercialisation by the organisational unit under review alongside scientific quality. Research departments in the Netherlands are not only reviewed with respect to their scientific quality and productivity, but also their societal relevance. This implies in principle that criteria on what constitutes valuable research are taken into account. Unlike in the UK, where the RAEs (Research Assessment Exercises) have direct consequences for the distribution of recurrent funding to research departments, the VSNU/QANU research assessments do not have an impact on the recurrent funding that is allocated by the Ministry of Education, Culture and Science. Outcomes of the research assessments, however, will be used by deans, executive boards and research councils in the allocation of research funding (Jongbloed & van der Meulen, 2006).

5.4 The creation of spin-off companies by Dutch public research organisations

Public research organisations in the Netherlands have increasingly responded to processes in their environment that stress the importance of knowledge transfer and commercialisation activities. In line with new institutional theory, we would expect public research organisations to conform to institutionalised norms and rules in their environment. A public research organisation will try to communicate to those organisations in its environment from which it mobilises resources that it is acting in good faith, and following norms and rules, by supporting, promoting and engaging in knowledge transfer. Conversely, resource dependence theory would expect public research organisations to support the creation of spin-off companies in order to mobilise resources from their environment.

We showed in Section 5.2 that policymakers and funding agencies have increasingly advocated the engagement of public research organisations in knowledge transfer and commercialisation activities. To further this aim, they have published white papers and introduced policies and financial incentives to encourage such activities. Figure 5.2 has already shown that the third stream income of universities rose significantly between 1990 and 2003. From the 1980s onwards, patenting and licensing activities by public research organisations in the Netherlands has also increased. Patent applications rose steeply from approximately 80 in 1981-1982 to over 330 in 1997-1998 (Tijssen et al., 2006).[19] Although there has been a decline in patenting since 1997-1998, the number of patent applications is still far higher than in 1981-1982.

A study by van Tilburg and Kreijen (2003) is the most comprehensive empirical survey in the Netherlands on spin-off company creation by public research organisations.[20] The study covers most Dutch public research organisations and estimates that 107 spin-offs were established annually by 29 public research organisations between 1999 and 2001. Before this period, the bulk of the Dutch public research organisations had already started to support the creation of spin-off companies by setting up technology transfer offices and incubators, indicating that most public research organisations were already

[19] Number of EPO and PCT patent applications at the EPO.

[20] Other studies that mention estimates of spin-off company creation by public research organisations in the Netherlands include an OECD study (2003b) which reported on IP-based spin-off companies of public research organisations in biotechnology and ICT in the Netherlands; a report by Senter (2001); and a study by Poutsma and de Wit (1995).

committed to spin-off creation at that time. The engagement of universities and non-university public research organisations in creating spin-off companies took off on a large scale in the 1990s. Figure 5.5.1, based on the study of van Tilburg and Kreijen (2003), shows in which years universities and other public research organisations in the Netherlands started to support the creation of spin-off companies. Looking at the engagement of Dutch universities and other public research organisations in spin-off company creation, we see they were most active in creating technology transfer offices and incubators for spin-off companies in the 1990s. In the 1980s, only four public research organisations set up support structures for spin-off company creation. Prior to 1996, 76% of public research organisations in the Netherlands did not have support structures for the creation of spin-off companies (van Tilburg & Kreijen, 2003).

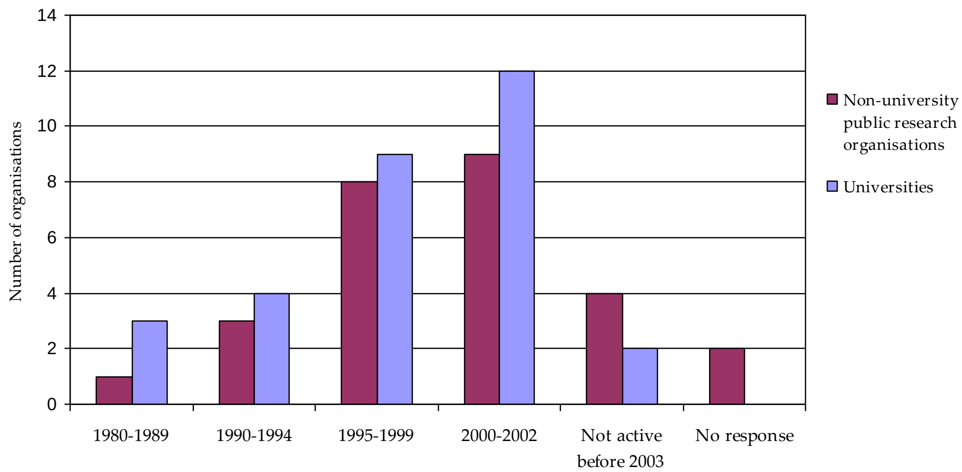

Figure 5.3. Number of Dutch universities and non-university public research organisations with spin-off support structures from 1980 to 2002

The study conducted by van Tilburg and Kreijen reported that only 1 of the 14 universities, and only 3 other non-university public research organisations, regarded the stimulation of spin-off companies as not being an important part of their activities. In 2005, 12 of the 14 Dutch universities had created holding companies or technology transfer offices to support patenting and the creation of spin-off companies (VSNU, 2005). The increasing attention paid by public research organisations to the creation of spin-off companies is also evident in their annual reports. Nowadays, all but a few public research organisations in the Netherlands promote their technology transfer and commercialisation activities in their communications to the outside world. To illustrate the scientific quality and societal relevance of their research activities, they pay particular attention to the spin-off companies they have helped to create, for instance by referring to them on their websites.

Public research organisations have several motivations to support the creation of spin-off companies. Some motivations are indicative of institutionally driven reasons, while others reflect more resource-driven reasons. Van Tilburg and Kreijen (2003) found that among Dutch universities (N=14), the two most cited motivations for stimulating the creation of spin-off companies were to enhance the image of the university (86% of respondents) and to show the university was fulfilling its societal mission (71%). These findings point towards the seeking of legitimacy by universities in the sense of adhering to these norms and rules in their environment that value engagement in knowledge transfer and commercialisation activities. Less frequently mentioned motivations for stimulating spin-off company creation were enhancing the relationship with private enterprises (64%), increasing the amount of third stream income (64%) and strengthening research activities (36%). These motivations indicate universities' interests in mobilising resources. National policy instruments that promote the creation of spin-off companies, such as Technopartner, could not have played a role in the initial efforts of universities to provide support structures for spin-off companies since the large majority of public research organisations had already created support structures.

5.5 Conclusions

This chapter provides a picture of the context in which public research organisations started to engage in knowledge transfer and commercialisation. It has specifically looked at the support for spin-off company creation. From the 1970s onwards, research funding has increased considerably. Project-based funding from research councils and contract research has increased faster than recurrent funding from the Ministry of Education, Culture and Science. Most of the new funding instruments that have been introduced over the years foster scientific research that will contribute to innovation. Project-based funds often require researchers to engage in partnerships with non-academic organisations. Scientific researchers who apply for research grants to STW and SenterNovem have to justify the societal relevance of their intended research. Researchers applying for grants have to specify which societal partners will participate in their projects and whether they have non-academic research partners that will co-fund their research projects. This means that private enterprises, including spin-off companies, have become attractive partners for researchers in their attempts to acquire research funding from government agencies. Although the environment surrounding scientific researchers has become increasingly conducive to collaboration with private enterprises, the traditional criteria of academic excellence have remained important for researchers. Research assessments, however, increasingly pay attention to the societal relevance of scientific research. Publishing articles in peer-reviewed journals is still the most important activity on which academics are evaluated in research assessments, but the criteria of scientific quality and productivity have been complemented by that of societal relevance. In general, funding agencies, review committees and policymakers have all increasingly started to include criteria related to societal relevance, contributing to innovation in the business sector and collaboration with non-academic research partners. Research commercialisation activities by public research organisations have also received increasing support as well. As a result, the environment of public research organisations has increasingly encouraged public research organisations to engage in spin-off company creation and to maintain relationships with industrial research partners.

The above mentioned developments have contributed to the reality that nowadays almost all public research organisations in the Netherlands actively support knowledge transfer to industry and support the creation of spin-off companies. The overwhelming majority of public research organisations have started to offer various types of support to scientific researchers who wish to collaborate with industry or start their own company. The fact that, from the mid-1990s onwards, the large majority of public research organisations started to support the creation of spin-off companies can be understood as an isomorphic process. Public research organisations cite motivations that reflect an adherence to norms and rules in their environment. At the same time, resource-based motivations for engaging in the support of spin-off company creation are also mentioned by public research organisations, suggesting that the reasons for the emergence of spin-off company support by public research organisations are not clear-cut. To shed more light on this point, Chapters 6 to 10, which deal with relationships with spin-off companies and the impacts these relationships have on the research portfolios, will also investigate the mechanisms that have led public research organisations to support the creation of spin-off companies.

Introduction to the case studies

In Chapters 6 to 10 we will present the eight case studies that were introduced in Chapter 4. In our presentation of the results we will be guided by the research model that was developed in Chapter 3 and the operationalisations of the variables presented in Chapter 4. Respondents that are quoted in Chapters 6 to 10 have been anonymised and are referred to by an abbreviation reflecting the research institute or spin-off company they work for.

In each of the case studies, we start with a description of the immediate organisational environments that the research departments are part of, i.e., the university and research institute of which they are part. We continue with a description of the preferences and resources of the research departments so as to understand the motivations of the research departments for engaging in relationships with their spin-off companies. Additionally, organisations in the environment of the research department, other than the spin-off companies, are described. We continue with a description of the history, the potential resources and the demands of the selected spin-off companies.

Subsequently, we describe the relationships that the research departments have maintained with their offspring. We discuss what constitutes the relationships between the spin-off companies and the research departments, what resources were exchanged and how the relationships evolved over time. This enables us to determine whether the research departments maintained relationships with the spin-off companies they helped to create, and if so, the type and intensity of these relationships. Finally, the impact of the relationships with spin-off companies on the research portfolios of the research departments is dealt with. The results from the case studies will be combined and analysed further in the comparative analysis in Chapter 11.

6 MedLab

This chapter deals with MedLab, a public healthcare institute, and two of its research departments: MedLab 1 and MedLab 2.

6.1 The research institute

MedLab is a large public healthcare institute affiliated to the Comprehensive Research University but forming an autonomous organisational entity consisting of twelve divisions. In 2006, the research institute employed 715 FTEs in research and education, in addition to its medical staff. The healthcare institute focuses on basic research, education and patient care, and has engaged in the support of knowledge transfer to a limited extent (ML0.1, ML0.3). A strategic document of the research institute states: "*As the institute is a public institution, fully developing [commercial] value is not our core activity. We do not concentrate our expertise on such development. … Although commerce is not our core activity, at the same time it is our social responsibility to offer these kinds of discoveries for commercial development.*"[21]

From 1995 onwards, policymakers within MedLab started to acknowledge the importance of knowledge transfer and commercialisation activities (ML1.1, ML2.1). In 1996, MedLab created a holding company for its spin-off companies. A year later, the MedLab holding company merged with the central holding company of the Comprehensive Research University, which also supported patenting and licensing. After 2000, MedLab expanded its support of knowledge transfer and commercialisation, and created an investment fund aiming to financially support spin-off companies. In 2004, an incubator facility for starting life science companies was introduced in collaboration with the Comprehensive Research University. Overall, the research institute does not have an elaborate technology transfer function in comparison with most public research organisations (ML0.1). MedLab does not view commercialisation as one of its core activities and believes it should limit both its engagement in knowledge transfer activities and the resources it devotes to them. The research institute's main motivation in starting to support knowledge transfer and commercialisation activities was the fact that other organisations in its environment were starting to pay more attention to these types of activities (ML2.1). The increasing attention to

[21] Website MedLab. Accessed 20th January 2010.

knowledge transfer, by policymakers as well as by public research organisations, created a sense of urgency for MedLab to also show that it produced knowledge relevant for society in order to avoid questions about the legitimacy of its research activities. In the following two sections, we investigate two of its research departments: MedLab 1 and MedLab 2.

6.2 MedLab 1

MedLab 1 is a research department that conducts research on immune system and anti-body medicines. The research department consists of 11 sub-groups. In 2007, the research department employed 65 researchers in total. Knowledge from MedLab 1 has led to the formation of two spin-off companies. This section focuses on the relationship of the research department with spin-off company BIO1, and the impact of this relationship on the research portfolio of one of the research groups within MedLab 1.

6.2.1 Preferences

Most researchers in the research department prefer to conduct basic research that does not necessarily lead to applications or patents (ML1.1, ML1.2). Unfortunately for the research department, its environment has made it increasingly clear that it should show the clinical relevance of its research. This means that it has become increasingly difficult to acquire significant research funding that would allow staff in the research department to conduct basic research. The head of the department, (ML1.1), feels he is forced to apply for grants that require clinical relevance and commercialisation: "d*oing basic research is very difficult nowadays. It's not wrong that we are working on projects with valorisation, but it can't be the only thing we do. There should be basic research as well."*(ML1.1) The changing norms and beliefs in its institutional environment have induced the research department to pay more attention to the clinical relevance of its research. *"We do not say anymore, we want to know how the immune system works. If we write that down we are dead. No, we say, we are doing it for the patient. And of course you want to do that as well."*(ML1.1) Nevertheless, the research staff would still prefer to focus on more basic research questions. The professor within the department, who helped to create BIO1, is interested in both basic research as well as in translating this to clinical applications. *"I have always said to myself, I want to do two things. As an academic I want to be involved in very basic* *aspects of the biology of antibodies. And that is something that still fascinates me. And I want to use a part of that knowledge simply to develop products."*(ML1.1)

The preference for basic research does not mean that the staff of the department has traditionally been against collaborating with industry. The strategy of the department has been to combine their preferences for basic research with the demands of the organisations from which they acquire research funding in order to maintain their research capacity. However, this is not always possible. *"In my former job we had criteria for what we thought was interesting research. Here, we ask ourselves is this interesting? If it is, then we might ask a factor two of the real costs. If it is not interesting at all, but we just need the money, then we might triple the real costs."*(ML1.1) Respondents stated that for the scientific community in which the department is embedded, conducting research in collaboration with industry is an accepted practice. At the same time, research activities that are related to clinical applications have become more important as research funders are moving away from basic research projects without obvious immediate clinical benefits (ML1.1)

6.2.2 Resources

The income from the MedLab research institute has been gradually declining, and this has made MedLab 1 increasingly dependent on external organisations to finance its research activities. MedLab 1 receives approximately half of its budget from institutional funding for its tenured staff and basic facilities (ML1.1). The amount of institutional funding itself has become insufficient to conduct research on an internationally competitive level and finances an increasingly smaller amount of research. This, and the fact that the medical centre rewards research departments that acquire research funding externally, has induced MedLab 1 to attract external funding from research councils, charities and industry to increase its research capacity. *"In the past there used to be more money. Funding from the universities has become a lot less. I think that it is a very difficult time for scientific research."*(ML1.3) In addition to the decline of institutional funding, MedLab 1 needs to co-finance most of its externally acquired research projects with institutional funding. The co-financing from institutional funding makes it very difficult for the research department to conduct basic research since the institutional part of its budget is depleted by co-funding externally acquired research projects. *"Twenty years ago we had a basic income. And that is still there, but we use it to match external projects. So the basic research funds go from being free to spend on pure science to a valorisation-driven topic."*(ML1.1)

The research equipment that MedLab 1 needs for its research activities is expensive. Laboratories are expensive and on-going developments in the research field mean that research equipment is soon obsolete. "*Labs are so expensive. We need machines here from 100,000 to 1.5 million Euros. They age rapidly, so you are in a constant need of money*."(ML1.1) As a result of the need for expensive research equipment, research partners who own the research equipment that the research department lacks are very attractive partners.

6.2.3 Organisations in the environment other than spin-off companies

In addition to BIO1, MedLab 1 can collaborate with several other organisations in its environment. MedLab 1 acquires approximately half of its budget from external sources. As a result, organisations in its environment other than the MedLab medical centre are of vital importance to its survival. Over 15% of the budget originates from contract research for pharmaceutical companies, including BIO1 (ML1.1). Further, NWO, STW, ZonMW, TI Pharma and the EU are sources of project funding. In addition, charities, such as the Aids Funds, KWF and LSBR, provide funding for research projects.

Researchers from MedLab 1 acquire most external funding from national research councils and the EU. The department acquires some funding from research councils such as NWO and ZonMW, but the amount of monetary resources available from these sources is relatively small (ML1.1). As a result of the attention to societal relevance in government research projects, it has become increasingly difficult for researchers from MedLab 1 to acquire funding for basic research projects. "*The funding agencies are steering towards applied research. People find out that real blue skies research has become incredibly difficult because funding goes to programmes with industry. All the research projects go through other programmes, outside of NWO, with constructions in which industry is automatically on board, where valorisation is sitting in the driver's seat. Policymakers deliberately choose not to distribute money through NWO. They think that NWO and the ivory towers, will not help to strengthen our economy because it is pure science.*"(ML1.1). Other sources for research funding, such as the EU, STW and SenterNovem, make up a large part of the research budget. As a result of the temporary nature of government research funding, and the necessity to collaborate with industry and the requirement of most government research funding organisations to co-finance research projects, MedLab 1 researchers are interested in collaborating with industry.

Charities are also an important source for research funding for MedLab 1. Most charities do not require researchers to collaborate with industry. However, research proposals do need to show the clinical relevance of the research. The likelihood of acquiring funding for a basic research project from charities is very low because the immediate benefits for the clinic are very hard to substantiate. *"The KWF, NKI and Kidney Foundation do not explicitly mention valorisation but you cannot do basic research for them anymore. It has to be translational."*(ML1.1)

In addition to BIO1, MedLab 1 collaborates with at least two other large multinational pharmaceutical corporations. These companies have large in-house research and development departments and an interest in long-term research. Internationally, pharmaceutical companies invest billions of dollars on antibody research and development annually, implying that pharmaceutical companies are organisations that could potentially supply large sums of research funding to the research department and provide it with access to research equipment and know-how (ML1.3).

6.2.4 BIO1: history, potential resources and demands

The creation of BIO1 can be traced back to the contacts of a MedLab 1 professor with a pharmaceutical company. Contacts with this pharmaceutical company resulted in substantial contract research projects in the 1990s. After several years of collaboration, the professor was asked by the pharmaceutical company to join the company. The professor refused this offer but accepted a proposal from the pharmaceutical company to create a subsidiary of the pharmaceutical company and become its scientific director. In 1998, plans were established to make the company an autonomous entity with the help of venture capitalists and, in 2000, BIO1 was officially founded. The professor became the chief scientific officer of BIO1 while maintaining his position at MedLab 1.

The monetary resources that BIO1 holds, as well as its possession of research equipment and expertise, and the overlap in research preferences make BIO1 a very attractive research partner for MedLab 1. Annually, BIO1 spends 60 to 90 million US dollars on research and development. Since 2007, the company employes 140 staff and specialises in the development and creation of human antibodies. Its goal is to develop antibody-based therapies to treat cancer, infectious diseases and inflammatory conditions. The company is interested in the initial steps in drug development. One product has so far been successfully developed and sold to a pharmaceutical company that will produce and market it. The company has a strong focus on research and is interested in basic research on antibodies, on which the research department is active. The nature of most of its research activities is such that they could also be conducted inside academia (ML1.3).

6.2.5 Relationship with BIO1

The interactions between MedLab 1 and BIO1 are presented in Table 6.3.5. The creation of BIO1, and its subsequent interactions with MedLab 1, are intertwined with the career of one of the professors at MedLab 1. We therefore start with a description of the relationship between the professor and the pharmaceutical company who helped to create BIO1. In the early 1990s, the now professor was a researcher at MedLab 1 and developed contacts with a pharmaceutical company from the USA. Contacts with the company intensified over the years and, in 1996, he was appointed to a professorial chair within MedLab 1. A first step towards the creation of BIO1 was taken when the professor decided to become the scientific director of a subsidiary of the pharmaceutical company in Europe. Researchers in his group, within MedLab 1, would work for this company and the company would own the intellectual property that was produced in the projects. The professor and his group benefited enormously from this exchange as the subsidiary company invested "*millions a year in the research group for work that was actually very basic research.*"(ML1.3)

Table 6.1. Relationship between MedLab 1 and BIO1

Non-monetary resources	**BIO1**
Joint publications with spin-off company	Major
Joint patent applications with spin-off company	Significant
Former research staff of the research department employed by spin-off company	Major
Personnel simultaneously affiliated to spin-off company and research department	Minor
Bachelor and master theses supported by spin-off company	None
Test data, facilities, instruments and prototypes obtained from spin-off company	Major
Monetary Resources	
Contract research commissioned by spin-off company	Major
Jointly acquired government-funded research projects	Minor
Financial support of PhD research projects	Major
Does research institute or its staff own capital stock of spin-off company?	Yes
Funds from spin-off in exchange for knowledge from research department	None
Donations received from spin-off company	None

In 1998, the professor was invited by the pharmaceutical company to create a separate company, BIO1, based on the subsidiary company. The professor became chief scientific officer of BIO1. He and his research group were still employed by MedLab 1 and remained physically located within MedLab 1. Although BIO1 started to fund major parts of the research portfolio. As a result, the group of the professor grew significantly. At least seven PhD projects were commissioned by the company for instance. In 2000, the research group consisted of approximately 30 researchers; half of whom were funded by research council grants and the other half by BIO1 (ML1.2, ML1.3) Researchers from both the company and the research department resided in the same corridor and informal contacts, where for instance developments in research projects were discussed, were an everyday occurrence. Since the research activities of the research department and the company were heavily entangled it became increasingly unclear for MedLab 1, for the researchers and for BIO1 who owned knowledge that was produced and who had the principal say in research and personnel related matters.

In 2001, the situation escalated. *"[BIO1] was asked to leave by the former leader of the department and they threatened to use lawyers. They got into a legal conflict."*(ML1.1) As a result, the spin-off company physically moved out of the research department that same year. The professor decided to leave the research department, together with the bulk of his research group, and transferred to BIO1 (ML1.3). In total more than 30 researchers moved to the spin-off company and about 5 researchers stayed behind. "*The best PhD students, they are now here [at BIO1], they have jobs as a scientist or manager."*(ML1.3) In the meantime, the professor maintained his chair within MedLab 1. Parallel to the departure of BIO1, another spin-off company of MedLab 1 also left the research department that year, taking with it an additional 15 researchers from other parts of the research department. "*So in a very short time, there was a lot of misery with spin-offs. So when I came here there was a lot of anxiety towards cooperation with companies."*(ML1.1) Not surprisingly, the conflict had a negative effect on the relationship between BIO1 and MedLab 1. Researchers remaining in the research department became hesitant about engaging in contract research with private companies, especially BIO1 (ML1.1). As a result, the relationship between MedLab 1 and BIO1 diminished significantly but remained existent.

In recent years, the relationship with the spin-off company has improved again as the research interests of BIO1 and researchers in MedLab 1 still overlap and people are regaining trust. *"We are gradually starting to collaborate again with [BIO1]. One of my employees has got a nice contract for about one million. For us that is a lot of money.* C*ollaboration with [BIO1] is an obvious thing to opt for. We have a lot of history and the research topics fit very well."*(ML1.1) The professor that helped to create BIO1 has mostly avoided commissioning contract research to the research group he is head of in order to avoid conflicts of interest (ML1.3). Besides the fact that the professor aims to avoid such conflicts of interests, the research group he is professor of is nowadays too focused on basic research to be interesting for BIO1 (ML1.2, ML1.3). *"[BIO1] is not interested in everything. They have to see an application. They think the things we do are too academic. You might think it is easy but you really have to search for something which is patentable."*(ML1.2) Nevertheless, the spin-off company still has a strong appeal to the researchers in the research department and is able to recruit researchers from its ranks as a result. *"I'm less happy with the fact that staff are moving to [BIO1]. I can only give them temporary contracts. It is very difficult to get a tenured position so they leave."*(ML1.2)

Overall, the relationship between the spin-off company and the research department has been very intensive. The spin-off company and its predecessor have invested several million Euros in research projects at the department that were central to its research activities. At the same time, the professor was able to acquire substantial government funding for basic research projects based on his academic reputation. Government funding did not support the relationship between the research department and BIO1 since the company did not participate in the acquisition of government-funded grants but preferred to commission projects in order to avoid interference by other organisations in its research projects. On a few occasions it did participate in government-funded projects but the predominant part of the relationship was formed by informal contacts and contract research.

During the relationship, researchers from the spin-off company and the research department have jointly produced approximately 100 publications (ML1.2). In addition to the large amounts of research funding that were provided to the research department, the interactions with BIO1 were also valuable because personnel in the company could provide MedLab 1 with know-how and research equipment. Researchers had access to large amounts of antibodies, and the use of research equipment sped up the research process and made it possible to conduct analyses which otherwise would not have been possible in the department (ML1.2).

6.2.6 Impacts on the research portfolio

The relationships with BIO1 had a significant impact on the research portfolio of MedLab 1. BIO1, and its predecessor, contributed greatly to the research capacity of the department and helped to considerably expand the research capacity and the research outputs of MedLab 1. MedLab 1 researchers were able to conduct research that was scientifically interesting to them. In order to acquire contract research, MedLab 1 had to accommodate some of the demands of the spin-off company, but the wishes of BIO1 were within the range of topics the professor of the research group was interested in. Patenting and development activities were considered a task for the spin-off company and therefore did not distract researchers from their core research activities, which they preferred to engage in. However, as a result of the conflict that emerged, the relationship deteriorated. Consequently, research funding from BIO1 almost completely stopped and the physical departure of the spin-off company from MedLab 1 led to an exodus of researchers, and the research group then reoriented itself towards basic research activities. In recent years, the relationship has improved and the researchers in the research department are once more attracted by the resources of BIO1. This time, however, they are also aware of the potential drawbacks that come with industry funding.

6.2.6.1 Resources for research

In this section, we discuss whether the relationship with BIO1 has led to changes in the number of contacts with industrial research partners, changes in income from industry and changes in the income from national government agencies and international funding agencies.

Respondents indicated that contacts with BIO1 did not lead to additional contacts with other companies. Researchers within MedLab 1 have maintained relationships with other companies for longer periods of time and these relationships were not established due to contacts with BIO1 personnel. After the conflict with BIO1, and the departure of the spin-off company together with another spin-off company in the research department, researchers in MedLab 1 became wary of collaboration with private companies, thereby reducing industry contacts and the potential for contract research (ML1.1).

Looking at the direct contributions of the spin-off, we see that BIO1 played an important role in creating additional research capacity. The acquisition of contract research projects, from BIO1 and its predecessor, enabled the professor to increase the research capacity of his research group and to engage in interesting and high-risk projects. In total, the spin-off company directly contributed several million Euros to the research capacity of the research group. According to respondents (ML1.1, ML1.2), the subsequent rise in research output contributed to the success that the group has had in its applications for research council grants. The investments of BIO1 had additional benefits for the research group. With the success of the professor in the acquisition of research council grants, the research department as a whole began to build up a deficit because it had to co-finance research projects funded by national and international research councils. Research funding from BIO1 and its predecessor provided the monetary resources needed to fill gaps in the budget of the research department. *"The problem was that those funds hardly compensated for overhead and animal testing. Because the lump sum kept getting smaller, it caused the department to run into deficits. Not because of [BIO1], that was covered very well. For years we had a lot of advantage of the interaction because that enabled us to fill the gaps that arose from our success in grant applications."*(ML1.3) The success of the professor, who had helped to establish BIO1, in acquiring national and international research grants was based first and foremost on his academic merits. Respondents indicated that the relationships with the spin-off company did not lead to the acquisition of additional research funding from government agencies. However, the additional research capacity which BIO1 provided led to a number of publications that provided a basis for grant applications to government agencies.

The conflict and the physical departure of the spin-off company negatively influenced the research capacity of the research group. The departure of BIO1 led to an exodus of researchers that severely reduced the research capacity of the research group. Only 5 out of 30 researchers in the research group remained after the departure of BIO1. The spin-off company did not significantly contribute to the research capacity of the research group after its departure. The main reasons for this were the strained relationship and the basic research orientation of the research group members that remained behind. The group and the company did not engage in government-funded projects and the group has had difficulties to attract research funding (ML2.2). Additionally, the departure of BIO1 and the professor limited the potential of the research group to acquire monetary resources from national and international research councils. After the departure of BIO1, the professor shifted most of his attention to supervising research activities within BIO1 while the executive leadership of the group was transferred to a senior researcher. According to the professor: *"The departure has been difficult for the group. I used to be the one that applied for all the grants. I built an enormous track record. [The new executive leader] is more junior and I don't have time anymore to write applications for 100,000 or 150,000 Euro."*(ML1.3)

6.2.6.2 Research agenda

We found that the relationship with BIO1 and its predecessor allowed the research group to continue its basic research activities while at the same time it had to accommodate for influences on its research themes. Research funding from BIO1 enabled the professor to significantly increase the research capacity of his research group while it was possible to work on research that was central to his interest. Research projects, totalling more than one million Euros annually, were commissioned *"for work that was actually very basic."*(ML1.3) BIO1 and its predecessor, naturally, had preferences for certain research themes. In consultation with BIO1 and its predecessor, the professor decided which research lines to continue and expand. As a result, the professor did not sense that he was forced to conduct certain research activities. Thus, although the research themes of the research group were influenced by the spin-off company, they remained within the domain of the professor's preferences in basic and translational research.

After the conflict with BIO1 and the exodus of researchers, the research group adapted a more basic research profile and started to focus on different themes. The professor maintained his professorial chair at the research group, but the executive leadership was transferred to another researcher. "I *was more interested in understanding antibodies; basic stuff but with a translational character. Her interests are in the cell-biological aspects of antibody receptors and that is a bit further from the interests of the company."*(ML1.3) In the years following the conflict with BIO1, the executive leader of the research group has chosen to retain a basic research focus despite the fact that it has been challenging to acquire research funding and the fact that BIO1 is mainly interested in patentable knowledge. The relationship that existed after the departure of the company led to changes in the research agenda within the boundaries of the projects that BIO1 engaged in. *"There is an influence on the parts they finance. They have a voice in that, absolutely, also when we have to make decisions in the research process. They may think certain aspects are important and we may want to discard them."*(ML1.2) Additionally, informal exchanges of information inspire researchers to look at other research problems and use different models in their research (ML1.2).

6.2.6.3 Research output

In this section we report on the effects of the relationship with BIO1 on the number of scientific publications, other research outputs and research quality.

During the period that the relationship with BIO1 existed, the scientific output of the research group rose significantly (ML1.2, ML1.3). According to the professor who helped to create BIO1, the increase in the scientific output of the research group was primarily caused by the quality of the research that was conducted and the fact that he was active on a research theme that was attractive for industry. *"My section expanded rapidly to a group of 30 people. We could get grants very easily because the work was good. It was a terrain that began to attract a lot of interest. We had a lot of NWO and KWF grants."*(ML1.3) BIO1 and its predecessor provided additional funding that expanded the research capacity of the research group, leading to a further increase in peer-reviewed publications. When funding from BIO1 stopped, and most researchers migrated to BIO1, the research capacity and publication outputs dropped. The research quality of the research group was not affected by the relationship with the spin-off company. According to respondents, the scientific quality of the group's research activities was due to its staff. [22] The spin-off contributed additional resources to expand the research activities of MedLab 1 and this provided a basis for the research activities and the scientific publications that came out of it.

The production of other research outputs, such as patents and the creation of clinical applications, was not affected by the relationship with BIO1 and its predecessor. Throughout its existence, the research group has preferred to focus on the production of scientific papers, not patent applications, and research activities have not led to patent applications by the research group itself. Based on contract research that was performed for BIO1, several patent applications have been filed by the spin-off company and the exclusive ownership lay with the spin-off company. The research group preferred to let the spin-off to file patent applications and to keep its own activities focussed on research. The research group has not been active in the development of clinically applicable therapies, nor has BIO1 asked the group engage in applied research activities because the spin-off company has the capacity to conduct a whole range of research activities itself.

[22] We could not rely on VSNU/QANU research assessment scores since the scores in the assessments also concern other research departments.

6.3 MedLab 2

MedLab 2 conducts research on antibiotic resistance, immune evasion and virology, and consists of 35 researchers. The research department has helped to create at least five spin-off companies (ML2.1). This section investigates the relationship that MedLab 2 has maintained with one of its spin-off companies, BIO2, and the impact of this relationship on its research portfolio.

6.3.1 Preferences

This research department has traditionally engaged in basic research as well as research activities that are closer to clinical application (ML2.1). Researchers in MedLab 2 have been open to commercialisation and collaboration with industry for many years even though their direct organisational environment has historically been reluctant in recognising industrial funding and commercialisation as accepted practices. *"We were active in the semi-commercial corner before words like valorisation were introduced. I have to go back to the head of this department. Twenty years ago he started with some commercial activities. And that was at the time that some universities collaborated with industry but it was mostly considered something dirty."*(ML2.1). Ten to twenty years ago, contract research for private companies was still relatively uncommon and frowned upon by most of his peers. At that time, research funding originated predominantly from government agencies and charities. According to the head of MedLab 2, nowadays, it is common for researchers in the field to patent their research findings, to collaborate with industry in research projects and to conduct research that is commissioned by pharmaceutical companies. As a result, he and his department feel very comfortable in engaging in relationships with industry.

6.3.2 Resources

The income from the MedLab research institute has been gradually declining and this has made MedLab 2 increasingly dependent on external organisations to finance its research activities. Like MedLab 1, MedLab 2 receives approximately half of its budget from the MedLab research institute and acquires the remaining part of its budget from external organisations. Institutional funding is insufficient to conduct research on an internationally competitive level and this has induced MedLab 2 researchers to focus on the acquisition of research funding from government agencies, charities and industry to maintain their research capacity at a desired level. As with MedLab 1, co-financing of external projects from institutional funding inhibits the ability to conduct free basic research since the institutional part of the department's budget is depleted by externally acquired research projects. Organisations that do not demand co-financing, such as industry, are therefore very attractive research partners.

The department requires expensive research equipment and facilities to conduct its research (ML2.1). In addition, research equipment is quickly obsolete. As a result, research partners who own research equipment which the research department lacks are very attractive.

6.3.3 Organisations in the environment other than spin-off companies

In addition to BIO2, the research department is able to collaborate with several other organisations in its environment. MedLab 2 acquires approximately half of its budget from government agencies and industry. In total, less than 15% of the research budget is acquired from industry (ML1.1).

The department acquires government funding from NWO, ZonMW, STW, SenterNovem and the EU and this forms an important part of the budget of MedLab 2. The ability to acquire funding for basic research has declined over the years because government agencies have reduced budgets for basic research and most of them require explicit proof of societal relevance or collaboration with industry. NWO and its subsidiary ZonMW have less stringent requirements although they also prefer to fund research that has a clinical relevance. Given the requirements to include industry in research projects, industrial research partners have become increasingly important for researchers at MedLab 2. At the same time, the ad hoc character of government funding creates uncertainty for certain research lines of the department as it is unclear whether follow-up grants will be acquired.

MedLab 2 started to collaborate with industry in a period when the scientific community in the Netherlands still acquired their research funding only from government sources. According to the head of MedLab 2, the openness of the research department to collaborate with private companies as well as the attractiveness of its research activities to industry led to collaboration with industry at an early stage (ML2.1). The private companies that the research department collaborates with have large monetary resources, making them attractive research partners. Further, their possession of research equipment and a longer-term research focus are important for the department.

6.3.4 BIO2: history, potential resources and demands

The ideas for creating a company started when the current department leader of MedLab 2 and one of his colleagues applied for a patent. The patent caught the attention of venture capitalists who offered to finance a company. The goal of the company would be to increase knowledge about the protein the department had discovered. In 2000, BIO2 was officially founded and the professor and his colleague chose to remain at the research department. In total, BIO2 existed for three years. At its height, the spin-off company employed 20 people. During the first period of its existence, BIO2 received almost seven million Euros from venture capitalists over a period of three years. The aim of this seed funding was to develop treatments based on four patents. There was a huge potential to form a strong relationship. The spin-off company needed the expertise from the department to increase its knowledge about the protein and possessed significant monetary resources. The department possessed personnel with the right expertise but did not have the monetary resources to support research projects on the theme the company was interested in. *"We saw the advantages. If you write an application for a research grant and you get a million, you get a lot. But you can also do that with industry."*(ML2.1) Unfortunately for the research department, three years later, clinical trial showed the protein produced undesirable side effects. As a result, the venture capitalists dropped their financial support, and the operations of the company were discontinued.

6.3.5 Relationship with BIO2

The interactions between MedLab 2 and BIO2 are presented in Table 6.4.5. The relationship was of a high intensity and consisted predominantly of contract research commissioned by the spin-off company. According to the professor of the research department, at least five million Euros were received from the company. Research funding from BIO2 proved to be much easier to acquire than funding from government funding agencies. *"It was easy money. You had to account for the things you did of course, but the money was there. If I saw a good PhD student or a postdoc I could hire him immediately."*(ML2.1) The large contributions of BIO2 created an additional research capacity within the department, which the department would otherwise not have been able to acquire from government grants. Research funding from BIO2 was used to employ 10 researchers and to procure research equipment (ML2.1). *"We had a lot of profit from those contacts. We could do whatever we wanted. We could buy equipment or appoint someone."*(ML2.1)

Table 6.2. Relationship between MedLab 2 and BIO2

Non-monetary resources	BIO2
Joint publications with spin-off company	None
Joint patent applications with spin-off company	Significant
Former research staff of the research department employed by spin-off company	None
Personnel simultaneously affiliated to spin-off company and research department	Minor
Bachelor and master theses supported by spin-off company	None
Test data, facilities, instruments and prototypes obtained from spin-off company	Minor

Monetary Resources	
Contract research commissioned by spin-off company	Major
Jointly acquired government-funded research projects	Major
Financial support of PhD research projects	Major
Does research institute or its staff own capital stock of spin-off company?	Yes
Funds from spin-off company in exchange for knowledge from research department	Major
Donations received from spin-off company	None

In addition to contract research that was commissioned by BIO2, the company also participated in a project funded by SenterNovem. The budget for this project was approximately two million Euros and was mainly allocated to the department. According to the respondents, the acquisition of this project led to a considerable enhancement of the relationship between the department and the company. In this sense, the funding environment was important in facilitating the relationship, but the relationship between the spin-off company and the department would have existed without external funding since the relationship existed first and foremost because of the contract research that was commissioned by the spin-off.

MedLab 2 became dependent on research funding from BIO2. "*It was a big risk that the company heavily invested in our research activities. But again, there is no 100% difference with government grants. They only last for three or four years as well. But the apparent promise from companies that the funds will keep coming is greater. You think that it will keep growing and growing. But that hope fell to pieces in one instance.*"(ML2.1) Two months before a second cash infusion into the spin-off, clinical trials indicated that the administration of the protein in humans had side-effects. As a result, venture capitalists withdrew their financial support. In the absence of other venture capitalists, BIO2 decided to discontinue its operations and the patents returned to the holding company of MedLab. Given that the department was predominantly financed by the spin-off company, the cessation of operations came as a shock. Fortunately for the department, the spin-off company managed to extend the support of the research activities of MedLab 2 for another half year, reducing the shock somewhat. The head of the department knew that after that period he would have to find research funding for his staff in order to keep them employed. *"As a group we went through a very bad period. At that moment people became very uncertain about their jobs. But I have to say, I don't regret it for one moment. The only thing I regret is the moment it all broke down. There was panic. You have to fire ten people. It was a big bite out of the group."*(ML2.1) During the existence of BIO2, MedLab 2 and the spin-off did not engage in joint publication of journal articles. The spin-off company paid the department for the creation and testing of large quantities of proteins in addition to the contract research that was commissioned.

6.3.6 Impacts on the research portfolio

The relationship with BIO2 had a significant impact on the research portfolio of the research department. As a result of the intense relationship, the research capacity of MedLab 2 expanded significantly. A large part of the research department became dependent on funding from BIO2. The increased research capacity enabled the research department to expand its basic research activities and continue working on topics that were central to its interests. At the same time, the major investments were not detrimental to research quality and provided a basis for writing high-quality publications. The demise of the company created severe funding problems for MedLab 2 and uncertainty about the viability of the research department. Fortunately for the research department, the relationship with BIO2 had provided a basis for high-quality publications in prestigious journals which provided a basis for the acquisition of government funding after BIO2 was discontinued.

6.3.6.1 Resources for research

In this section, we discuss whether the relationship with BIO2 has led to changes in the number of contacts with industrial research partners, changes in income from industry and changes in the income from national government agencies and international funding agencies.

Following the contacts with BIO2, and the venture capitalists who financially supported the spin-off company, the members of the department *"still have contacts with a number of small companies for whom we do semi-commercial activities."*(ML2.1) Thanks to these contacts, the research department was able to acquire funding to support further research on the proteins that were discovered. *"We have some SenterNovem projects; those are grants of half a million. We still have* *them because of [BIO2]."*(ML2.1) The research department came into contact with a pharmaceutical company that was interested in the patents and the know-how about the isolated protein. This company obtained the patents on the protein and participated in an STW research project. *"That has been beneficial for the group. We got two postdocs, one PhD and two analysts for that project."*(ML2.1) In addition to the STW subsidy, MedLab 2 received a European subsidy to support personnel to work at the company.

During and after its existence, the spin-off had a large impact on the acquisition of monetary resources by the research department from government funding agencies. First of all, the relationship between BIO2 and the research department enabled the acquisition of research funding from SenterNovem. The participation of BIO2 in a SenterNovem-sponsored research project enabled the department to acquire approximately two million Euros, a large amount of research funding for the department. Without the spin-off company, the research department would not have acquired the research project since this research project required industrial participation, and BIO2 had a reputation as a promising biotech start-up (ML2.1). The second way in which the relationship had an impact on the acquisition of government funding is of an indirect nature. BIO2 gave the research capacity of MedLab 2 a huge boost. The increased research capacity, and the freedom the research department to spend those resources, enhanced the quality as well as the quantity of the research output. *"The company contributed money, simply money. That was so much money at the time, and that was used for research. It was a pile of money you could do something crazy with. And that created speed in the research process. Speed we could have never had based on normal grants."*(ML2.1) Researchers from the research department published in top international journals. As a result, the department established itself as one of the international frontrunners in its field. *"It created an acceleration that brought the research to such a level that we still benefit from it."*(ML2.1)

The discontinuation of the spin-off company resulted in a large funding gap. After the discontinuation of BIO2, the research that the department had published, helped it to acquire research funding from government funding agencies. *"After the company left, I started writing proposals for grants like crazy and because we had such fantastic publications I wrote 11 proposals and I got 10 funded. At that moment that was more money than we received from [BIO2]. So if you consider that, it all ended well."*(ML2.1) However, the leader of the research department would have preferred the relationship to have taken a less turbulent course since it caused a lot of unrest and uncertainty in the department. *"We fought our way out of* *that by generating money through the normal channels. And when you look back now you can say it ended better than before the spin-off company was here."*(ML2.1).

6.3.6.2 Research agenda

We showed that MedLab 2 received large amounts of research funding from BIO2 and also engaged in a large government-funded research project. The topics in these research projects fitted very well with the preferences of the research department. *"I did it for fun, without any pressure from outside. And it was possible for us to avoid influence on our research. It was a really good period. I never had the idea we were forced by industry."*(ML2.1) The research department was even able to obtain financial support for a number of high-risk research projects that were not in line with the direct interests of BIO2. *"There was a line that originated from the research on the protein, but the company was not interested at all in it. Nevertheless, we arranged that they financed that research as well. We promised the company that if we would do research in that area, we would find similar molecules. So, for the company, it became a long-term investment."*(ML2.1)

Although the investments of BIO2 did not create a significant shift in the themes of the research department, the investments did have a significant longer term impact on the portfolio of the research department. The large investments by BIO2, and the subsequent scientific successes of the department, focussed its research activities on a specific research line. Research on immune evasive proteins became the most important line of research of the department. *"If the company would not have been here, this research line would probably have not grown so fast. Maybe eventually it would have, but not so fast. A side effect is that there is less time for other things. Nobody forced me, but people just go for the things that are most successful. In the meantime my group has found about 30 of the same types of molecules and bacteria."*(ML2.1)

The major investments by BIO2 did have the potential to shift the research agenda into a more applied direction. However, this did not occur. *"We were always careful to conduct basic research. At that time we thought; you see, you can combine basic research and commercialisation. Our research was really very basic research on a molecular level. I had ten researchers who were paid by money from the company. These people conducted publishable basic research. We were not forced to create a product. We were trying to discover the function of the molecule."*(ML2.1) The spin-off company was aware that conducting applied research would have made no sense because more basic research questions regarding the property of the protein needed to be addressed before applied research could be conducted that could lead to clinical applications. The research agenda was also not influenced because of the tradition of the research department: semi-commercial activities were already part of the activities of the research department (ML2.1).

6.3.6.3 Research output

In this section we report on the effects of the relationship with BIO2 on the number of scientific publications, other research outputs and research quality.

As a consequence of the increased research capacity and the quality of its staff, MedLab 2 was able to increase the quality and number of publications (ML2.1). *"Money from [BIO2] absolutely had an impact, but that also was because we were successful. We started to publish in such high quality journals. We published in Nature."*(ML2.1) The research department was able to conduct high-risk basic research in addition to projects that were specifically targeted to investigate the protein which BIO2 was interested in. Some of these high-risk projects led to the publication of findings in prestigious journals. The research funding that was provided by BIO2, or acquired in collaboration with BIO2, provided a basis on which high quality research output was created. Without this funding, the department would not have been able to conduct basic research on a number of proteins and publish the results in internationally high-ranking journals.[23]

We have no indication that other research outputs of MedLab 2 were affected by the relationship with BIO2. After the discontinuation of the spin-off company in 2003, the head of the department has contributed to at least seven patent applications. These activities fit with the tradition of the research department of engaging in semi-commercial activities in addition to research. The research department applied for patents on a similar basis before the relationship with BIO2 materialised. Further, respondents claim that the relationship with BIO2 did not induce MedLab 2 to engage increasingly in the production of outputs such as patents since the spin-off company was mainly interested in expanding basic knowledge about the protein. The company even allowed MedLab 2 researchers to spend their funding on basic research on other proteins. Given that the discontinuation of BIO2 jeopardised the viability of the department, and created uncertainty for its staff members, the head of the research department has become

[23] We could not rely on VSNU/QANU research assessment scores since the scores in the assessments also concern other research departments.

hesitant to engage in other commercialisation activities. "*I told companies, the first two to three years I will not do anything commercial. Let's focus on science for a while. Now the companies start to knock on the door again, asking me if it isn't time to do something again.*"(ML2.1)

7 PharmLab

This chapter describes the relationships of the PharmLab 1 research department with two of its spin-off companies, BIO3 and BIO4, and the impact of these relationships on the research portfolio of the department.

7.1 The research institute

PharmLab 1 is part of a pharmaceutical sciences research institute within the Comprehensive Research University, the PharmLab research institute. In 2007 the research institute had a research capacity of 111 FTEs in research. The university considers itself a research university with a strong interest in basic research. It mission is to *"to carry out high-quality fundamental research in the pharmaceutical sciences. Specifically, to perform conceptual research focused on the discovery, development, and use of drugs."*[24] Although clinical relevance constitutes an important part of the mission, active knowledge transfer has not been central to the mission of the research institute until recently. In the opinion of the directors of the research institute, knowledge transfer and commercialisation activities should be conducted primarily to acquire additional resources while its research activities should be focussed on long-term academic interests (PL0.2).

Looking at the support of commercialisation activities, we find that PharmLab has traditionally paid little attention to commercialisation activities. A strategic plan of the research institute states that *"The climate within the university was long felt not to be stimulating or accommodating with regard to starting businesses from a research basis"*. The university, it is a part of, started to support patenting and spin-off creation in 1998 through a holding company. An incubator facility for new life science companies was introduced in 2004, which is relatively late in comparison to other universities in the Netherlands. According to respondents, the university followed other universities in the Netherlands in their support for commercialisation activities (PL0.2, PL1.1). The support of commercialisation activities in the PharmLab research institute itself began to take substantial shape in the late 1990s. According to respondents, the research institute started to support spin-offs and other commercialisation activities because the institutional

[24] Annual report 2007, PharmLab

environment was paying increasing attention to the societal relevance of its research. At the same time, the staff of the research institute started to accept commercialisation activities as a part of academic activities.

7.2 PharmLab 1

PharmLab 1 conducts research on the design of drug delivery systems. In 2007 the research department employed almost 27 FTEs in research. Two spin-off companies have originated from PharmLab 1; BIO3 and BIO4. This section describes the relationships of the research department with BIO3 and BIO4 and the impact of these relationships on the research portfolio of PharmLab 1.

7.2.1 Preferences

The research department aims to perform basic research in pharmaceutics and transfer the results into delivery systems.[25] Although the research department is interested in contributing to fundamental understanding of drug delivery systems, PharmLab 1 regards testing and application of its drug delivery systems important as well (PL1.1). The research themes of PharmLab 1 are suitable for commercialisation activities and researchers in the department are open to conducting applied research activities (PL0.2, PL1.1). However, the research department's most important goal is to focus on basic research on drug delivery systems. "*Valorisation is beautiful, and it has to happen, public-private collaborations. But you need to have something to valorise. In other words valorisation comes for a large part from basic research. There should be a balance in that.*"(PL1.1)

The department is interested in collaboration with industry. However, the research department attempts to ensure that research projects with industrial partners do not jeopardise research activities and academic output. *"Sometimes we get grants from industry to do projects, and one of the criteria we have is that in the long run we should be able to publish. If industry is not willing to allow that, then we do not start the collaboration. Because in the end we want to have publications."*(PL1.1) The department has a track record in patenting and licensing activities and staff is encouraged to engage in these activities (PL1.1) The creation of spin-off companies is also encouraged. *"I really encourage people to do so. Because it is*

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[25] VSNU Quality Assessment of Research 2003, QAR documentation. PharmLab.

important that we demonstrate that we are not doing just science. And I am also pragmatic, so when these companies or spin-offs grow, then hopefully they start collaborating with us."(PL1.1)

During the 1990s, the environment of the department became more positive about engaging in collaborations with industry. *"In 1986 I was part of the faculty council. I wanted to do things then with Pharmaceutics. But you could not do that because profits were dirty. That was the time when we were with the back to the market. Now people think very different about that."*(PL0.2) Nowadays, research assessments are increasingly paying attention to societal relevance in addition to scientific merits (PL1.1) While the importance of other types of research outputs has increased in the eyes of the department and its peers, scientific output is still considered the most important type of output. *"For us it is important that we can demonstrate that we are not doing only basic research, but that we also have an eye for potential applications. In the present atmosphere that is absolutely necessary for us."*(PL1.1)

7.2.2 Resources

In the period from 1996 to 2007, the research budget which the department receives from the PharmLab institute has fluctuated but was relatively stable overall. At the same time, an increasing part of the total budget is financed through externally funded research projects (Figure 7.1). In comparison to other research departments in this study, PharmLab 1 is in a position of relative luxury. In 2007, there were still at least three PhD students who were paid directly from institutional funding. In these projects, basic research is conducted on themes the department itself decides upon. This independent first stream research funding is important to create viable new research lines and to perform high-risk research (PL1.1) Until 2007, institutional funding of tenured staff was not yet dependent on externally acquired projects. The department would receive institutional funding to cover matching costs, but it was not forced to work on externally acquired projects, for instance with industry, in order to cover its expenses for tenured staff (PL1.1, PL0.2).

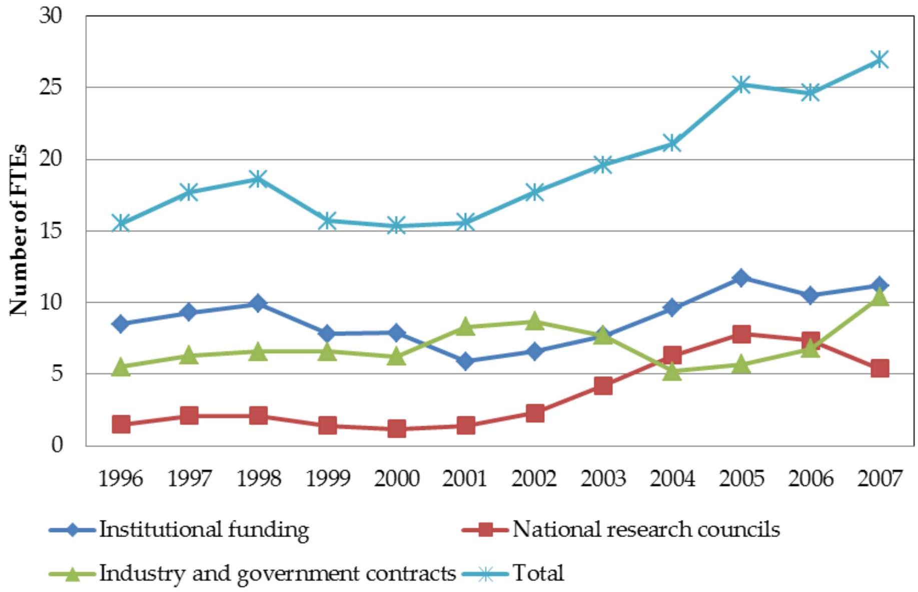

Figure 7.1. Research funding input of PharmLab 1 by source, 1996-2007[26]

PharmLab 1 is dependent on expensive research equipment which requires substantial funding. *"We need the huge infrastructure to do our work, it is a key element of our success."*(PL1.1) Until 2007, the department could still rely on the research institute to cover part of the costs of its research equipment, which somewhat limited the necessity to find research partners that were in possession of research equipment it needed (PL1.1)

7.2.3 Organisations in the environment other than spin-off companies

In addition to BIO3 and BIO4, the department can collaborate with several other organisations in its environment. PharmLab 1 received funding from government funding agencies and other industrial research partners. Until 2000, most of the staff of the department was funded from institutional funding. From 2001 onwards, external funding has become the largest source of research funding of the department (Figure 7.1).

[26] Income from national research councils and from industry and government contracts includes co-financing from the research institute.

The research department acquires research funding from national and international government sources. Within the Netherlands, the most important source of funding is STW. In recent years, other research funding agencies such as SenterNovem and TI Pharma have become increasingly important for the department. Most of the externally acquired funding are distributed under the pretext of societal relevance and knowledge transfer with industry (PL0.2, PL1.1). Respondents of the department do not feel they are forced by these funding agencies to work on topics they do not prefer, given the fact that the preference of the research department also lies in conducting research which is attractive for industry. However, it has made it important for PharmLab 1 to maintain good relationships with industrial research partners so that they can participate in collaborative research projects.

PharmLab maintains relationships with several industrial research partners, among which there are multinational pharmaceutical companies with whom it participates in government-funded research projects. These companies commission contract research as well. The department considers them valuable research partners since they have the research budgets and the time horizon to invest in long-term research projects. In collaborating with these companies the department prefers to sell patents to the companies in exchange for research funding.

7.2.4 BIO3 and BIO4: history, potential resources and demands

BIO3 originates from a contract research project that was conducted for an industrial research partner of PharmLab 1 and which resulted in a number of patent applications. The PhD student involved in the research project chose to create a company based on the patents as the company that commissioned the contract research was not interested in further investing in them. PharmLab 1 actively supported the creation of the company and a Biopartner grant was acquired that would fund a postdoc position for 18 months. The company was officially founded in 2004 with the aim to develop pharmaceutical compounds against inflammatory disorders. One of the professors of the research department became part of the advisory board of the company and the university holding company and some PharmLab 1 staff members obtained shares of BIO3 in exchange for the intellectual property rights. In 2007, the company consisted of five employees, implying that BIO3 is a small-scale drug development company and the company was still in the process of developing its products without substantial backing of venture capitalists. The intention of staff of BIO3 has been to keep in close contact with the department because it provides the company with the latest information about the research line which its patents originate from.

BIO4 was created by one of the professors of PharmLab 1 in 1995. BIO4 was one of the first companies to originate from the PharmLab research institute and was founded in a time when support structures for the development of spin-off companies were still absent at the university. During its existence the company has been able to grow considerably and in 2007, the company employed approximately 150 persons. The activities of the company comprise for 50% of research and development activities and for 50% of services to other companies. BIO4 develops drug delivery technologies and as a result it is eager to maintain in contact with PharmLab 1. BIO4 has connections with other research department and regularly commissions projects that have a basic character. According to the chief scientific officer of the company, PharmLab 1 is the preferred supplier of academic knowledge for BIO4 but not an exclusive provider of academic knowledge (BIO4.1).

7.2.5 Relationships with BIO3 and BIO4

The interactions between BIO3 and 4, and the department are presented in Table 7.1. The relationships with both spin-off companies differ considerably. BIO3, a small drug development company which exists for a few years, has collaborated in two projects and is not able to commission research because it lacks the financial resources. Hence, the relationship is of relatively low intensity. BIO4 on the other hand, participated in several government-funded research projects and a significant amount of contract research in exchange for patent licenses. As a result the department has been able to appoint several postdocs and PhD students.

Table 7.1. Relationships between PharmLab 1 and BIO3 and 4

Non-monetary resources	**BIO3**	**BIO4**
Joint publications with spin-off company	None	Significant
Joint patent applications with spin-off company	None	Significant
Former research staff of the research department employed by spin-off company	Minor	Significant
Personnel simultaneously affiliated to spin-off company and research department	Minor	Minor
Bachelor and master theses supported by spin-off company	None	None
Test data, facilities, instruments and prototypes obtained from spin-off company	Minor	Significant

Monetary Resources

Contract research commissioned by spin-off company	None	Significant
Jointly acquired government-funded research projects	Minor	Major
Financial support of PhD research projects	None	Significant
Does research institute or its staff own capital stock of spin-off company?	Yes	No
Funds from spin-off company in exchange for knowledge from research department	None	Significant
Donations received from spin-off company	None	None

The relationship between BIO3 and the research department has been of a relatively low intensity. During the start-up phase BIO3 was supported by a Biopartner grant which enabled the CEO of the company to conduct a postdoc research project at PharmLab 1. So far the company has collaborated with the department in two research projects, an STW project and an NWO project. In these projects, the company does not conduct research itself but is informed about new developments and physical materials are exchanged. Because the company lacks the necessary research budgets, BIO3 does not commission contract research. For the company, the informal contacts it maintains with the professors and one technician in the research department are the most valuable. The company and the department have not shared research facilities and neither joint publications nor joint patent applications were produced. Respondents stated that the absence of these type of collaborations is *mostly caused* by the relatively short existence of the company (PL1.1, BIO3.1).

The level of interactions between the department and BIO4 has been quite significant. Researchers within the company maintain informal contacts with PharmLab 1 staff and occasionally, the company invites PharmLab 1 members to brainstorm sessions to discuss possible research directions. The company collaborated in at least six STW projects in which the company has contributed in-kind resources and money. BIO4 also involved the department in three SenterNovem projects that were initialised by the spin-off. In addition to the collaboration within the government projects, BIO4 has commissioned several research projects and made investments in research equipment in exchange for patents that were licensed (PL1.1). In total approximately 12 PhD research projects have been supported by the company, which is an indication that the company was interested in rather long-term and basic research activities of the department. About 20 joint publications have so far been produced and at least three patents were applied for collaboratively. The company is an important employer of PhD students and postdocs from the department. *"Of the PhD students that have finished about ten are now working at [BIO4]."*(PL1.1)

Looking at role of government funding in supporting the relationships between the department and the spin-offs, we see that the presence of government funding strengthened the relationships with the spin-off companies (PL1.2). At the same time, collaborations with the companies would have occurred even without the presence of government funding. For both spin-off companies, informal contacts with employees of the department was very valuable and government-funded research projects were not a precondition to collaborate.

7.2.6 Impacts on the research portfolio

The relationships of BIO3 and BIO4 with PharmLab 1 differed considerably, and as a result had differing impacts. BIO3 was a start-up of relatively small size while BIO4 was a multinational company with whom the department collaborated intensively. The relationships created additional research capacity within the research department. BIO4, supported PhD projects and helped to acquire government research projects that require industrial participation. BIO4 was able to influence the research themes of the department within the research projects it was involved in. These impacts on the research topics fitted with the larger mission of the department to conduct research on the design of drug delivery systems. The activities of the department focussed on more basic research activities during the relationships with the spin-offs. This development could not be attributed to relationships with the spin-offs but were caused by a reorientation of the research department that was based primarily on scientific interests. Effects on the research agendas and research outputs were very limited because the spin-offs make up a small part of the organisations in the environment of the department. As a result, other organisations and the preferences of the department itself had much more influence on the research agenda and the outputs.

7.2.6.1 Resources for research

In this section, we discuss whether the relationships with BIO3 and BIO4 have led to changes in the number of contacts with industrial research partners, changes in income from industry and changes in the income from national government agencies and international funding agencies.

Regarding changes in the contacts with industry the following can be observed. Annual reports of the PharmLab research institute stated that the amount of industrial research partners of PharmLab 1 rose from two in 2001 to six in 2007 (Figure 7.2.). The two spin-off companies are included in these figures. The chief scientific officer of BIO4 maintained contact with PharmLab 1 over a long period of time. Contacts with the spin-off companies however did not contribute to the proliferation of contacts with other industrial partners because the research department historically has strong contacts with pharmaceutical companies (PL1.1).

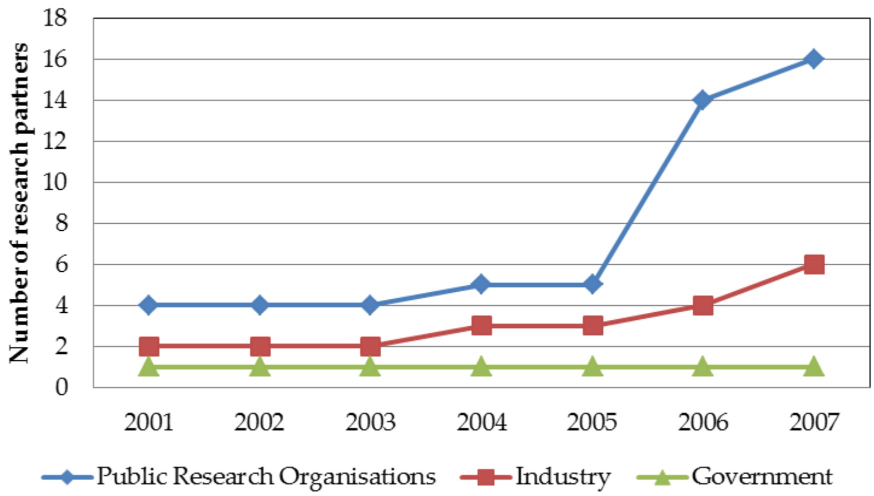

Figure 7.2. Research partners of PharmLab 1, 2001-2007

The relationships with the spin-off companies did not significantly alter the composition of the research activities of PharmLab 1 other than the fact that BIO4 invested significant amounts of contract research funding and BIO3 and BIO4 participated in a large number of government-funded research projects over a long period of time. We showed in Section 7.2.5 that BIO4 invested significant amounts funding in the research department through contract research. This investment led to an expansion of the research capacity of the department. In addition, BIO4 participated in at least nine government research projects that require industry to participate. Respondents from BIO3 and BIO4 stated that their participation in project proposals for government research projects enhanced the chances of success (PL1.1, PL1.2). *"STW projects for instance, if there is no user, then the project will not be granted any funds."*(PL1.1) However, spin-off companies are a part of a larger environment in which other industrial research partners are present as well. *"It is not that I now need to see partners that I do not want to collaborate with; no, I am already collaborating with them and we can get additional money to really expand what we do."*(PL1.2) The exclusivity of the spin-off companies is therefore also somewhat limited as regards legitimising government funding.

When we look at the impacts of the relationships on the acquisition of research funding from other research partners, we see that the relationships did not have a significant effect. Over the years, the composition of research projects has changed. In the 1990s, the research department received significant contract research funding from industry (Figure 7.1). In recent years, PharmLab 1 has relied less on funding from companies but has been especially successful in acquiring funding from NWO. *"In past times we would obtain one Euro from NWO and STW and two from industry. I think that nowadays it is the opposite. We get much more money from STW and NWO."*(PL1.1) This shift in research funding cannot be attributed to collaboration with the spin-offs or other industrial partners. PharmLab 1 choose to reorient part of its activities on basic research on polymers and this reorientation was not inspired by industrial partners but by academic interests. Initially this research line was supported by institutional funding. Investments in this research line started to pay off and as a consequence, grants from STW and NWO were acquired.

7.2.6.2 Research agenda

According to respondents from the spin-off companies, collaborations with PharmLab 1 give the companies a chance to influence the ideas and the research processes in the department. *"By participating in work meetings you will influence the line of the research group. If project A gets a support letter of us and project B does not, then the next request will take this into account. People who know me well come to me beforehand and tell me their plans and ask me if that is interesting for us."*(BIO4.1) Outside formal project meetings staff members of the research department and the spin-off companies discuss possible proposals. *"What happens regularly is that people who know me, come to my office and tell me their plans and to ask me if it would be a viable proposal"*(BIO4.1) Contacts between PharmLab 1 and BIO4 help the research department to be aware of the research themes the company is interested in. *"Every now and then, say two to three times a year I visit them and discuss all projects we have with them. And then they tell me this is interesting, that is not interesting."*(PL1.1) However, the department does not feel it is pressured to follow the demands of the spin-off companies. It draws inspiration from the contacts it has with the companies. *"For us it has been a very natural process. I don't experience that we have to engage in valorisation. We always have done that. So experience it not as a nuisance or that it limits me in my academic freedom."*(PL1.1) One of the members of the spin-off companies believes that the long history of collaboration with his company led to an understanding that research activities should be focussed on what problems they actually would like to address, either on the short or the long term. *"To think about what we call the medical needs. I see proposals of research groups on a regular basis and they ask me to participate. And groups I have contact with a lot discuss in the proposal what do we want to do, which problem do we want to solve. And less we have a good idea and we will see what happens. But that is for a large part also the zeitgeist."*(BIO4.1) Thus, the contacts with the spin-off companies have an effect on the research themes of the research department but within the scope of its general mission; the design of drug delivery systems.

We already showed that the focus of the department has moved towards more basic research activities. In earlier years, the department was heavily funded by industrial partners among which BIO4. *"We have become broader. Now we are operating earlier in the research trajectory. We made a conscious choice to do that. We wanted to strengthen our molecular-biological expertise. We make new chemical structures, polymers et cetera. We can sell that type of work very well at NWO and in STW like structures. We focused on that a bit more for the past ten years. We started that from first stream funding and that has translated into success in second and third stream."*(PL1.1) The shift of the research department to include more basic research activities into the research portfolio was not facilitated by the presence of BIO3 and BIO4. The research department was motivated to increase its expertise based on scientific considerations and funded this line of research from its own resources. The success in this line of research was further stimulated by the acquisition of research funding from NWO and STW, not from industrial research partners and the spin-off companies in particular.

7.2.6.3 Research output

In this section we report on the effects of the relationships with BIO3 and BIO4 on the number of scientific publications, other research outputs and research quality.

Contract research from BIO4, and the participation of BIO3 and BIO4 in nine government research projects, increased the research capacity of the department. The increased research capacity, in turn, has contributed to the publication output of the department. As is visible in Figure 7.3, scientific publications have fluctuated over the years but have risen significantly in the period from 1996 to 2007. *"We have doubled in the last five years, not just in terms of PhDs and postdocs but you can also see it in our scientific output. Five years ago we had thirty publications per* *year, this year it will be sixty."*(PL1.1) The relationships with the spin-offs had an impact number of scientific publications, but a rise in the acquisition of external projects has been one of the major factors in increasing the publication output (PL1.1, BIO4.1). According to the CSO of BIO4, the rise in scientific publications *"has not been [BIO4]'s influence alone, but it certainly played a role in the growth of the group. The department has become much larger because there has been a lot of second and third stream income. And the group also grew because a number of employees were financed by [BIO4]. And because the group could publish and because they could attract good personnel they could get additional funds."*(BIO4.1)

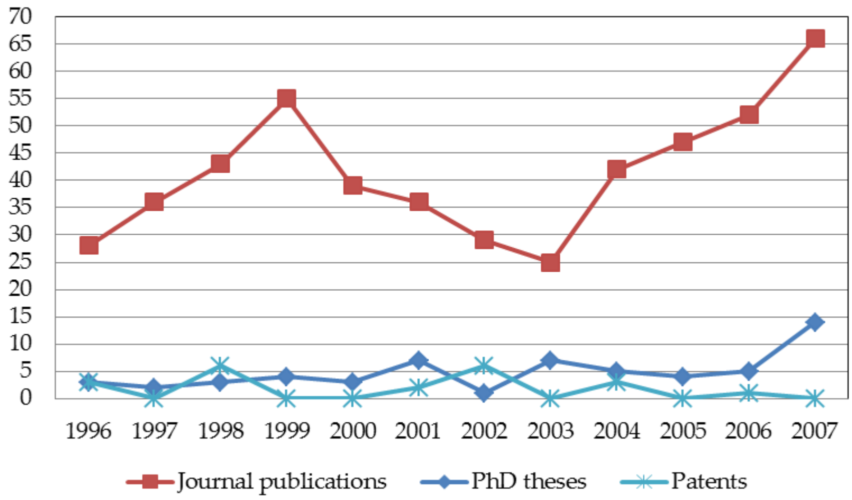

Figure 7.3. Research output of PharmLab 1, 1996-2007

Looking at the research quality of the department we conclude that the spin-offs made up a small part of the environment of the department and that the relationships with BIO3 and BIO4 did not have an impact on the research quality. The research department has received two research assessments during its existence. The first assessment covered 1992 to 1995, a second assessment covered 1996 to 2001. The research quality improved in these assessments but not due to the presence of the spin-off companies. BIO4 has contributed to the research capacity but respondents stated that the quality of the research activities and the outputs are caused by the personnel of the department (PL1.1, BIO4.1). The latest research assessments did however credit the department for having *"strategic alliances with private companies so that the research may find concrete applications* *through patents."*[27] And the department leader claims the presence of the spin-off companies has benefited the assessment of the department. *"We have got spin-offs, a couple of ideas of us are in clinical trials. I think that that only stands on the positive side of the assessment."*(PL1.1)

The relationships with BIO3 and BIO4 did not impact on outputs such as patenting or the development of clinical applications. Patenting has been a persistent activity of the research department, as is visible in Figure 7.3., and the contacts with the spin-off companies did not change the attitude of the department in this respect. On average PharmLab 1 filed two to three patents annually (PL1.1). At the same time, the department leader stated: *"Our goal is not to create products. We cannot do that and should never do that."*(PL1.1) The creation of practical clinical applications, , was not central to the interests of the department and has not changed due to the relationships with the spin-off companies.

[27] Assessment of research quality, PharmLab, 2004

8 ICTInstitute

This chapter describes the relationships of the ICTInstitute 1 research department with two of its spin-off companies, ICT1 and ICT2, and the impact of these relationships on the research portfolio of the department.

8.1 The research institute

The ICTInstitute is a non-university research institute for mathematics and computer science. The research institute is one of the nine research institutes of NWO. In 2007, the research institute employed 156 FTEs in research. The mission of ICTInstitute is to perform frontier research in mathematics and computer science and to transfer new knowledge in these fields to industry and society in general.[28] The research institute is principally financed by the Dutch research council NWO and it has traditionally focused on basic research. *"We don't say we valorise this and that. But our research should have societal relevance."*(II0.1)

During the second half of the 1990s, the research institute started to focus more explicitly on commercialisation activities. As a research institute focused on basic research, its main concern had been to conduct scientific research of an internationally competitive level. However, during the early 1990s the research institute noticed that its environment was gradually paying more attention to knowledge transfer and commercialisation. At the same time, ministerial funding to NWO came under increasing scrutiny. At that point, the institute felt it needed to show to its primary sponsor, NWO, that research funding it received from the research council was a good investment. The more difficult financial situation and *"the reaction to societal developments triggered a specification of our mission"*(II0.2). So in reaction to developments in its environment, the research institute responded in order to show that it was acting in good faith and thus secure research funding from NWO. The response of the research institute consisted of a re-specification of its mission and the institute also started to dedicate resources to the support of spin-off companies. An incubator facility was established in the year 2000, which is late in comparison to other public research organisations in the Netherlands. The research institute allows its staff to create a company and in the case the company will cease to exist within two years, staff is allowed to return to the

[28] ICTInstitute Strategic Plan 2007-2012.

research institute. It is clear that the research institute was not motivated to engage in the support of spin-off companies because it thought this would be beneficial for its research activities. Conversely, the motivations of the institute lay in showing its sponsor that it was engaging in commercialisation of its research results, thereby maintaining legitimacy.

8.2 ICTInstitute 1

ICTInstitute 1 is a research department that conducts research on software engineering and multi-media applications. In 2007, ICTInstitute 1 employed approximately 43 FTEs, including support staff. Two spin-off companies have originated from ICTInstitute 1: ICT1 and ICT2.

8.2.1 Preferences

The department is mainly interested in conducting basic research and it sees in collaboration with industry the possibility to show that the knowledge they develop is useful for society.[29] Collaboration with industry is welcomed by the staff in the department since it provides a way to apply and test systems they have developed (II1.1). Working with companies is regarded as something positive as long as research can be conducted that is in the interest of the researchers in the research institute. According to the head of the department, "*of course it is great when contract research can support research, but it is research what it is all about in the end.*"(II1.1) Staff of the department prefer to conduct relatively basic research but they feel that societal relevance and commercialisation have become dominant criteria to get their research funded. "*At the moment it is almost not done to think about a problem if there is not a company you can name that will market it. So I would like to get rid of all these research schemes.*"(II1.1). Collaborating with industry is fine for staff in the department as long as it is not detrimental to their academic freedom. The head of the research department (II1.1) regards the freedom to publish information from collaborative research with industry as an import precondition to engage in collaborations with industrial partners. The peers of the department nowadays perceive collaboration with industry as part of everyday life. Whereas informatics research used to be relatively basic, researchers nowadays are used to show the societal relevance of their research and knowledge transfer between them and societal partners (II0.1, II0.2).

[29] Evaluation 1999-2004 ICTInstitute.

8.2.2 Resources

Because funding from NWO to the institute has come under pressure, funding from the ICTInstitute has steadily decreased over the past 15 years. Institutional funding to the department has steadily decreased from over 70% to less than 60% in 2007. In comparison to other departments in our sample, ICTInstitute 1 still receives a high amount of institutional funding in relation to its total research budget. This allows the department to conduct research which is shielded from thematic programmes of Dutch research councils and industrial research partners. Nevertheless, the decreasing institutional budget together with the necessity to co-finance externally acquired projects, has somewhat limited the capacity of the department to maintain autonomy over its research agenda. *"It looks as if we are relatively free to choose our research topics, but our basic subsidy is increasingly absorbed by research projects that require matching. I think that if you take into account the matching of research projects we are just above 40% which is left of the institutional budget."*(II1.1)

The research department is not in need of capital intensive research equipment in its research activities and therefore it is not bound to follow research along the lines that would fit with research equipment it would have owned.

8.2.3 Organisations in the environment other than spin-off companies

In addition to ICT1 and ICT2, ICTInstitute 1 can rely on many other organisations in its environment for research funding. Government agencies, as well as academic and industrial research partners are the most important organisations in the environment of the department. As is visible in Figure 8.1, external funding doubled from 1999 to 2007. The single most important organisation for the research department in terms of external funding is NWO. Additionally, STW, SenterNovem, the EU and the Telematics Institute provide the department with research funding. Between 1999 and 2007, the share of contract research in relation to the total amount of externally acquired funding actually declined from approximately 25% to slightly over 10%, making contract research a relatively small activity for the department in comparison to the total research budget.

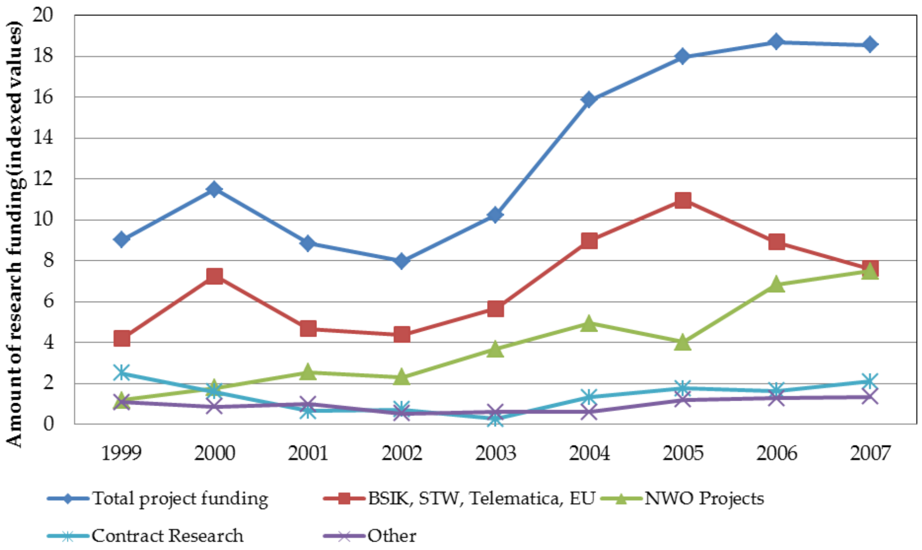

Figure 8.1. Research funding input of ICTInstitute 1 by source, 1999-2007[30]

Looking at the government agencies that provide funding for the research department we see that the department draws the dominant part of its research funding from NWO, i.e., directly through project funding and indirectly through its institutional funding. Approximately 70% of the total research budget originated from NWO in 2007 (II1.1). NWO funding funnelled through the recurrent part of the research budget is not tied to criteria, and resources can be spend on basic as well as applied research. Project funding from NWO does not require the participation of industry although societal relevance has become increasingly important for NWO. In addition to funding from NWO, ICTInstitute 1 acquires a large part of its budget from SenterNovem, STW and the EU. In contrast to NWO funding, these sources all require collaboration with industry. It implies that it is important for ICTInstitute 1 to have industrial research partners, such as spin-off companies, which may participate in project applications and collaborative research.

In addition to ICT1 and ICT2, the department collaborates with several small as well as large multinational companies. The department maintains long standing collaborations with some of these organisations. In relation to the overall

[30] The actual amounts of project funding are confidential. We have masked the actual amounts and present indexed values in order to show the relative importance of the various funding sources.

research budget these companies have commissioned a relatively modest amount of contract research.

8.2.4 ICT1 and ICT2: history, potential resources and demands

ICT1 was founded by four researchers of ICTInstitute in 1998. The goal of the spin-off company was to develop a web-based multimedia player system. The development of an actual system was not regarded as an activity that should take place within the department and therefore ICT1 was created. In addition to the four researchers that initially left the department, more researchers left the research institute at a later stage and joined the spin-off company. It proved to be difficult to sell the technology and in 2002 ICT1 ceased to exist. After the discontinuation of the company, all former researchers of the research institute were allowed to return to the research institute. At its peak the company employed 12 staff members. Since the company was relatively small, had a short-term research focus and was continuously looking for income, it was not interested in supplying the research department with money to conduct research. The spin-off company was active on a theme central to the research department it originated from. Initially half of the employees remained in the research department. However, the CEO of the former company stated: "*Half of my group remained so you keep interacting with them a bit and that's fine. But someone else presided over the group, someone with another preference and another direction.*"(II1.2) This contributed to a shift in research agendas between the spin-off company and the research department.

ICT2 is a company that delivers services for the improvement of legacy software. The research of two professors of ICTInstitute 1 formed the basis of the company and these professors hold shares in the company. ICT2 was founded in 2000 and employed approximately 20 people in 2007. The company uses knowledge from the institute to analyse software systems and assess potential risks and improve performance of these systems, a topic that is still very central to the interests of the research department. The company is still interested in the developments in the research department although over the years it has started to pay more attention to its consultancy activities, which rely less on state of the art academic knowledge from ICTInstitute 1. Furthermore, the timeframes of scientific research projects are too long for the spin-off company to be of interest which makes the company reluctant to invest significant funding directly in the research department.

8.2.5 Relationships with ICT1 and ICT2

The interactions of the research department with ICT1 and ICT2 are presented in Table 8.1. Overall, the relationships between ICTInstitute 1 and the two spin-off companies were of a low intensity. Spin-off companies are regarded entities that leave the institute because they do not fit with the activities of a research department anymore (II1.1, II1.2). The relationship between the spin-off companies and the research department has a limited timeframe in which the cognitive proximity of both entities are still relatively similar. *"On the day the company starts the divergence is already taking place. So there is only a limited window of opportunity that the department and the spin-off can sit together in a privileged way to talk to each other. You know each other well, and you are able to distinguish each other's interests very well. After that the department simply continues to develop new knowledge."*(II1.1) Collaboration with ICT1 and ICT2 occurred in five government-funded research projects. In these research projects the spin-off companies did not directly contribute resources to ICTInstitute 1. Other than the collaboration in the government-funded projects, the relationships with the spin-off companies were mainly informal. Ideas were exchanged, spin-off companies articulated their demands and gave researchers of the department information about the problems the companies were dealing with. The spin-off companies did not support the research activities of the research department in financial terms and were therefore of limited interest to the department as it could also rely on other companies in its environment (II1.1).

Table 8.1. Relationships between ICTInstitute 1 and ICT1 and 2

Non-monetary resources	**ICT1**	**ICT2**
Joint publications with spin-off company	Minor	Substantial
Joint patent applications with spin-off company	None	None
Former research staff of the research department employed by spin-off company	Major	Minor
Personnel simultaneously affiliated to spin-off company and research department	None	None
Bachelor and master theses supported by spin-off company	None	None
Test data, facilities, instruments and prototypes obtained from spin-off company	Minor	Substantial
Monetary Resources		
Contract research commissioned by spin-off company	None	None
Jointly acquired government-funded research projects	Minor	Minor
Financial support of PhD research projects	None	None
Does research institute or its staff own capital stock of spin-off company?	Yes	Yes
Funds from spin-off company in exchange for knowledge from research department	None	None
Donations received from spin-off company	None	None

The relationship between ICT1 and ICTInstitute 1 was mostly informal and consisted of exchanging ideas and *"keeping each other informed of developments."*(II1.2) Since part of the research department moved to the spin-off company and the other part of the research department remained at the institute, the informal exchanges of ideas initially occurred on a daily basis. Shortly after the creation of the company and the departure of some of the researchers, the research interests of the spin-off company and the research department started to diverge. The group of people that stayed at the research institute were appointed with a new head and the spin-off sought to distance itself from academia *"to make clear that we were a company, not a research project."*(II1.2) During its existence, ICT1 and the research department participated in three government projects that required the participation of industry. According to the respondents, these research projects were a continuation of the already existing relationship and did not add to the intensity of the knowledge transfer between the two organisations. After the bankruptcy of ICT1, staff members of the company were allowed to return to the research institute (II1.1, II1.2).

ICT2 collaborated with ICTInstitute 1 mostly informally for testing and feedback purposes and collaborated with the department in a SenterNovem sponsored research project. Additionally, the company was asked to participate with the department in a project for another company. According to the CEO of ICT2, the connections with the department *"are not intensive but remain existent"* because several ICT2 employees have worked at ICTInstitute 1 and are keen on keeping in contact with their former colleagues (ICT2.1). At least three PhD students have entered the company, something that has been beneficial for the company. It has led to technological developments as well joint publications with members of the department.

According to the respondents, government funding instruments that aim to encourage science-industry relationships were not important in supporting the relationships between the research institute (II1.1, II1.2, ICT2.1). Informal exchange of information would have taken place even when the government-funded research projects would not have existed. Further, respondents felt that government-funded research projects encouraged them to include industry even if there would be no intrinsic motivation to do so (II1.1, II1.2).

8.2.6 Impacts on the research portfolio

Because of the low intensity of the relationships, the impacts of ICT1 and ICT2 on the research portfolio of the department were insignificant. In comparison to the overall research portfolio of the research department, relationships with the spin-off companies were insignificant and the department had a large number of other companies it could collaborate with. And in most cases, the research department could rely upon other companies to provide legitimacy to acquire government research funding which requires or prefers industrial participation. Respondents regarded the spin-off companies as entities that did not fit with the department anymore and left the research institute. After the spin-offs left, the research department resumed conducting basic research. The spin-offs hardly contributed to the research capacity of the department as they only participated in four government research projects and did not commission any contract research. The research agenda was at most inspired by the spin-off companies in specific research projects they participated in. Not the spin-off companies, but the quality of the staff of the research department, and their ability to mobilise resources from organisations in the environment were major factors that contributed to the research quality.

8.2.6.1 Resources for research

In this section, we discuss whether the relationships with ICT1 and ICT2 have led to changes in the number of contacts with industrial research partners, changes in income from industry and changes in the income from national government agencies and international funding agencies.

Regarding changes in the contacts with industry, we found that the research department maintained contacts with a large number of companies during its existence. In 2005, the department reported that it collaborated with 50 companies. Respondents of the research department stated that the relationships with the spin-off companies did not increase the departments' contacts with other companies. Other companies and their academic network were mentioned as having contributed to contacts with other industrial research partners. (II1.2, ICT2.1).

The contributions of the spin-off companies to the research capacity in relation to the overall research budget were insignificant. The spin-off companies did not expand the network of the research department and as a result, no additional resources were acquired from other industrial research partners. When we look at the impacts of the relationships with ICT1 and ICT2 on the acquisition of funding from government sources, we see that the impacts were very small. In Section 8.2.3 we showed that a significant part of the funding sources of the research department values the participation of industry. We found that, in total the spin-off companies engaged in four government-funded research projects that require industrial participation. Respondents stated that the presence of the spin-off companies helped to acquire the research projects. *"[A spin-off company] defines the external legitimacy instantaneously. So if you work on topics that are related to external problems in industry you don't have to explain why you are doing this research. When you are doing theoretical research this is much more difficult to explain."*(II1.1) Although at least four collaborative research projects existed, none of these projects was initiated by the spin-off companies and if the companies would not have been there, the department *"would have gotten the project with another small company."*(II1.1) As a result, these four government-funded projects would have taken place even without the spin-offs. However, since the cognitive and geographical proximity is relatively high, and the spin-off companies and the research department are well acquainted with each other, the spin-off companies are an attractive partner for the ICTInstitute 1.

8.2.6.2 Research agenda

The relationships with ICT1 and ICT2 have at best inspired researchers within the research department to look at other research problems. The spin-offs, for instance, provided staff of ICTInstitute 1 with relevant research problems they can apply in their research proposals. "*We feed the research world with certain themes, developments and methods*."(ICT2.1) Given the fact that the relationships have been of a minor intensity, it is not surprising the impacts on the research themes were small and that the spin-offs were not able to have a more direct way of influencing the research themes of the department. Other organisations in the environment of ICTInstitute 1 were far more important for their survival (cf. Figure 8.1). *"There are no changes in our research group, other than some small adjustments. It is much more important for us what The Hague and Brussels spend their money on. I tend to think that people with bags of money have much more influence, and spin-offs do not have that kind of money. More often they come to ask for money."*(II1.2) On the long term however respondents reported that research agendas adjusted to industry in general because they inspire the research agenda. *"We should not do the chores for the companies. But on the other hand it is very interesting to let your research be inspired by external questions."*(II1.1)

The balance between applied and basic research in the department was not affected. The research department is interested in basic research and aims to conduct research that produces result five to ten years from now (II1.2). The relationships with the spin-off companies did not consist of significant numbers of research projects or funding and as a result, a core characteristic, such as the balance between basic and applied research, was not affected.

8.2.6.3 Research output

In this section we report on the effects of the relationships with ICT1 and ICT2 on the number of scientific publications, other research outputs and research quality.

The relationships with the spin-off companies did not contribute to the number of scientific publications. Figure 8.2. displays the output of the research department from 1997 to 2006. As is visible in this figure, the amount of publications rose significantly in this period. The increase in publications were tied to an increase in research capacity that came from government agencies, not the spin-off companies (cf. Figure 8.1). ICT1 and ICT2 only participated in four government projects in the period 1997 to 2007. During this same period the research department engaged in 20 to 45 research projects annually, making any impact on the research output small. Additionally, the spin-off companies were mostly not interested in scientific publications. *"We are focused on publishing articles. That is a thing companies are not interested in. We have several publications with companies but that is after persuading them. Most companies think it is nonsense."*(II1.1)

The research quality of the department was not affected by the relationships with the spin-offs. In the research assessments, which the department has received, the department has been credited for its excellent research quality and its ability to acquire external funding.[31] The department is also credited for its contacts with external partners to test prototypes and its long track record in researching basic research problems that are translated into practical solution for industrial partners.[32] The research quality of the department is supported by the research staff and their ability to acquire external research projects from government agencies and industrial organisations other than the spin-off companies.

[31] Evaluation 1993-1998, ICTInstitute.
[32] Evaluation 1999-2004, ICTInstitute.

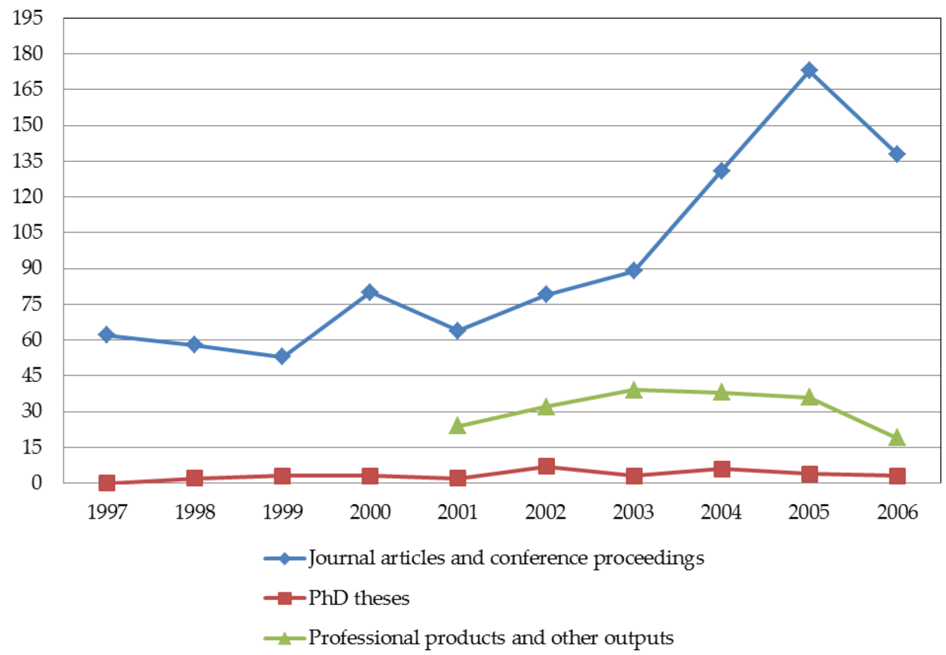

Figure 8.2. Research output of ICTInstitute 1, 1997-2006

In addition to scientific publications, ICTInstitute 1 produced demonstrators and application prototypes, but these outputs were not affected by the relationships. The research department did not engage in patenting and the spin-offs did not have any effect in this respect. As is visible in Figure 8.2., between 19 and 39 professional products and other outputs were produced annually between 2001 and 2007. From its onset, the research department aimed to contribute to the solution of societal problems and was willing to produce systems that have relevance for industry in addition to its basic research activities. The relationships that existed between the department and its offspring did not alter the output of the department since the department was already active on producing outputs such as demonstrators and software applications and the relationships were very limited (II1.1).

9 ICTLab

This chapter with ICTLab, an informatics research institute of the Technical University, and two of its research departments: ICTLab 1 and ICTLab 2. The two departments that are dealt with have maintained relationships with four spin-off companies: ICT3, 4, 5 and 6.

9.1 The research institute

ICTLab is a research institute that conducts research on telematics and information technology and employed approximately 250FTEs in research in 2007. ICTLab aims to conduct technology oriented research that can be integrated in practical contexts relatively easily. Conducting basic research is not an explicit part of the mission. Collaborating with industry, health care, financial and governmental organisations is an important part of the everyday life of researchers in the research institute. *"Of all projects we participate in there are only one or two that do not involve industry. And involvement can mean paying for the research, being part of a user group or being a partner in the research process."*(IL0.1)

The Technical University, in which ICTLab resides, is a front runner in providing support structures for commercialisation and spin-off companies. As a university it was one of the first public research organisations in the Netherlands to dedicate resources to the creation of spin-off companies (Clark, 1998). In its conception the university *"was expected to link up with industry. Equally important, it was also conceived as a regional university … to help the development of that particular region."* (Clark, 1998, p.40). Already in the 1980s, the support of spin-off activities was seen as an active way to contribute to the mission of the university and to acquire additional research funding. As early as 1979 the university set up an industrial liaison office to facilitate interactions with industrial research partners and to increase income from private companies (Maassen & Buchem, 1990). In addition to the support facilities that are offered centrally by the Technical University, researchers from the research institute can rely on support from the institute itself. The institute and the university are motivated to engage in the support of spin-off companies because from their inception it was clear the part of their mission is to engage in knowledge transfer activities. At the same time, the business director of the research institute states that support of spin-offs may lead to industrial research partners that can be full-fledged research partners of the institute (IL0.1), which is indicative of resource-based motivations. So in the case of the ICTLab research institute both resource and institutional motivations have played a role in supporting the creation of spin-off companies.

9.2 ICTLab 1

ICTLab 1 is a department that conducts research on the design of interactive information systems. In 2007, the research input in terms of scientific staff consisted of over 25 FTEs. Two spin-off companies have originated from ICTLab 1: ICT3 and ICT4.

9.2.1 Preferences

The research department aims to integrate fundamental insights into working information systems and basic research activities make up a small part of the portfolio of the department (IL1.2). The mission of the department is to "*support interactions with and within smart environments and to support the use of and the interaction with multimedia information.*"[33] Collaboration with industry occurred on a frequent basis and was considered beneficial for the research department and a natural extension its research activities (IL1.1). At the same time, staff of the department regarded the tendency of funding agencies to make science-industry collaboration a precondition for funding an undesirable development. The staff of the department believes that scientific research should have societal relevance but should not be automatically tied to knowledge transfer with industry. One strategy of the department to conduct long-term and in-depth research was to shield PhD students from knowledge transfer activities as much as possible, as the PhD projects were the only way for the research department to engage in such research.

According to respondents, scientific excellence is still the criterion that is most valued by the scientific community. However, respondents stated that the scientific community, which they are part of, in addition to basic research, has increasingly valued research that addresses and solves problems which industry is confronted with. Research assessments have changed as well in the opinion of the respondents. *"The most important thing is still if that they see if you have good publications in journals. But there is also an indicator relevance of research. That would not have been there ten years ago."*(IL1.2).

[33] Scientific report 2003-2005 ICTLab 1, 2007.

9.2.2 Resources

ICTLab 1 received an institutional budget for research from the research institute. Figure 9.1 displays the income it received from the research institute, from research councils and from contract research for governments and industry. During the 1990s institutional funding remained relatively stable but allocation of the institutional budget became increasingly tied to the performance of the department. The size of the institutional budget and the criteria that were tied to it left little to no room for the department to conduct research that did not include industry or other societal organisations. *"In practice we do not have no free first stream research. Everybody of the tenured staff and the PhD students, 90-95% works on projects that are externally financed. And we need external funding to conduct our research."*(IL1.1) In the funding allocation model that existed between 2002 and 2007, institutional funding was allocated on the basis of the achievements of the research department, which included the size of externally acquired research projects and the number of PhDs produced by the research department. In addition, externally acquired research projects required co-financing and drained the institutional budget of the department. Prior to 2002, the research institute occasionally provided funding for PhD students (IL1.1).

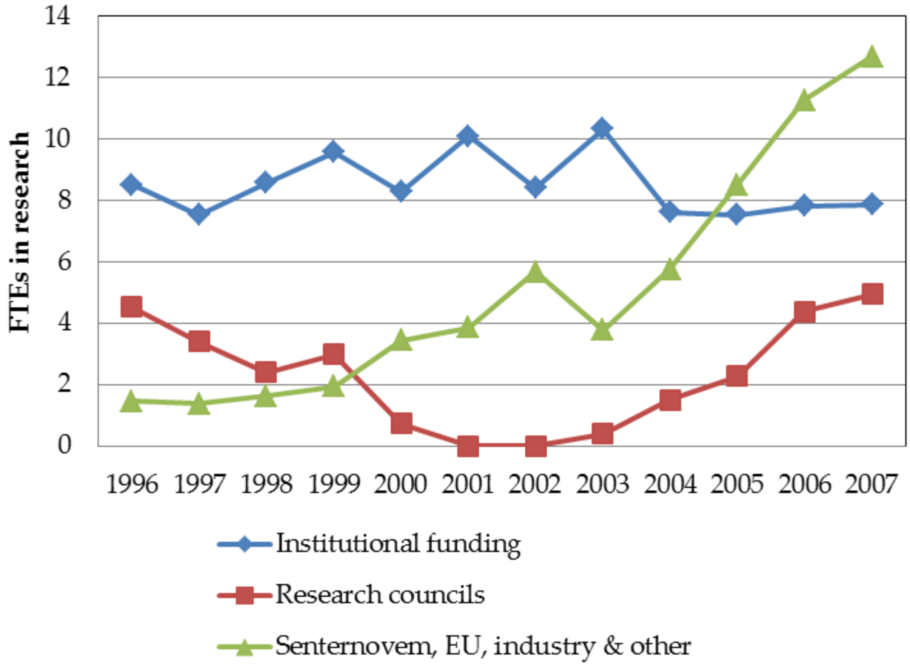

Figure 9.1 Research funding input of ICTLab 1 by source, 1996-2007[34]

Looking at the resources that the department needed to invest in research equipment we see that ICTLab 1 conducts research on themes that require relatively inexpensive research equipment. No large investments in equipment were needed to support the research activities of the department. As a result, investments in equipment did not limit the choice of the research themes, nor did it incentivise the department to seek industrial research partners with certain research equipment.

9.2.3 *Organisations in the environment other than spin-off companies*

In addition to receiving funding from ICT3 and ICT4, ICTLab 1 obtained funding and other resources from other organisations in its environment. Over the period we observed, the department came to rely increasingly on funding sources that required the department to collaborate with industry. As is visible in

[34] We rely on the research input in FTEs because reliable financial data from before 2003 was unavailable.

Figure 9.1, the composition of research funding changed profoundly from 1996 to 2007. The share of institutional funding dropped and external organisations funded an increasing part of the research activities of the department. The department increased its income from Senternovem, the EU and industry from less than 2 FTEs in 1996 to almost 13 FTEs in 2007. These sources (see the line with triangular shapes in Figure 9.1) required science-industry collaboration or consisted of projects for industry. The acquisition of externally funded research projects that required participation of industry became vital for the survival of ICTLab 1. STW, which required industrial participation as well, played a minor role in project funding of ICTLab 1. NWO funding supported a relatively small part of the research budget of the department. The department acquired NWO funding in the past, but the department had difficulty attracting substantial amount of NWO funding since it is not primarily basic research oriented (IL1.1).

The research department maintained contacts with several companies and non-profit organisations. Multinational companies were important research partners of the research department. *"We have a lot of companies whom we have contacts with, especially in the form of bachelor and master student projects."*(IL1.2) However, the industrial research partners themselves were not an important source of research funding.[35] Overall, contract research for industrial research partners was limited since companies were only inclined to commission short-term research projects. At the same time, staff of the department regarded the companies as important partner for government projects since most of the times they needed to show that industry was interested in the research proposal or that it would participate in a research project. When companies chose to participate in these government-funded research projects, the research department needed to take into account their demands. Not doing so would lead a company to decline cooperation and a failure of the department to obtain a research grant (IL1.1).

9.2.4 ICT3 and ICT4: history, potential resources and demands

ICT3 was founded by four graduates in 1996. The spin-off company specialised in language technology and developed software to structure and access information. In 2007, the company consisted of 10 employees. Employees of the spin-off company personally knew researchers from the research department from the time they studied at the research department and the company was interested in the speech technology that was developed at the research department. Over the years however, the interest of the company in the

[35] Scientific report 2003-2005. ICTLab 1, 2007.

technology of the department declined, mainly because the themes that the department and the spin-off were active on, diverged (ICT3.1). Because of its size, the company did not have a sufficiently large research budget that enabled it to commission research projects.

ICT4 was founded in 1999 by a graduate student of ICTLab 1. He was assisted in his efforts by one of the senior researchers in the department and the technology transfer office of the institute. The company developed software for virtual training. All the software engineers that worked for the company originated from ICTLab 1. In 2007, the company consisted of eight employees. The company was in principle interested in collaboration with the department but there were some factors that limit the relationships. One of the barriers for collaboration was the use of different programming software. Second, the department and the spin-off were interested in different types of output, which made collaboration less profitable. *"[ICT4] wants to have something that is quick, but we have very different demands from the software we write"* according to an associate professor of ICTLab 1 (IL1.2) The research budget of the company itself was not sufficient budget to directly sponsor research projects at the department, nor was the company interested in long-term research projects.

9.2.5 Relationships with ICT3 and ICT4

Table 9.1 displays the relationships between ICTLab 1 and its two spin-off companies, ICT3 and ICT4. Overall, the relationships with the spin-off companies were of a very low intensity. Although the environment of the research department was conducive to university-industry collaboration, and the department was interested in working with industry, the interactions with the spin-offs companies have been very low except for research projects that were conducted by students. The spin-off companies did not co-publish with the department, nor did they patent or exchange personnel. Student research projects are the most significant form of collaboration as they provide valuable information for both the spin-off companies and the department. *"Look, spin-offs are not such important partners moneywise. These are small companies in the vicinity, and it is good they are here, there are a lot of positive things you can say about them, but they don't have a lot of money. (*IL1.1) One of the spin-off companies collaborated with the research department in two government projects. But in respect to the total research budget these research projects were insignificant. *"The activities with [ICT3} and [ICT4] are relatively small. They only have contact with me and [the head of the department] and someone else. They do not play an important role in our* *group."*(IL1.2) Contacts with the spin-off companies, on the other hand, were more continuous in comparison to contacts with other companies. By increasing their involvement in government-funded research projects in the future, the department hoped to strengthen their relationships with them.

Table 9.1. Relationships between ICTLab 1 and ICT3 and 4

Non-monetary resources	**ICT3**	**ICT4**
Joint publications with spin-off company	None	None
Joint patent applications with spin-off company	None	None
Former research staff of the research department employed by spin-off company	Minor	None
Personnel simultaneously affiliated to spin-off company and research department	None	None
Bachelor and master theses supported by spin-off company	Significant	Minor
Test data, facilities, instruments and prototypes obtained from spin-off company	Minor	Minor
Monetary Resources		
Contract research commissioned by spin-off company	None	None
Jointly acquired government-funded research projects	Minor	None
Financial support of PhD research projects	None	None
Does research institute or its staff own capital stock of spin-off company?	No	No
Funds from spin-off company in exchange for knowledge from research department	None	None
Donations received from spin-off company	None	None

ICT3 collaborated with ICTLab 1 on research that concerns the extraction of information from speech. Internships of students enabled ICT3 to acquire state of the art knowledge from the research department and were they main mode of collaboration. Annually, approximately four to five students conducted their bachelor or master research at the company. In addition to the student research projects, the company and the research department cooperated in two government projects. The first project was initiated by a third party that approached the department for contract research (IL1.1) The second project involved an EU subsidy which ICT3 acquired and in which the department had a small role (ICT3.1). The company did not commission contract research to the department. *"If we collaborate it is often because of a subsidy. These subsidies produce extra activities and the subsidies require industrial participation."*(ICT3.1) ICT3 was not interested in publishing, therefore no joint publications with ICTLab 1 were produced.

The relationship between ICT4 and the department consisted predominantly of the support of bachelor and master student research projects. On average, the company supported two students per year. And several of these students found a job at ICT4. *"All software developers that are working here come from [ICTLab*

1}."(ICT4.1) The main benefit of the collaboration with ICT4 was that the department was able to obtain new ideas for its research activities and that it used software of the company to enhance the graphics of their prototypes and demonstrators (IL1.2). The department attempted to involve the company in government research projects but efforts failed because grants applications were declined by government agencies. *"So far the collaboration is in the form of students but we hope a new project will change that."*(IL1.2) The company is not interested in patenting and publishing, therefore none of these types of collaborations occurred. ICT4 did not directly finance research since its budget did not allow it to do so. However, it hoped to maintain a long-term relationship with the research department (ICT4.1).

Looking at the role of the funding environment in supporting the relationships between ICTLab 1 and its spin-offs, we found only ICT3 participated a government project. Given the fact that the spin-offs did not have the budgets to support extensive relationships with the department, government support could have led to more intense relationships. However, the department could choose from various organisations in its environment with whom to collaborate with and initiatives that involved ICT 3 and 4 thus far did not materialise in granted project applications.

9.2.6 Impacts on the research portfolio

The relationships of the department with ICT3 and ICT4 did not have an impact on the research portfolio of the research department. The relationships between were of a very low intensity and as a result of that, the spin-offs were of a low importance to the department. The research department collaborated with over 20 other private companies and non-profit organisations that collaborated more intensely with the research department. This mitigated the importance of the spin-off companies. As a result, it is not surprising that there are no impacts on the research portfolio. Research agendas were not influenced by the spin-off companies. Publications were deemed an academic affair in which ICT3 and ICT4 did not participate. The amount of research projects acquired by the research department depended on its academic quality. Industry was supportive in obtaining government research projects but the spin-off companies themselves engaged only in one government project with the department. Research agendas and research outputs were unaffected by ICT 3 and 4.

9.2.6.1 Resources for research

In this section, we discuss whether the relationships with ICT3 and ICT4 have led to changes in the number of contacts with industrial research partners, changes in income from industry and changes in the income from national government agencies and international funding agencies.

The relationships with the spin-off companies did not lead to additional contacts with other companies. Respondents stated that the department had a well-developed network of companies with whom the already had contact (IL1.1, IL1.2). The spin-offs did not contribute to the network of the department by introducing new organisations with whom the department could collaborate. ICTLab 1 maintained contacts with 20 other companies, with whom it, in most cases, had more intensive relationships.

Contract research for ICT3 and ICT4 did not occur so the companies did not directly contribute to the research capacity of the department. Because the spin-offs did not contribute to the contacts with other industrial organisations, they also did not contribute indirectly to an increase in the research capacity of the department by attracting more contract research from other companies. Looking at the effects of the spin-offs on the acquisition of government research projects, we found that only ICT3 collaborated in one government projects, which made the direct impact of the spin-offs insignificant. Respondents from the department stated they were willing to engage in research collaborations with ICT3 and ICT4. However, the spin-off companies were part of a large group of companies which the department was acquainted with. The research department maintained contacts with over 20 companies that participated in government-funded research projects. *"In those projects we have a tighter connection with other companies than with our spin-offs. It involves a lot more money. Or it actually involves money whereas with the spin-off companies it is mostly about bachelor and master students and sometimes a small project. And that is not the big numbers that go into EU projects or BSIK projects."*(IL1.1). So, due to the presence of several other companies that could collaborate with the research department on themes central to the research department, participation of the spin-offs in government projects was also low.

9.2.6.2 Research agenda

The spin-off companies did not have a significant impact on the research agenda of ICTLab 1. *"I don't think they influenced the research agenda. Well, with this new project. That will give us a lot of PhD positions and that will have an impact on our research agenda. But we wrote that proposal. They did not write it and they did not come* *to us with ideas. We thought about what could be a nice role for them. They can do something they are good at and we hope they will pick up some of our ideas and that we end up with something nice."*(IL1.2) Respondents of both spin-off companies also stated that neither the interactions nor the presence of their companies led to thematic changes or more applied research activities. *"I don't think we have a lot of influence. We are interested in ways to have that and we would like to contribute to the success of the group."*(ICT3.1) Collaboration with ICT3 and ICT4 did not lead to changes in the themes of the research department but it has enabled the department to create more appealing demonstrators (IL1.2). The fact that the spin-off companies did not have an impact on the research themes and the balance between basic and applied research can be attributed to the following factors. The collaboration with ICT3 and ICT4 was of a very low intensity and the spin-off companies were only a small part of the environment of the research department. The companies were not able to commission significant research projects at ICTLab 1, whereas the department itself acquired most of its research funding from government sources.

9.2.6.3 Research output

In this section we report on the effects of the relationships with ICT3 and ICT4 on the number of scientific publications, other research outputs and research quality.

No impacts were reported on the amount of scientific publications of the department. The output of the department fluctuated over the period from 1996 to 2007 (Figure 9.2), but these fluctuations chiefly follow the increase in research FTEs (Figure 9.1), which were not caused by the spin-offs. *"Publishing is purely a task for us. A spin-off company will never say to us, let's publish a paper. Why would they do that? They do not have time for it and there is nothing in it for them."*(IL1.2) The creation of the publications is disconnected from relationships with industry. Given the fact that the relationships with ICT3 and ICT4 were of a very low intensity, expertise and knowledge did not contribute to the creation of publications as well.

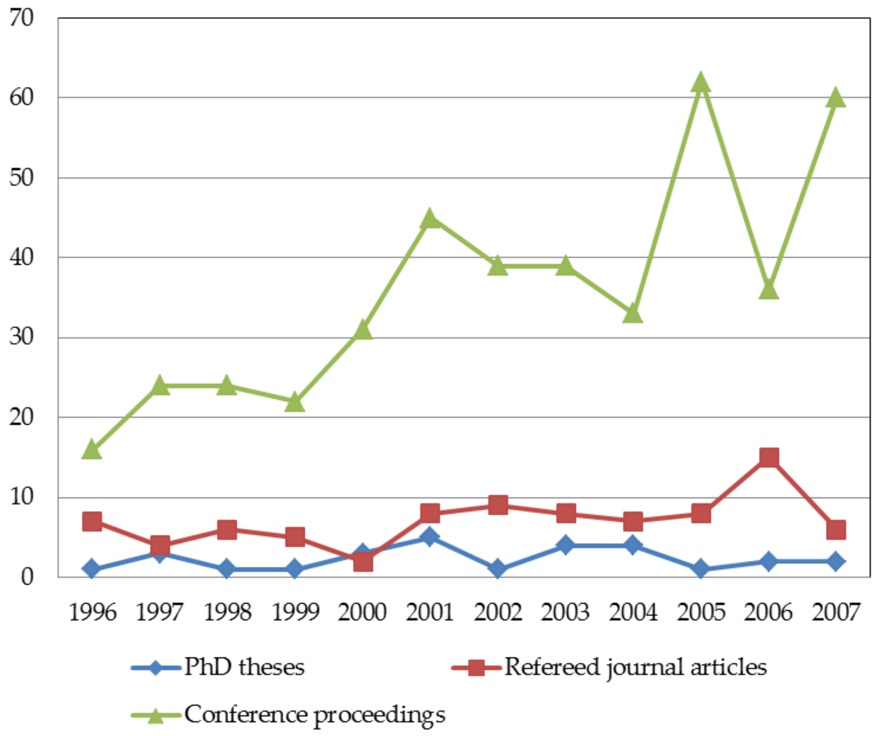

Figure 9.2. Research output of ICTLab 1, 1996-2007

Because of the low intensity relationships with ICT3 and ICT4, the research quality was unaffected. One research assessment credits the department with its strong connections with industry.[36] At the same time, respondents stated that they did not think the spin-offs added to the scientific reputation and the research quality of the research department. *"I don't think it has had an influence. We are so small."*(ICT3.1) It was far more important for the research quality of the department to have the right staff. Staff that can write good scientific publications and that can attract funding from government sources.

Regarding other types of research output we found that the creation of the demonstrators was not influenced by the presence of the spin-off companies, nor did the creation of the spin-off companies lead to a shift towards other kinds of research outputs. The department did not engage in the application of patents

[36] Assessment of research quality, Computer Science. QANU, May 2004.

(IL1.2). The creation of the demonstrators by the department increased in the past years but this was not due to the presence of the spin-offs. *"We did not create demonstrators ten years ago. But in the past years that has increased a lot. They are built for projects. It is not obligatory. In almost all projects we have a demonstrator."*(IL1.2) The creation of demonstrators became a normal part of the research activities of the research department since the demonstrators and prototypes were regarded as appealing to research funding agencies, media and students. Additionally, the demonstrators enabled the research department to test whether the produced knowledge is working in an empirical set up. *"For instance, what we want to do research on is the social interaction between persons and systems. You cannot do that if you do not have a prototype or a demonstrator."*(IL1.2)

9.3 ICTLab 2

ICTLab 2 is a department that conducts research on energy-efficient designs for computer systems. In 2007, the department consisted of 25 FTEs in research. Two spin-off companies have originated from ICTLab 2: ICT5 and ICT6. This section describes the relationships of the department with these spin-off companies and the impact of the relationships on the research portfolio of ICTLab 2.

9.3.1 Preferences

The staff of ICTLab 2 is mostly interested in research that translates basic research into technological applications. Rather, the departments' mission is to create knowledge in the form of software and chip designs that contributes to the solution of problems it knows industry is confronted with. *"My scientific question always has a clear industrial background. I always ask myself, what can I do with this? We don't have an interest that is only scientific."*(IL2.3) The leader of the research department voices a similar opinion: *"I think it is important that research we do is used as well. In the past someone's PhD would end up on the bookshelf. But I think that the research we do with community money should be really used by industry."*(IL2.1) The research department has a long tradition of collaborating with industry. From its inception, ICTLab staff sought to collaborate with industry in order to engage in societally relevant research (IL2.2). However, the staff is also alert that is does not engage in scientific research that only benefits the companies it collaborates with and does not contribute to the scientific reputation of the department. *"You have to ensure that you can do solid research. And sometimes that* *involves doing research companies are not ready for yet. We have to work on problems that become relevant for companies five years from now."*(IL2.1) Because of its interest in conducting research that is relevant for society, it is also motivated to stimulate knowledge transfer. *"If something looks promising we try and look if we can help to commercialise it. But we don't check on a daily basis what could be valorised."*(IL2.1) In the scientific community, commercialisation activities have become an accepted part of the research activities of academics. In assessments, peers are increasingly focussing on outputs such as demonstrators, patents and prototypes (IL2.2). In summary, collaboration with industry is welcomed by staff of the department and societal relevance is a part of everyday life of researchers in the department.

9.3.2 Resources

Like ICTLab 1, the department receives institutional funding from the ICTLab research institute. Figure 9.3 displays the income that ICTLab 2 receives from the research institute, from research councils and from contract research for governments and industry. From 1996 to 2007 tenured staff has fluctuated between two and seven FTEs and allocation of the institutional budget has become increasingly tied to the performance of the department. The size of the institutional budget and the criteria that are tied to it leave little to no room for the department to conduct research that does not include industry or other societal organisations. In practice all tenured staff work on externally acquired research projects since institutional funding is used to co-finance externally acquired research projects (IL2.1). The absence significant amounts of institutional funding inhibits the ability of researchers in the research department to conduct high-risk research since all research projects are conducted with the consent of either industry or funding agencies or both. As a result, the department attempts to rely on bachelor and master students to conduct research on certain themes that are not popular with funding agencies and industry (IL2.3).

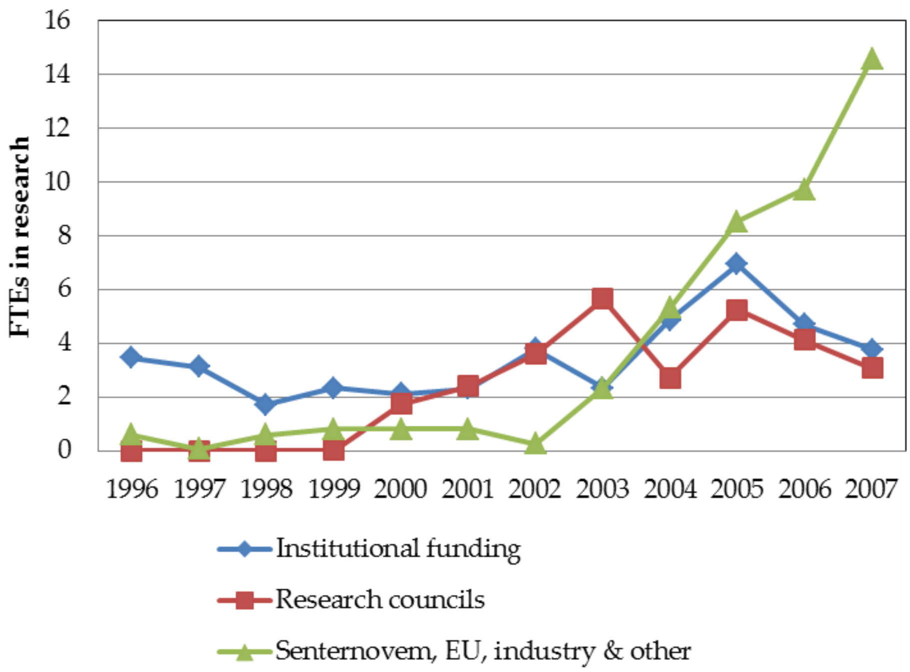

Figure 9.3. Research funding input of ICTLab 2 by source, 1996-2007[37]

The research department conducts research on the design of embedded systems, which also involves testing of hardware systems. Development and testing of the designs occurs mostly via software models. However, the department also relies on companies to develop hardware that can be tested in the research department.

9.3.3 Organisations in the environment other than spin-off companies

In addition to ICT5 and ICT6, the department can acquire research funding and other resources from several other organisations in its environment. From 1996 until 2002, ICTLab 2 received most of its funding from the ICTLab research institute and STW. This changed after 2002 when EU research programmes and industrial research partners started to support the predominant part of the research activities of the department.

[37] We rely on the research input in FTEs because reliable financial data from before 2003 was unavailable.

The government agencies from whom the department receives research funding all require or prefer the department to engage in collaboration with industry (IL2.1, IL2.3). *"Submitting a project proposal without industry almost does not stand a chance. But I do not experience that as something bothersome. I know what I want to do and there are enough companies who have the same interests as we do. And at the moment, the pressure is not so strong that we are stepping outside of our own research agenda to obtain funding. We are active in an area that is very interesting for companies."*(IL2.3) As a result of the demands of government agencies to include industry in projects, industrial organisations are welcome partners in the research projects of ICTLab 2.

Especially after 2002, private companies have started to support large parts of the portfolio of the research department. Between 2003 and 2005 for instance, four PhD positions were funded by multinational companies.[38] Because the research department conducts research on themes that are popular with industrial companies and because of personal relationships with some companies, it is relatively easy to acquire research projects (IL2.1, IL2.3). Because of the similarity in research agendas the department is able to conduct research that is central to its interests. The support of PhD projects is welcomed very much as these projects do not require the department to co-finance the activities.

9.3.4 ICT5 and ICT6: history, potential resources and demands

ICT5 originates from an EU-funded research project. Interest from industry, in the results of the research project, prompted researchers from the department to commercialise their findings. The spin-off company was founded in 2004 by three members of the research department and conducts research and product development in the area of RFID systems and wireless sensor networks. ICT5 has successfully developed several products and employed 15 people in 2007. The spin-off company operates in area that is central to the interests of the department. ICT5 conducts research to develop its products and for these development activities the company is also dependent on research funding from government funding organisations such as STW and SenterNovem since it does not have the resources to conduct development activities from its own resources. This implies that there is a good basis for collaboration in government projects but that the department cannot expect the spin-off to finance significant amounts contract research (IL2.2).

[38] Interim research assessment 2003-2005 ICTLab 2, 2007.

ICT6 was founded in 2005 and originates from an STW research project that was conducted by the research department. Three PhD students from ICTLab 2 used the knowledge created in the research project to found a spin-off company in the area of chip-technology and energy efficient digital signal processing. The spin-off company acquired two Technostarter-subsidies from STW to further develop the knowledge that was created in the original STW research project. Based on the subsidy, one of the founders could extend his PhD into a postdoc position at the research department. In 2007, the company employed 12 staff members. ICT6 has finished developing its first products but still, more than half of the activities of the company concern research and development (ICT6.1). The company is interested in collaborating with the research department since the research department is still active on themes central to the interests of the spin-off company but lacks the necessary resources to commission contract research projects.

9.3.5 Relationships with ICT5 and ICT6

The interactions of the research department with ICT5 and ICT6 are presented in Table 9.2. Overall, the relationships between the research department and its spin-off companies are of a minor intensity. Formal cooperation in government-funded research projects occurred in at least six projects. ICT5 and ICT6 would have liked to commission contract research projects to a more significant extent but are limited by their relatively small budgets and short time horizons. In comparison to the total budget of ICTLab 2, the participation of ICT5 and ICT6 in research projects composes a small part of the total activities. This is also caused by the fact that the department collaborates with many other industrial research partners in addition to ICT 5 and 6. The relationships with both companies are highly valued nevertheless because interests are quite similar and personal relationships are well-developed. The companies still keep a close eye on the developments in the research department and informal exchanges of ideas are highly valued.

Table 9.2. Relationships between ICTLab 2 and ICT5 and 6

Non-monetary resources	**ICT5**	**ICT6**
Joint publications with spin-off company	Significant	Significant
Joint patent applications with spin-off company	None	None
Former research staff of the research department employed by spin-off company	Minor	Minor
Personnel simultaneously affiliated to spin-off company and research department	Significant	Minor

Bachelor and master theses supported by spin-off company	Significant	Minor
Test data, facilities, instruments and prototypes obtained from spin-off company	Major	Significant

Monetary Resources

Contract research commissioned by spin-off company	Minor	None
Jointly acquired government-funded research projects	Significant	Minor
Financial support of PhD research projects	Minor	None
Does research institute or its staff own capital stock of spin-off company?	Yes	Yes
Funds from spin-off company in exchange for knowledge from research department	None	None
Donations received from spin-off company	None	None

Personal relationships between ICT5 and the department were well developed. Although the relationship with ICT5 was of a significant intensity, collaboration with the spin-off company decreased somewhat over the years. Important for the relationship was that one of the founders of the company retained his position in the research department (IL2.2). Two other former department members left the department to work full time for the company. ICT5 participated in at least five government-funded research projects with the department. The company had contacts with at least eight PhD students of the research department. As a result of the contacts with the company, the PhD students received know-how and information on the relevance of the research problems they work on (IL2.2) Additionally, the department was able to gain access to soft- and hardware for which it paid a reduced price (IL2.2) The only form of contract research was an employee of the company who was paid to conduct his PhD research at the research department. The company co-published articles with members of the department on at least eight occasions. Co-patenting on the other hand did not occur because the department was not interested in patenting and the company aimed to protect its intellectual property rights.

ICT6 was only involved in one government project with the department and as a result, the relationship with ICTLab 2 were of a minor intensity. No research projects were commissioned by the company. The main reason for this was a lack of resources. Although the extent of the formal relationships was not significant, a large number of informal interactions occurred. *"Actually we have a lot of collaborations with [ICT6]. And that is because [ICT6] departed from the department physically not so long ago. We see them on a regular basis and the connections are really tight with those guys"*(IL2.3). The spin-off company engaged in joint publications with the department on at least five occasions. Co-patenting did not occur. The department used prototypes, software updates and ideas from the company, which the PhD students used in their research projects (ICT6.1). Respondents expected that the intensity of the relationship with the company will decrease in the future. *"You notice that they have moved to a different location. The contacts are* *already less frequent and start to weaken. Their focus is also changing, in the end they have to produce a product."*(IL2.3)

The funding environment had a limited positive effect on the relationships between the department and its offspring. We already showed that the department acquired most of its funding from sources that require or prefer research proposals to include industrial research partners. *"The EU, and others as well, say: we love spin-offs, we give you money for this project. Mostly, we want to do research and they do a part of the research and we do a part of the research. And for that we both get money from the EU."*(IL2.3) Funding from government projects facilitated interactions between the spin-offs and the department in six research projects. However, actual interactions with the spin-off companies occurred mostly outside the research projects. Without the government projects, the relationships would have occurred anyway, although the relationship with ICT5 would be of a lower intensity.

9.3.6 Impacts on the research portfolio

The relationships with ICT5 and ICT6 had a small impact on the research portfolio of ICTLab 2. The informal interactions, and the participation in at least six government projects and a contract research project, created additional research capacity. After 2002 the research capacity of the research department has risen considerably. This rise was mainly caused by the success of the research department in acquiring funding from the EU and industrial research partners. In the research projects, in which the spin-offs participated, the spin-offs were able to negotiate specific research topics. These topics were always within the mission of the department and the department, most of the times, was the party that initiated the research projects. The balance between basic and applied research was not affected. The department was already active in applied activities and as a result the connection with the spin-off companies did not force the department to change its research focus. The additional research capacity made a small contribution to the research output of the department while research quality was unaffected. Although other types of research output were not affected, the spin-off companies did act as a vehicle to outsource some of the chip-development activities, which are not the core business of the department.

9.3.6.1 Resources for research

In this section, we discuss whether the relationships with ICT5 and ICT6 have led to changes in the number of contacts with industrial research partners, changes in income from industry and changes in the income from national government agencies and international funding agencies.

The relationships with the spin-off companies led to additional contacts with other companies. The spin-offs collaborated with other companies, with whom the department was not acquainted with (IL2.2, IL2.3). These companies were interested in the work of the research department and were introduced by ICT5 and ICT6 to researchers from the research department. However, since the department already maintained contacts with many other companies[39], the limited additional contacts were of minor importance to the research department (IL2.3). The department already maintained contacts with many other companies with whom it could collaborate in research projects or with whom it could engage in informal exchanges of knowledge and materials.

Over the years, ICTLab 2 received a considerable amount of research funding directly from industrial partners. The spin-off companies themselves however, did not contribute significant amounts of funding to the research department because they lack the resources to commission research projects (IL2.1, IL2.3). Only one PhD student was financially supported by a spin-off. Apart from that no direct research funding was provided to the department. Looking at the changes in research projects with other private companies we can also conclude that the relationships with the spin-offs did not have an impact. Respondents from the department stated that the department has traditionally maintained good connections with other industrial partners and that these good connections resulted in the direct support of several PhD projects by these other companies.

Looking at the contributions to the research capacity of the department in terms of government research projects we found that the companies participated in at least six government projects. These government projects required industrial participation and as a result, the spin-offs were important partners in these research projects. *"It is always good to have SMEs in the project because the EU and STW like to see new companies. You stand stronger because an SME is involved. The reviewers think that it is important."*(IL2.1) Even if the spin-offs did not participate in government research projects, the department mentioned them in their project

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[39] In the period 2003-2005, the research department maintained contacts with at least 34 companies. Source: Interim research assessment 2003-2005 ICTLab 2, Technical University , 2007.

proposals to show that the knowledge it developed was fit for commercialisation and that it had a track record (IL2.3). At the same time, the role of the spin-offs was mitigated by other companies that existed in the environment of the department. Between 2003 and 2005 for instance, the research department reported that it maintained contacts with at least 32 other companies.[40] The presence of the spin-off companies, their visibility to the outside world and their participation in projects made the department aware that the lines of research in which they operate were valuable. *"What you see is that in the vicinity of the project I worked on, there continue to come more and more projects and I think our company contributed to that. That part of the group has grown to 12 to 15 persons."*(ICT6.1) As a result, the department started to apply for more government funding for these research lines and has been very successful in applying for these grants. As is visible in Figure 9.3, the amount of externally acquired research funding rose significantly in the period from 2004 to 2007.

9.3.6.2 Research agenda

The success of the spin-off companies, and the publicity that surrounded them, made the department aware that lines of research, out of which the spin-offs originated, were promising. As a result, these lines of research became more important for the department. *"Activities on this topic were zero, I started that from the beginning onwards. And it is seen now by the faculty as an important thing. I expect the activities in this area will continue to grow. They are even going to create a new [professorial] chair in this field."*(IL2.2) At the same time, the staff of the department did not feel that their interactions with ICT5 and ICT6 diminished the autonomy over their research agendas. *"Until now we have always succeeded to define the project proposals and those proposals go to companies. We have got this idea, would you like to participate? And most of the times they think it is interesting."*(IL2.1) Another staff member stated: *"The fact that you have a joint project proposal has an influence on your research. But on the other hand, we have a clear vision on what we want to work on as a department. We are working on energy efficient systems and we want to work on dynamic systems and that is a very clear demarcation of our activities."*(IL2.3) The founder of one of the spin-off companies and a former member of the department stated that the influence of his company on the research themes covered was very small (ICT6.1). In the projects in which ICT5 and ICT6 participate, they are able to communicate their demands. *"We have an effect on the department. Because when we*

[40] Interim research assessment 2003-2005 ICTLab 2, Technical University , 2007.

join a project proposal we want to care of our interests. But that is still in line with the research that the department wants to conduct."(ICT6.1)

The balance between basic and applied research was not affected by the relationships with ICT 5 and 6. The research portfolio of the research department was experimentally oriented from the onset of the department and the relationships with the spin-offs did not alter the departments' focus (IL2.1, IL2.2, IL2.3). The relationships were not that intensive that the department became dependent on spin-off company funding to support its research activities. The success of the spin-off companies did trigger an awareness within the staff of the department that commercialisation activities can be rewarding. As a consequence other persons in the department began to look for possibilities to the create a company as well (IL2.2)

9.3.6.3 Research output

In this section we report on the effects of the relationships with ICT5 and ICT6 on the number of scientific publications, other research outputs and research quality.

The participation in government projects helped to increase the research capacity of the research department. Through this way, the spin-offs had a limited impact on the amount of publications that were produced by the department. However, the large increase in scientific publications from 1996 to 2007 (Figure 9.4) is best explained by the quality of the scientific staff and their ability to acquire research funding from industry and government sources. The spin-off companies themselves participated in at least 13 joint publications with the department. Respondents indicated that papers were more easily accepted for publication when industrial research partners participated (IL2.2, IL2.3). *"In our research, it is often necessary for publications to show that it works, not simply that you can simulate something. You need to verify your ideas. So in the situations that we have chips from the spin-off companies this has a lot of added value."*(IL2.3) With regard to the research quality of the department, we find that the spin-offs did not have an impact. Respondents stated that the quality of research is caused by the staff of the research departments. Spin-off companies may contribute to the research capacity of the department but the staff of the department writes the publications and is responsible for the acquisition of project funding. The research department received one research assessment, and in this assessment it was credited for the *"very strong connections to industry"*.[41] The assessment occurred before the spin-offs were created.

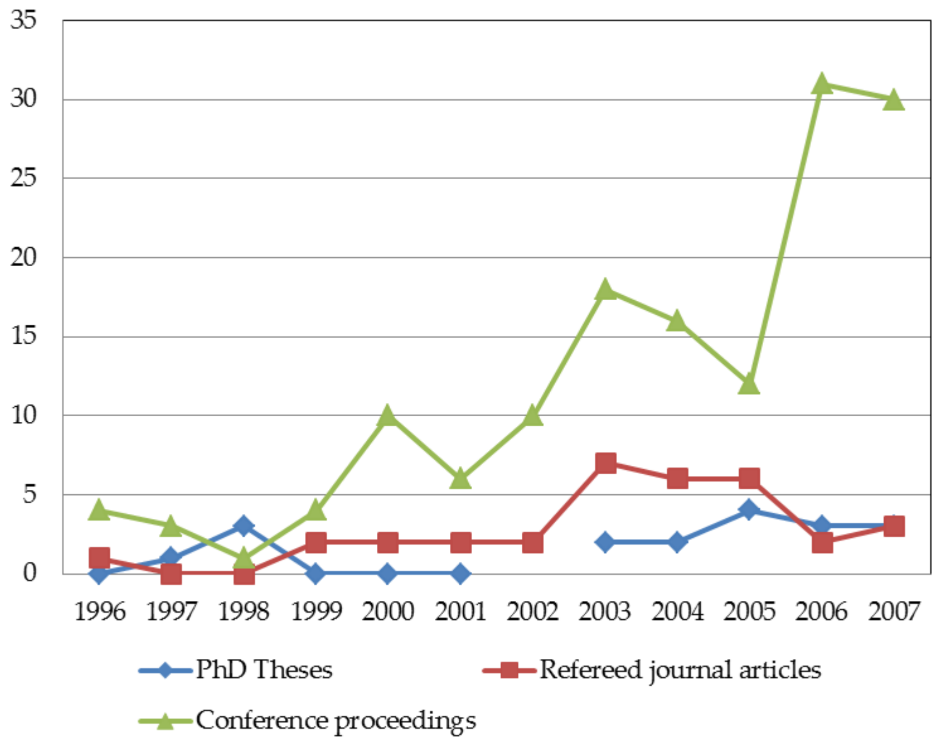

Figure 9.4. Research output of ICTLab 2, 1996-2007

There is no indication that the development of prototypes, demonstrators and patents increased due to the relationships with the spin-off companies. The creation of prototypes and demonstrators, was a normal part of the activities of the department since the department was interested as well in testing chips and software models (IL2.1). Given the interest of ICTLab 2 in industrial problems, the testing of chips and software was already an intrinsic part of the research activities of the department before the creation of ICT5 and ICT6. The spin-offs were used to outsource some of the development activities of the research department. Outsourcing development activities enabled to department to spare time and costs. *"For me an added value of a spin-off like this is that I start with a*

[41] Assessment of research quality, Computer Science. QANU, May 2004.

scientific problem without knowing exactly what kind of application it will have. Well at some point you get to a point that you have a lot of things to find out practically which you can hardly call scientific. And if I would have to outsource that it would cost a lot of money. So [ICT6] has an interest to do the development work and we have an interest in the results because it involves our ideas. So they make the building blocks for us to make the next step. We can experiment with those chips."(IL2.3) In addition to testing chips and software models, ICTLab 2 applied for two patents, one in 2004 and one a year later. These applications were not related to activities with the spin-offs.

10 NanoLab

This chapter considers NanoLab, a nanoscience and technology research institute, and two of its research departments: NanoLab 1 and NanoLab 2. The two departments have maintained relationships with five spin-off companies, NANO1, 2, 3, 4 and 5.

10.1 The research institute

NanoLab is a research institute that is part of the Technical University. In 2006, the institute employed approximately 300 researchers. The mission of NanoLab is to conduct excellent research, both in basic and applied research areas. The research institute aims to support the commercialisation of knowledge that is produced by its researchers and it is very interested in stimulating the collaboration of its researchers with industry. Spin-off companies form an important asset of the research institute and the aim of the institute is to produce between four and five spin-offs annually (NL0.2). *"Spin-off companies are complementary to the scientific qualities of the institute. If people see our spin-offs, they know we have something extra to offer."*(NL0.1)

The Technical University, in which NanoLab resides, is a front-runner in providing support structures for commercialisation and spin-off companies. As a university, it was one of the first public research organisations in the Netherlands to dedicate resources to the creation of spin-off companies (Clark, 1998). From its conception, the university *"was expected to link up with industry. Equally important, it was also conceived as a regional university … to help the development of that particular region."* (Clark, 1998, p.40). Already in the 1980s, the support of spin-off activities was seen as an active way to contribute to the mission of the university and to acquire additional research funding. As early as 1979 the university set up an industrial liaison office to facilitate interactions with industrial research partners and to increase its income from private companies (Maassen & Buchem, 1990). In addition to the support facilities that are offered centrally by the Technical University, support for spin-off companies is also offered by NanoLab. The research institute has three main motivations to support the creation of spin-offs. Firslty, because the region in which the research institute resides, lacked relevant industry, educated personnel and students would leave the region. The creation of industrial research partners would lead to the absorption of personnel and PhD students and would also contribute to the transfer of knowledge from the research institute (NANO1.1). Second, spin-off companies would be able to use the clean-room facilities of the institute and share the costs, thereby lowering the exploitation costs of the research equipment and facilities for the research departments. Third, private companies in the vicinity of the research institute could function as research partners and sponsor research. The motivations of the research institute are indicative both of resource-based motivations as well as institutional motivations. Increasing the employment opportunities for personnel and students fits with the mission of the Technical University to enhance the economic and social prospects of the region it is part of. At the same time, sharing exploitation costs and seeking to create new research partners are clearly resource-based motivations.

10.2 NanoLab 1

NanoLab 1 conducts research on the fabrication of nano- and micro-mechanical devices. In 2007, the research department employed almost 23 FTEs. Four spin-off companies have originated from the research department: NANO1, 2, 3 and 4. This section describes the relationships of the research department with these spin-off companies and the impact of these relationships on the research portfolio of NanoLab 1.

10.2.1 Preferences

The research activities of NanoLab 1 are divided into five themes: basic micromachining plus four application-oriented themes: sensors, actuators, fluid handling systems and nanotechnology.[42] The mission of the department is *"to develop and explore micro- and nano-systems for social advances and benefits, to ensure a close link between research and education and to form the nucleus of spin-off companies."*[43] The research department operates in a research field in which scientific knowledge production is intertwined with the creation of technological applications. Scientific research projects are aimed at producing technological breakthroughs and the ultimate goal of researchers in the research field is to advance their technological abilities. As a result, the utilisation of knowledge by companies is an important indicator of scientific success. In addition to its interests in commercialisation activities, the department would also like to

[42] Website NanoLab 1. Accessed on 31 August 2009.
[43] Research assessment 1999-2004. NanoLab 1.

conduct research with a long-term and high-risk character. *"Valorisation is beautiful and I understand that everybody who puts money into research wants to see something in return. But don't expect every project to have value for industry. Give us the chance to develop the basic infrastructure on which industry in the Netherlands can build."*(NL1.1) The head of the department understands that government funding needs to produce certain results. However, he also believes that his department should focus on topics where the outcomes will be uncertain and which will not be funded by industry as a result. So, the department is very open to collaboration with industry, but would like to conduct basic research as well. The knowledge it produces flows to companies in its environment and, for the scientific community which the department is part of, the creation of spin-off companies and collaboration with industry is an accepted practice and seen as a sign that the knowledge that is produced is relevant and applicable.

10.2.2 Resources

During the past 15 years, institutional funding of the department has been increasingly tied to the acquisition of government-funded projects that require co-financing. Data that are available on institutional funding show that in the period 2003-2007 institutional funding almost doubled (Figure 10.1).[44] However, this institutional funding has been provided to the department to co-finance externally funded research projects. So, as a result of the funding allocation model, the department has not been able to conduct basic research activities from its institutional funding. *"There is no more first-stream funding. There are always criteria attached that other people formulate. So we do not have the possibility anymore to say: we think this is interesting so that is what we are going to do."*(NL1.1) According to another senior researcher of the department: *"We are like a company. We have obligations to have everything financially in order and to have sufficient income. On the other hand, we are very limited in how we can spend our income."*(NL1.2)

[44] It is worth noting here that the rise in funding after 2005, visible in Figure 10.1, is mainly due to another research department that was added to NanoLab 1.

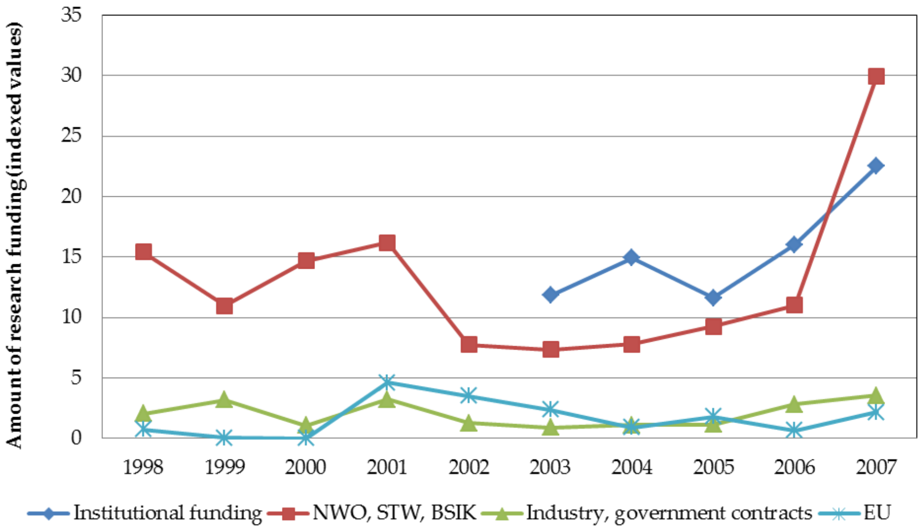

Figure 10.1. Research funding input of NanoLab 1 by source, 1998-2007.[45,46]

The research department requires expensive research equipment to conduct its research activities. The expensive equipment limits the ability of the research department to swiftly adjust its research agenda. *"You are stuck with the facilities you have. We make use of the clean-room. There is equipment there worth about 50 million Euros. And I cannot say to a company I want to do something else."*(NL1.1) This indicates that swiftly changing the direction of research is difficult. At the same time, companies that are able to offer the department the use of its research facilities, or that can support part of the research infrastructure of the department, are very attractive for the research department as it reduces the costs of the department's research activities (NL1.1).

10.2.3 Organisations in the environment other than spin-off companies

In addition to institutional funding, NanoLab 1 acquires approximately half of its research budget from external sources. The main sources of external funding are STW and SenterNovem. To a smaller extent the EU, NWO and private companies finance parts of the portfolio of the department (Figure 10.1). Since 2001, it has become more difficult for the research department to acquire research

[45] Reliable data on institutional funding before 2002 were not available.
[46] The actual amounts of project funding are confidential. We have masked the actual amounts and present indexed values in order to show the relative importance of the various funding sources.

funding from external sources (NANO1.1, NANO2.1). One of the respondents explains*: "In the 1990s [NanoLab 1] had an excellent position. Over the years, research funding has shifted towards other topics. So they are looking very much for new funding opportunities."*(NANO2.1) A research assessment in 2000 states: *"The field and the group have a future although the research area was more promising five years ago."*[47] As a result, the department is very willing to cooperate with industry in order to supplement its research budget.

Government agencies finance approximately 95% to 98% of the research budget of NanoLab 1 (NL1.2). The largest sources of external funding, STW and SenterNovem, require the department to include companies in their research proposals and research projects. Not doing so drastically reduces or even removes the chance that funding will be provided by these agencies. Over the years, research projects that require the participation of industry have become the main source of funding for the research department (NL1.1). According to the leader of the department, there are almost no projects in the portfolio that do not include industry since institutional funding is tied to externally acquired research funding. *"So that means that all research we do is connected to technological applications. It's not that we are engaged in applied research but we generate knowledge that is useful for companies, strategic or very concrete"*(NL1.1). The leader of the research department states that the obligatory participation of companies in research projects is detrimental to the research department's ability to conduct research that is potentially ground breaking since such research does not typically fit with the demands from private companies. *"What I miss nowadays is free basic research funding to do crazy things. That is not possible right now."*(NL1.1)

Despite the willingness of the department to collaborate with industry, only a small part of the annual budget of NanoLab 1 is acquired from private companies. The research department maintains relationships with several small and large multinational companies in addition to the relationships with its spin-off companies (NL1.2). Private companies do not usually invest in PhD research projects but tend to contribute materials, know-how and practical design problems. *"Contract research from companies is not based on their interests but on how much money they have."*(NL1.2) In addition to the limited monetary resources of the companies which the department has contact with, these companies have short time horizons which restrict long-term investments in the department. On average, private companies are concerned with what can be accomplished in one or two years, not in 10 to 20 years (NL1.1).

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[47] Research assessment, NanoLab 1 1994-1998, VSNU.

10.2.4 NANO1, 2, 3 and 4: history, potential resources and demands

In 1995, NANO1 was founded with the aim of becoming a prototype fabrication company. The idea was that the company would be the commercial outlet of knowledge that was created at the NanoLab institute. In 2007, the company employed 25 people. The spin-off company develops and produces micro-electro-mechanical systems and integrated optics, two key areas of interest for the department. NANO1 is interested in the research activities of NanoLab 1 and keeps its expertise up-to-date by stationing its employees in the NanoLab clean-room together with researchers of the NanoLab institute (NANO1.1). NANO1 is interested in collaboration with the department but finds that the durations of the research projects are long and results often are not concrete enough to lead to applications. Unfortunately for NanoLab 1, the research budget and the time horizon of the company do not allow it to commission substantial amounts of contract research. Additionally, the company can conduct its development activities with other organisations. "I*t is not our goal to engage in projects only with the university. We look for the best possible partners in each project and, if knowledge from the university fits within the project then we try to get the university on board."*(NANO1.1)

NANO2 originates from a PhD research project within NanoLab 1. The spin-off company was founded in 1998, and in 2006 it employed 10 staff members. NANO2 develops and produces microphone systems to measure particle velocity of gasses and fluids. This is one of the main themes in the research programme of the research department. The spin-off company is very interested in knowledge that is developed in the research department. NANO2 is particularly interested in testing and developing particle sensors from NanoLab 1. At the same time, the research department is not regarded as the sole provider of knowledge and the company has contacts with other public research organisations in the Netherlands and abroad. As a result of its small size, the company lacks significant resources to directly invest in the research department, and the company itself has sought to attract government funding to enhance its relationships with NanoLab 1 and other academic departments.

NANO3 was founded in 1994 to develop microfiltration membranes. At the time of its creation, the founder of NANO3 worked at NanoLab 1. The spin-off company never fully developed into a commercial company but maintained a strong research profile, closely related to academic research (NL1.2, NANO2.1).

At its height, the spin-off company employed four people. The CEO of NANO3 maintained a scientific profile and, after a few years, started to work once again at the research department. Because of its scientific focus and modest size, the company does not offer monetary resources since any research funding would be spend by the company on in-house research. At the beginning of 2007, the founder of the company accepted a professorial chair at another university in the Netherlands. As a result, NANO3 still exists but the activities of the company have decreased and as a result the potential for interaction with NanoLab 1 is very limited.

NANO4 originates from a master thesis project conducted at NanoLab 1. The company was founded in 1999 and is specialised in the etching of structures in glass. The knowledge on which the company is based comes from two departments: NanoLab 1 and 2. In 2007, the number of employees at the spin-off company totalled 25. NANO4 aims to develop its own technologies to develop and produce glass-based chips. In order to further this aim, the spin-off company relies on knowledge that is developed in NanoLab 1 and 2. The spin-off company can offer the departments chips which the departments can test and experiment with. The company is also interested in using the clean-room facilities of NanoLab. Although there is a strong basis for collaboration, the company does not have the resources to commission long-term contract research projects.

10.2.5 Relationships with NANO1, 2, 3 and 4

The interactions between NanoLab 1 and its four spin-off companies are presented in Table 10.1. Overall, the relationships between NanoLab 1 and the spin-off companies have a minor intensity. However, in total the relationships have contributed a substantial amount of resources to the department. Spin-off companies have engaged in exchanges of ideas, test data, computer chips and facilities. Informal exchanges of resources occurred mostly in the clean-room of the research institute. In addition to these interactions, collaborations with the spin-offs occurred to a significant extent in government-funded research projects. The spin-offs collaborated with the department in at least 16 projects that were funded by national and international government agencies. These projects were jointly acquired, and in these projects, materials were exchanged and the spin-off companies were kept up-to-date on the research activities of the department. According to the head of the research department, an important reason for researchers within the research department to collaborate with spin-off companies is to acquire research funding. *"Without these interactions we will not be able to get research funding. The only way to obtain funds for research in our field is to do something that is relevant for industry."*(NL1.1) At least 16 joint publications with the spin-offs appeared in peer-reviewed journals, mostly because individual staff members of the companies had a scientific background. Patenting was not a common occurrence, and only NANO4 engaged in joint patenting with the department. The research department engaged in contract research with two of the spin-off companies. However, looking at the size of the contract research projects, we have to conclude that contract research made up a minute part of the research budget of the research department. As a result, other organisations in the environment have been far more important in terms of providing resources for NanoLab 1.

Table 10.1. Relationships between NanoLab 1 and NANO1, 2, 3 and 4

Non-monetary resources	**NANO1**	**NANO2**	**NANO3**	**NANO4**
Joint publications with spin-off company	None	Minor	Substantial	Minor
Joint patent applications with spin-off company	None	None	None	Minor
Former research staff of the research department employed by spin-off company	Minor	None	Minor	Minor
Personnel simultaneously affiliated to spin-off company and research department	None	None	Minor	Minor
Bachelor and master theses supported by spin-off company	Minor	Minor	<missing>	None
Test data, facilities, instruments and prototypes obtained from spin-off company	Minor	Substantial	Minor	Substantial
Monetary Resources				
Contract research commissioned by spin-off company	Minor	Minor	None	None
Jointly acquired government-funded research projects	Substantial	Minor	Substantial	Substantial
Financial support of PhD research projects	None	None	None	None
Does research institute or its staff own capital stock of spin-off company?	No	No	No	Yes
Funds from spin-off company in exchange for knowledge from research department	None	None	None	None
Donations received from spin-off company	None	None	None	None

NANO1 has a long standing relationship with the NanoLab research institute. Since the creation of the spin-off company, informal contacts have existed between employees of the spin-off and researchers from NanoLab 1. The intensity of the relationship between the research department and the spin-off company has fluctuated and overall has been modest. *"For a while we engaged less in projects with the university. Now it is increasing again. I notice that outside the projects we increasingly have contact with the research department to gain access to certain technologies."*(NANO1.1). NANO1 has collaborated with the research department in EU projects. In the first five years of its existence, the company attracted personnel from the research department. Tenured staff, however, remained in the research department. Two employees of NANO1 are working in the clean-room of NanoLab, which gives the company access to research equipment and leads to informal contacts with researchers from the research departments of NanoLab. The spin-off company participated in at least two STW research projects and two other government-funded projects with the research department. Additionally, the department has engaged in small contract research projects, for instance to test chips.

The relationship between NANO2 and the department has been of a low intensity and started with a valorisation grant from STW. In addition to this research project, NANO2 contributed financially to an STW project that funded a postdoc and a PhD student. In the framework of the research project, the company made use of the clean-room facilities of the research institute. The department also received sensors from the company. The leader of the department states that *"[NANO2] is important for us at this moment. We have intensive collaborations with them."*(NL1.1) However, the relationship between NanoLab 1 and NANO2 has been turbulent at times, especially because the company was interested in having a greater influence on the research agenda of the projects in which it participates. The inability to influence the research activities of the department contributed to the decision of the spin-off company to move to another region where it has sought contacts with other academic partners. For the research department, the collaborations have been useful. *"If you look at [NANO2] you see that, during those years, our relationship was mutually beneficial. This has not been without tension, but the collaborations were useful for us."*(NL1.2) The research department received products from NANO2 which it used in its research activities. In the near future, the spin-off company hopes to invite NanoLab 1 to join in EU seventh framework programmes. In these projects, the company hopes to exert more influence on the research agenda of the department.

Because of the academic character of NANO3, the relationship between the company and the department has involved a substantial number of research projects. It participated in at least three STW research projects and in a large research programme sponsored by SenterNovem. Participation in government-funded research projects has been common since the interests of the CEO have been to conduct scientific research and to develop products. This made participation in government-funded research projects attractive to the company and explains the relatively high number of joint publications with the research department in comparison to the other spin-off companies of NanoLab 1.

The relationship with NANO4 was mostly characterised by participation in government-funded projects, informal contacts and the supervision of bachelor and master students. The intensity of the relationship is gradually declining. NANO4 participated in one STW research project and in a large SenterNovem sponsored research programme together with NanoLab 1. Chips from the spin-off company were used by NanoLab 1 and at least one co-publication was produced. The company did not support bachelor or master students of the department but collaborated in this respect with the other department, NanoLab 2. The relationship between NANO4 and NanoLab 1 was especially intensive during the start-up phase of the spin-off company. During that time, the company still needed to develop the basic techniques to design and produce glass chips. *"At the start of the company we collaborated a lot with [NanoLab 1] to see how you could make the chips. … And for the basic techniques we still use the people of [NanoLab 1]."*(NANO4.1) After this period, the company started to benefit more from knowledge from other research departments within the NanoLab research institute.

Looking at the influence of the funding environment on the intensity of the relationships of the department with its spin-off companies, we see that government projects were an important enabler of the relationships between the spin-off companies and NanoLab 1. For the department, it was very difficult to acquire funding that did not require the participation of industry and, as a result, spin-offs were an attractive partner. The spin-offs in turn did not have the resources to commission research projects. As mentioned earlier, the spin-offs collaborated in at least 16 government projects. In these projects ideas were exchanged as well as materials, and the spin-offs had a chance to witness developments. As a result, the projects contributed significantly to the intensity of the relationships.

10.2.6 Impacts on the research portfolio

Although the spin-off companies collaborated with NanoLab 1 on a considerable number of research projects, the research portfolio of the research department was not significantly influenced by the spin-off companies. Respondents regarded spin-off companies as entities that commercialise knowledge from the research department and would stay in the area to become research partners. However, because contract research was very limited, direct steering of research agendas did not occur. The most important form of collaboration, for the research department, was the participation of spin-off companies in a large number of government-funded research projects. The ideas of spin-off companies were used by researchers in the research department to formulate new research proposals. Researchers of NanoLab 1 could operate relatively autonomously in these government projects and the research department was able to reject most of the demands of the spin-off companies since the research department had the final say over the direction of these research projects. However, the department did not dismiss demands entirely. Spin-off companies could vote with their feet: if they did not like a research project, they would not participate. Further, ignoring the demands of the spin-off companies would harm the future relationship between the research department and the spin-off companies, thereby leaving the department short of organisations that could provide important support in acquiring government-funded research projects. The relationships with the spin-off companies did not lead to an increase of patent applications and prototypes. On the contrary, the spin-off companies enabled the department to outsource some of its development activities, thereby allowing NanoLab 1 to focus on research rather than development activities.

10.2.6.1 Resources for research

In this section, we discuss whether the relationships with NANO1, 2, 3 and 4 have led to changes in the number of contacts with industrial research partners, changes in income from industry and changes in the income from national government agencies and international funding agencies.

The number of contacts which the department maintained with industry was not affected by the presence of the spin-off companies. According to the respondents from the research department, the department already had well-developed connections with industry and the spin-off companies did not introduce new research partners (NL1.1, NL1.2). Representatives of the spin-offs indicated that, in the long-term, their presence could increase the departments' contacts with industry. *"We also lure clients to the region to set up research projects. So in the long-term this could have an effect."*(NANO4.1) However, the most important way to attract industry for research projects was to conduct high quality research according to respondents from NanoLab 1 (NL1.1, NL1.2).

The direct monetary contributions from the spin-offs to the research capacity of the departments were small. Only NANO1 and NANO2 commissioned contract research by the department, and these projects were not large enough to fund a PhD student. The director of the research institute stated that some of the other spin-offs in the institute *"have such a size that if we want to do research and they can benefit from it, that they will commission research."*(NL0.1) In practice, however, the amount of contract research commissioned by the spin-off companies to the department is still very small and insignificant in terms of the total research budget of NanoLab 1. *"You can see a small increase of revenue from companies but it is not much and that is because there is not much involvement of companies in research. At the moment their attention is too fragmented. A project for a PhD position requires several hundreds of thousands of Euros. Companies can't afford that. They would like to, but the risk is too high."*(NL0.1) The spin-offs did not contribute to additional contacts with industry and, as a result, no additional revenues from other companies were acquired to supplement its research budget.

The spin-off companies did however help to acquire a large amount of government research projects that contributed significantly to the research capacity of the department. The department acquired funding predominantly from government sources that required industrial participation. In almost all the research projects, industrial research partners participated and provided ideas for research themes and materials, or were directly involved in research activities. *"When we have an STW proposal we need to describe what will happen with the knowledge. To write that up convincingly you need people from industry."*(NL1.1) Respondents stated that the presence of the spin-off companies helped to acquire government-funded research projects (NL1.1, NL1.2, NANO1.1, NANO2.1). The fact that the department created spin-off companies, as well their possible participation in research projects, was mentioned in project proposals (NL1.1, NANO1.1). *"They show that we are not just fooling around. They are the proof that what happens here is relevant for society and the economy."*(NL1.1) Further, the spin-off companies were instrumental in convincing government agencies that money spent on research at NanoLab 1 would result in benefits for society. According to the respondents, the presence of the spin-off companies led to a higher chance of success in applying for research grants from agencies that require or prefer industrial participation. *"If you participate in a round with 20 proposals for STW you will be judged on scientific merits as well as societal relevance. Has it been helpful for us that [NANO2] was part of the project? I think it indeed contributed to a greater chance of success than normal."*(NL1.2) At the same time, researchers from NanoLab 1 stated that spin-off companies were only part of the story and that scientific excellence remained the most important factor in successful acquisition of government research funding.

For the research institute as a whole, the presence of spin-off companies was very beneficial. According to the director of the research institute *"it would have been a lot more difficult to persuade the Ministry of Economic Affairs that they should fund several research programmes. The fact that we have those spin-off companies tipped the balance because it convinced them it is also useful for the economy. Spin-offs are very tangible."*(NL0.1) One of the spin-off companies even became the coordinator of an 18 million Euro research programme.

10.2.6.2 Research agenda

The spin-off companies had little impact on the research themes of NanoLab 1. Only in the projects where they participated could spin-offs could articulate their demands, and their participation in research projects supported certain lines of research. Given that the spin-off companies commissioned insignificant amounts of contract research to the research department, a direct and visible influence on the research agenda was absent. *"If you do not have money nothing happens. The only way to get the university working for you is to bring money yourself."*(NANO1.1) However, the presence of the spin-off companies in at least 16 government-funded research projects enabled the companies to influence the direction of the research projects somewhat. Researchers from the research department received information from the companies regarding relevant practical problems (NL1.1, NANO1.1). Nevertheless, the abilities of the spin-off companies, to steer research activities within these government-funded projects were relatively limited according to respondents. *"In our STW projects, for example, about 80% is funded by STW and 20% by industry. In one project there are multiple companies so one company can never say I want you to do this. And in the end the responsibility for the project is the the researcher's. So companies cannot say I want you to do this. But we take their interests into account because we need them for our research funding. Submitting the research proposals is in a sense not optimal for industry. In research you come across interesting things. Then we start looking for companies that we think might be interested."*(NL1.2) Thus, the steering abilities of the spin-offs were limited because the initiative for most research projects lay with the research department, the department was solely responsible for conducting most research projects and the participation of multiple companies in projects hampered demand articulation. In addition, the research equipment that the department owned limited the influence of any organisation on the research agenda of the research department (NL1.1). It takes several years to change themes according to the leader of the department. However, within research themes it is possible to switch topics. *"The projects we conduct with industry are always in the same area of our activities, but the topics spread easily. You think to end up somewhere, but most of the times you end up somewhere else doing something different. Then the problems we are looking into are totally different. Something like that happens a lot"*(NL1.1)

One line of research did become more important for the research department due to the interest of NANO2 and other companies, while activities on another theme were halted. *"Within the department, a lot of research was done on resonating sensors and it turned out that industrial interest was so little that this research line was terminated. The flow sensor, on the other hand, was sort of a new research line that was started. Later, that part of the research department focused on microphones, and new projects were started. That was something successful."*(NL1.2) The research line on flow sensors, benefitted from contract research that was conducted for a large multinational company, and NANO2 participated in three government-funded research projects. *"Every spin-off is part of one of the research themes of the department. Programmatically we did not change significantly because of the spin-offs, but you could say we could hold on to that research line because we scored with those projects. The spin-offs confirmed the line of research, but you can't say we would not have done the research without these companies."*(NL1.1)

The research agenda of NanoLab 1 did not become more applied or costumer-driven because of the relationships with spin-off companies. *"We have always had a mix employing certain technologies for applications. We have also had basic research projects about the characteristics of silicon and other topics."*(NL1.2) The research department did however need to bargain with spin-off companies about topics in order to persuade them to participate in research projects. *"In STW projects you can only interest companies who are precise about what they want to have. The limitation for us is that when we can't find a company that likes it, we don't get the money. So it's a negotiation and if none of the companies like it we don't get any money."*(NL1.1) According to representatives of the spin-off companies, the challenging financial situation of the department made it more inclined to incorporate demands of private companies into research proposals and research projects. According to the leader of the research department (NL1.1): *"It happens that we say let us see if we can make companies more enthusiastic about a proposal. On the other hand, we would like to* *be more fundamentally focused and we hope to find other companies with a longer term focus."*

10.2.6.3 Research output

In this section we report on the effects of the relationships with NANO1, 2, 3 and 4 on the number of scientific publications, other research outputs and research quality.

According to respondents, the production of scientific publications was only affected by the contributions of spin-offs to the research capacity through their participation in government research projects. As is visible in Figure 10.2, there have been significant fluctuations in the research output of the department. There was a slight decrease in scientific publications between 1997 and 2005. After 2005, another research department was added to NanoLab 1. Overall, the scientific output of the research department followed the fluctuations in the research budget of the research department. Spin-off companies participated in at least 19 publications with researchers from the department. Ten of these publications were produced in collaboration with the CEO of NANO3 who had a strong scientific focus. Mostly, the spin-off companies did not have an interest in publishing their research in scientific journals and benefitted more from protecting their knowledge (NL1.1). When joint publications did occur, the spin-off companies were asked to make a minor contribution to an article while the main responsibility for such an article belonged to researchers of NanoLab 1 (NL1.2).

We found no indications that the relationships with the spin-off companies contributed to the research quality of NanoLab 1. The research department received two research assessments. In these research assessments, the research quality of the department was rated 'good'[48] and then 'very good'[49]. The spin-off companies helped the research department to acquire research funding but the quality of the research activities of the research department was based on the staff within NanoLab 1 (NL1.1, NL1.2). So, the relationships with the spin-offs were very important for the department, but the relationships did not influence the core activities of the department other than providing information and

[48] Research assessment 1994-1998 NanoLab 1, VSNU.
[49] Research assessment 1999-2004 NanoLab 1, QANU.

legitimative support for research projects. In its latest research assessment, NanoLab 1 was credited with *"the impressive number of spin-offs"* and its clear strategy to transfer knowledge to existing industry and start-up companies.[50]

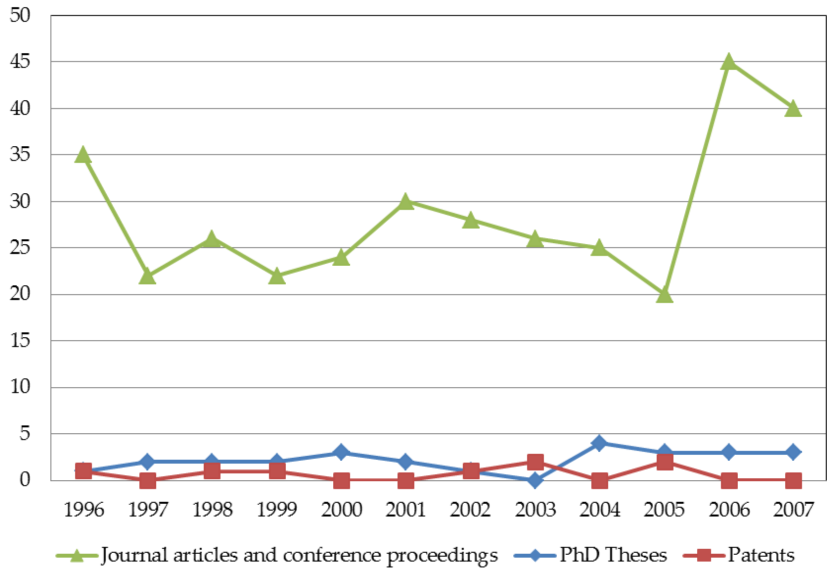


Figure 10.2. Research output of NanoLab 1, 1996-2007

Looking at the impacts on other research outputs, we found that the relationships with the spin-off companies did not lead to an increase in patent applications and prototypes. Spin-off companies allowed the department to outsource certain development activities, which allowed NanoLab 1 to focus on research activities rather than spending time on the development of chips. The research department applied for approximately one patent each year (Figure 10.2), but patenting was not a priority for the department and the department preferred its industrial research partners to apply for patents. *"We try to avoid patenting. It is very expensive and it involves a lot of work."*(NL1.1) Respondents indicated that interactions with the spin-off companies did not lead to a reorientation towards more technological research outputs such as prototype computer chips. Rather the conversely: respondents reported that NANO 1, 2 and 4 provided the research department with chips, sensors and other materials that NanoLab 1 used in its research activities. For the research department, the presence of the spin-off companies meant that it could outsource certain development activities and did not need to produce some materials itself but

[50] Research assessment 1999-2004 NanoLab 1, QANU.

could acquire these materials relatively inexpensively to use in its research activities. So, the presence of the spin-off companies actually contributed to a more articulate demarcation of research and development activities that helped NanoLab 1 to focus on research activities instead of developing of chips and sensors.

10.3 NanoLab 2

NanoLab 2 conducts research on micro- and nano-fluidic phenomena and lab-on-a-chip systems. In 2007, the research department consisted of 16 FTEs all active in research. The department helped to create two spin-off companies: NANO4 and NANO5. This section describes the relationships of the research department with these spin-off companies, and the impact of these relationships on the research portfolio of NanoLab 2.

10.3.1 Preferences

The mission of the department is to engage in basic research as well as creating actual prototype systems. *"Half of the projects are initiated out of scientific curiosity and half out of applied motivations."*(NL2.1) Creating technological applications is an important goal of the department, and researchers in NanoLab 2 are interested in engaging in knowledge transfer (NL2.1, NL2.2). *"My interests have always been twofold. How does something work and what can you do with it. If I find something beautiful I feel an obligation to see if I can do something with it in practice."*(NL2.1) Respondents also indicated that they wanted to conduct research on issues that do not lead directly to technological breakthroughs and they stated that it was important for their research quality to conduct research that did not have an application in mind from the onset (NL2.1, NL2.2). As a result of its interests in technology transfer, the department is open to collaboration with industry. Collaboration with industry and the transfer of knowledge to industry is a key indicator of success. However, this does not mean that knowledge transfer activities dominate the agenda of the department. *"It is not the case that our research agenda is dictated by whether or not something can be valorised. In our group we have two areas. The one is more focussed on creating knowledge and understanding things. On the other hand, we have projects which we formulate to reach a certain technical goal."*(NL2.1) Looking at the scientific community of the department, we see that it operates in a research field in which scientific knowledge production is intertwined with the creation of technological applications. Scientific research projects are devised with concrete technological breakthroughs in mind, and the ultimate goal of researchers in the research field is to advance their technological abilities in order to measure and manipulate biological material on an ever smaller scale. As a result, collaboration with industry is a common occurrence.

10.3.2 Resources

Like NanoLab 1, NanoLab 2 had experienced that institutional funding was increasingly being tied to the acquisition of government-funded projects that require co-financing. In principle this would have limited the ability to set its own research agenda, e.g., to conduct basic research. However, as is visible in Figure 10.3., from 2003 to 2007 the department was able to almost double the institutional funding it received. Further, this rise in institutional funding was not related to external funding that needed to be co-financed by the institute. Instead, the department received institutional funding that came from part of a budget that stimulates strategic research areas. In total, the department received additional institutional funding for at least four basic research projects (NL2.1). This type of funding was very valuable for the research department since it allowed the department to conduct research on topics it thought were very important, and basic research, that did not include demands from external organisations such as industry or government agencies.

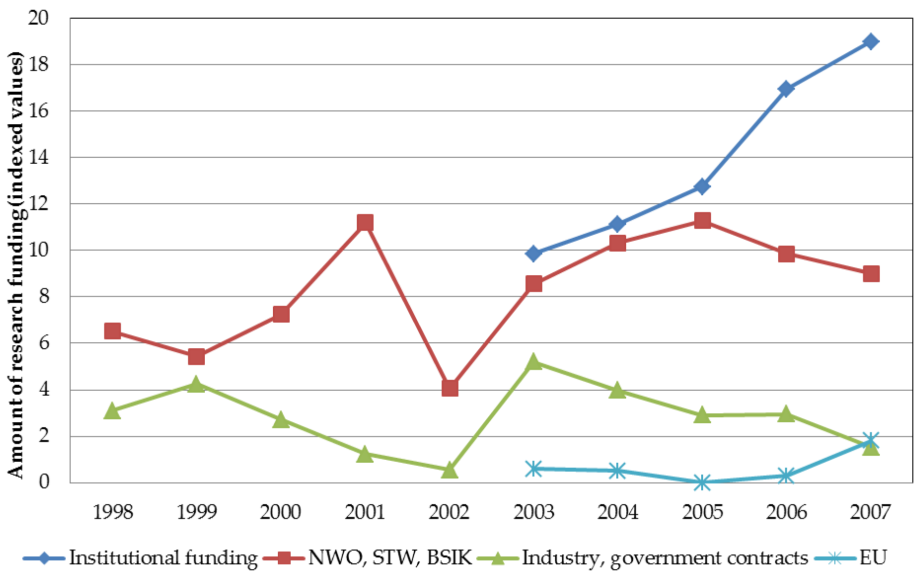


Figure 10.3. Research funding input of NanoLab 2 by source, 1998-2007[51,52]

Like NanoLab 1, NanoLab 2 requires expensive research equipment to conduct its research activities. The investments in equipment limit the ability of the research department to swiftly adjust its research agenda. This means that swiftly changing the direction of research is difficult. At the same time, companies that are able to offer the department the use of their research facilities or that can support part of the research infrastructure of the department are very attractive as this reduces the cost of the department's research activities (NL2.1).

10.3.3 Organisations in the environment other than spin-off companies

In addition to NANO4 and NANO5, the department is able to collaborate with several other organisations in its environment. NanoLab 2 received funding from government funding agencies and industrial research partners. Most external research funding originated from STW, NWO, FOM, and SenterNovem. A minor share of the research funding came from the EU and private companies. As can be seen in Figure 10.3, there was a significant fluctuation in funding received from government agencies over the period 1998-2007.

Predominantly, externally funded projects were acquired from government agencies. Most of these agencies require the participation of industry. However, NanoLab 2 has also been able to acquire research funding from organisations that do not require industrial participation. According to the leader of the department: *"It is easier to get money if you can show usefulness. But I deliberately have some projects in which utilisation is not part of the project. In which we only want to know how something works. And we can get that money from FOM and also within Nanoned there is some space for those projects"*(NL2.1) A senior researcher in the research department felt that without demonstrating the relevance for industry, mobilising research funding from government sources is difficult. *"If I would see a potential application of knowledge in about 10-15 years and I can't prove it then it is really difficult to get money for that."*(NL2.2) The research projects the researcher attempts to get funded cannot be conducted without company involvement. *"If I would have been*

[51] Before 2001, EU research funding was administered as part of contract research. Reliable data on institutional funding before 2002, and EU funding in 2001-2002, were not available. The decline in funding in 2002 is caused by a reorganisation of the research department.
[52] The actual amounts of project funding are confidential. We have masked the actual amounts and present indexed values in order to show the relative importance of the various funding sources.

more fundamentally oriented, I would have submitted my proposals to other agencies like NWO or FOM. Then I would not have needed companies in my proposals."(NL2.2)

A small part of the research activities of the department was funded by industrial research partners. Overall, the companies which the research department collaborated with were relatively small in size and lacked substantial research budgets. *"Really large companies will not invest that fast in these types of technologies because it's not their core business"*(NL0.2) These relatively small companies also lacked a long-term research focus and, as a result, were not interested in being involved in government-funded research projects that did not produce short or medium term results. *"What is lacking is not money for basic research as such, but if I have an idea that could work out in ten years from now, industry is not interested."*(NL2.2) As a result, industrial organisations are seen as attractive partners for applied research projects. The research department shared research equipment with private companies in the NanoLab clean-room. Companies hired equipment, thereby decreasing the costs of the facilities to the department.

10.3.4 NANO4 and NANO5: history, potential resources and demands

In Section 10.2.4. we discussed the history, potential resources and demands of NANO4. We therefore proceed here with a description of NANO5.

The roots of NANO5 can be traced back to an attempt to measure substances in blood. An STW research grant resulted in a completed PhD project on this topic. The technology that was developed in the project looked promising and STW supported the initial activities of NANO5 by providing a valorisation grant that funded further development of the technology. Additionally, the research department supported the company by providing facilities and a four-month contract for a co-founder of the company. NANO5 was officially founded in 2006 and consisted of three employees in 2007. The company developed diagnostics technology to measure electrolytes in blood. In 2007, the first product of the company was still under development. The knowledge the company was based upon was knowledge from the research department and this was also central to the interests of the research department as it concerned the development of lab-on-a-chip systems. The company was heavily focused on product development and was awaiting the clinical validation of a prototype chip that measured lithium (NANO5.1). Since the spin-off company was still developing its first products and was relatively small, it relied on knowledge that was present at NanoLab 2 and was interested in maintaining a strong link with the research department. NANO5 would have liked to commission contract research at

NanoLab 2 but stated that this has not been possible because it lacked the necessary monetary resources.

10.3.5 Relationships with NANO4 and NANO5

The interactions between NanoLab 2 and its two spin-off companies are presented in Table 10.2. Overall, the relationships between the department and the two spin-off companies were of a low intensity but, nevertheless, important for the research department. *"I collaborate with large companies as well, but they are end-users and are only interested in what you can do with it. And that's why I need the spin-off companies. They stand between us and these companies."*(NL2.2) The companies enabled the research department to test knowledge that was developed, but the monetary resources that the spin-off companies possessed were not sufficient to commission contract research at NanoLab 2. All the formal research collaborations were financed by government agencies that promote university-industry collaboration and commercialisation. Informal collaborations were an important part of the relationships with both companies. Informal meetings led to exchanges of ideas and materials and kept the parties up-to-date on the latest developments. In addition, supervision of student thesis projects provided another important platform for knowledge exchange. Joint publications occurred only with NANO4 and one joint patent application occurred with NANO5. On several occasions chips were exchanged for knowledge from the research department.

Table 10.2. Relationships between NanoLab 2 and NANO4 and 5

Non-monetary resources	NANO4	NANO5
Joint publications with spin-off company	Minor	None
Joint patent applications with spin-off company	None	Minor
Former research staff of the research department employed by spin-off company	Minor	None
Personnel simultaneously affiliated to spin-off company and research department	None	Minor
Bachelor and master theses supported by spin-off company	Substantial	Major
Test data, facilities, instruments and prototypes obtained from spin-off company	Substantial	Minor
Monetary Resources		
Contract research commissioned by spin-off company	Minor	None
Jointly acquired government-funded research projects	Minor	None
Financial support of PhD research projects	None	None
Does research institute or its staff own capital stock of spin-off company?	Yes	Yes
Funds from spin-off company in exchange for knowledge from research department	None	None
Donations received from spin-off company	None	None

Looking specifically at the relationship with NANO4, we found that the relationship was of a low to medium intensity. Over time, the relationship with NANO4 slightly decreased in intensity and, overall, the relationship of NanoLab 2 with NANO4 was more intense than the relationship between NanoLab 1 and the spin-off company. While formal collaboration between NanoLab 2 and NANO4 in research projects was relatively limited, informal exchanges of knowledge and materials was frequent. The company and the department collaborated in two STW research projects. Respondents indicated that, on several occasions, the research department received chips from NANO4 to use in its research projects. In addition, NANO4 supported approximately two to three students from NanoLab 2 with their thesis projects at any one time. The company utilised the expertise of these students to conduct research and development activities. The use of bachelor and master students allowed NANO4 to have access to the state-of-the-art knowledge of the research department for an insignificant amount of monetary resources. At the same time, it enabled the company to increase its steering capacity and to have control over the knowledge that was produced (NANO4.1). In the STW projects, the spin-off company has far less ability to influence the research projects of the research department (NANO4.1). The research department is consulted in the design of chips for customers of NANO4. The company directly funded applied research projects of no more than *"a few thousand Euros"* each (NANO4.1). This amount of contract research was very small in comparison to the total research budget of NanoLab 2. Two researchers from the research department moved to NANO4 and at least three students of the research department started working for the spin-off company after graduation. The spin-off company produced chips that were used by NanoLab 2 and at least two joint publications were produced.

The potential for collaboration with NANO5 was limited because the spin-off had been created relatively recently. The intensity of the relationship with NanoLab 2 was low and occurred through informal interactions outside government research projects. The spin-off company was located in the same building and on the same floor as the research department. The relationship between NanoLab 2 and NANO5 consisted of informal exchanges of information and materials, and through the support of bachelor and master thesis projects. NANO5 utilised student projects as a medium to develop its products and to acquire knowledge from the research department since its monetary resources were limited and students provided a low cost way of acquiring state of the art knowledge from the department (NANO5.1). So far eight student projects have been supervised by the spin-off company. No joint publications were produced, nor has NANO5 commissioned contract research at the research department or participated in government-funded research projects with NanoLab 2.

Looking at the role of the funding environment in supporting the relationships, we can see that funding instruments that support science-industry relationships have not contributed to more intense relationships between NanoLab 2 and its spin-off companies. The bulk of the interactions between the spin-off companies and the department occurred through informal interactions. In the two government projects in which NANO4 participated, collaboration was limited.

10.3.6 Impacts on the research portfolio

The relationships with NANO4 and NANO5 had a very limited impact on the research portfolio of NanoLab 2. Spin-off companies were regarded as entities that showed that the research department was successful in creating societally relevant knowledge. However, since the spin-off companies did not have significant monetary resources at their disposal, and participated in only a few government-funded research projects, both the resources for research and the research agenda were hardly affected. The resources that the research department draws from these relationships are access to information and equipment such as computer chips which facilitate the research department in keeping up with developments in industry. The spin-off companies helped the research department to formulate new research questions, which inspired the research agenda. Research quality was not affected but was driven by the excellence of the research staff and their ability to acquire funding for basic research projects from NWO and FOM, as well projects from STW and Senternovem that included industry. NANO4 and NANO5 made up a small part of the environment of the department, and the department relied far more on other organisations for research funding. The spin-off companies did benefit the image of the department and made it easier to show to funding agencies that their research activities would provide relevant outcomes for society. The department also benefitted from the spin-off companies by outsourcing part of the chip development activities of the department, which enabled the department to focus on its research activities.

10.3.6.1 Resources for research

In this section, we discuss whether the relationships with NANO4 and NANO5 have led to changes in the number of contacts with industrial research partners, changes in income from industry or changes in the income from national government agencies and international funding agencies.

The relationships with NANO4 and NANO5 did not lead to an increase in contacts with industry. The research department already had a well-developed network of companies with whom it collaborated in various projects that were funded by STW and SenterNovem. The industrial research partners of the research department were attracted to NanoLab 2 because of its scientific quality and its research themes (NL2.2) In the long term, however, the spin-off companies could contribute modestly to the contacts with other industrial research partners (NANO4.1) Further development of the spin-offs may lead to contacts and, as a result of that, additional funding may be acquired from other companies.

The spin-offs made small contributions to the research capacity of NanoLab 2, which were insignificant in comparison to the overall research budget. *"There are not that many spin-offs that start a research project at the university. What you do see is that they put forward their questions. The communication lines are very short, also because people share the facilities a lot, and you can talk to the people on the lab floor."*(NL0.1) Contributions from other industrial partners did not change because of the relationships with the spin-off companies. The spin-off companies did not add contacts to the network of the department and, as a result, no additional funding capacity was attracted from other companies.

The relationships with NANO4 and NANO5 did have an impact on the income from national government agencies and international funding agencies. However, participation by the spin-offs in government projects had no impact. Only NANO4 collaborated with NanoLab 2 in government-funded research projects. Between 1999 and 2004, 23 research projects were funded by STW, FOM, the EU and SenterNovem, while 8 research projects were also co-funded by private companies. NANO4 participated in only two of these research projects. As such, the two projects in which the spin-offs participated were a very small part of the total portfolio. NANO4 was asked to participate in project proposals because STW values an industrial presence, and especially of SMEs. Within the framework of the two STW projects, NANO4 legitimised the acquisition of research funding. "[NANO4] *was involved because we asked them. We had a project where we had to have an SME so we asked someone we knew."*(NL2.2) What was very important for the department was the fact that its contribution to the creation of two spin-off companies helped to convince funding agencies that societally relevant knowledge was being created at NanoLab 2. *"We use the companies for STW proposals as a positive thing. We show that there are spin-offs that came from [NanoLab] research departments to show that we are also focused on generating applications."*(NL2.2) The leader of NanoLab 2 stated that NANO4 and NANO5 were beneficial for the reputation of the research department. This translated into the acquisition of research projects in which the spin-off companies themselves did not participate. *"I think that valorisation activities are good for the image of our group and, because of that, we are granted more projects.* I*t has been easier to acquire research funding because we have the reputation that we are able to valorise research."*(NL2.1) So, the scientific excellence of the department and its ability to do well in the area of knowledge transfer was beneficial for its research capacity. The department was able to acquire additional research projects for both basic research projects and projects that involve industry (Figure 10.3).

10.3.6.2 Research agenda

Overall, the research themes covered by NanoLab 2 were not affected by the relationships with the spin-off companies (NL2.1, NL2.2, NANO4.1, NANO5.1). *"There were a couple of projects on sensors, market-oriented ones, but the focus of the department on sensors was already there."*(NANO5.1) The research themes that NanoLab 2 engaged in with the spin-off companies were a natural part of the themes covered by the research department. The relationships with the spin-off companies were also insignificant in comparison to the total research portfolio of the research department (NL2.2). In the projects in which NANO4 participated, the spin-off had only a limited ability to influence activities because, ultimately, the researchers of NanoLab 2 had the final decision over the direction of the research projects, and multiple companies participated in the research projects. In the long term, the relationships with the spin-off companies are bound to create small changes. Informal contacts, knowledge transfer in bachelor and master student projects, and collaboration in research projects provided researchers of NanoLab 2 with information on problems that the companies were confronted with. These problems were relevant for the research department since they were used as inspiration for research proposals. *"In addition to the fact that you need companies for financing your research, companies show you what they are interested in and thereby steer our research. In meetings with companies, I often find out that I have a wrong idea about what their problems are and what they need. Companies play an essential role. It's a mirror. Without those companies I would probably have had less focus."*(NL2.2)

Relationships with NANO4 and NANO5 did not lead to significant changes in the balance between basic and applied research. The research department engaged in basic research projects, as well as projects with a more applied character in which it collaborated with industrial research partners. The spin-off companies, like other industrial research partners, were able to participate in research projects, but the research department did not engage in more applied research activities as a result. The spin-offs were important for the department, but after the creation of the companies, the attention of the department shifted back to research activities. *"The leader of [NanoLab 2] has ideas and he develops them and a spin-off evolved from that. And if that company is successful it might have a small impact on the research activities. However, the attitude is; ok we did that and now we move on."*(NL0.1) The research department remained focussed on its research activities because they are central to its success and the basis for its long-term survival. The support structures of the university also helped in remaining focused on its core activities. *"The university has all kinds of organisations who support and advise people. That's a good thing because we can focus on the things we are good at: the scientific part."*(NL2.1)

10.3.6.3 Research output

In this section, we report on the effects of the relationships with NANO4 and NANO5 on the number of scientific publications, other research outputs and research quality.

The relationships with NANO4 and NANO5 did not contribute to the publication output of the research department. The department grew dramatically from 1996 onwards. Changes in the research output of the department roughly held pace with the fluctuations in the research budget of the department (Figures 10.3 and 10.4). Publishing was regarded as an academic activity and NANO4 contributed insignificantly to the publications of the department. Further, the resources from the spin-off companies were very limited in comparison to the total set of activities and, as a result, no impacts were reported on the creation of scientific publications, an activity considered a core interest of the department.

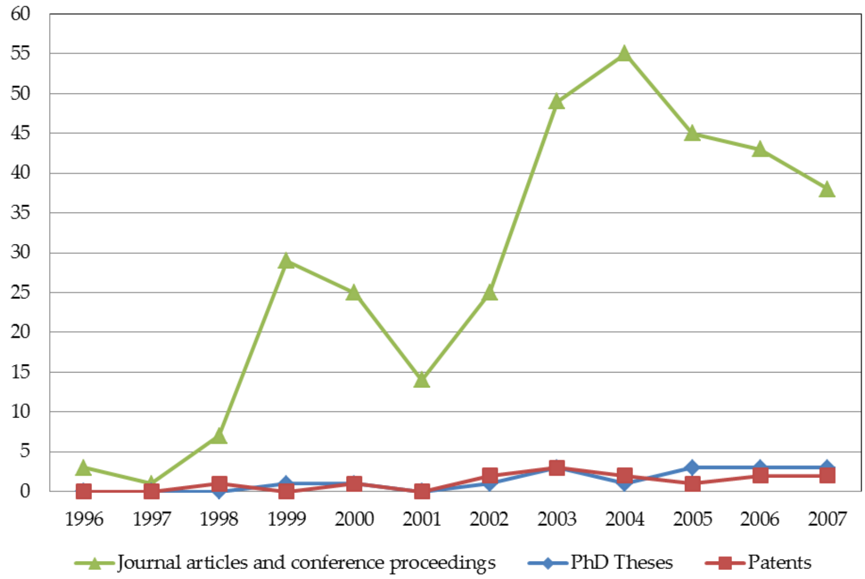


Figure 10.4. Research output of NanoLab 2, 1996-2007

Research quality was also not affected. NanoLab 2 received two research assessments and in both research assessments the department was found to have an 'excellent' research quality.[53] The department was praised for its excellent basic research with societal relevance and its ability to attract *"substantial funding"*.[54] The research quality of the department was based on its staff and their ability to attract funding for basic research activities. The relationships with the spin-off companies were important, but occurred on the periphery of the research activities of the department. Research activities were inspired by the spin-offs and other companies but they did not contribute expertise to the department. Interestingly, the last research assessment encouraged NanoLab 2 to increase its relationships with industrial research partners and to increase the number of spin-offs to validate scientific research.[55] The leader of the research department on the other hand, regards research as the single most important aspect and of vital importance to the success of the research department. *"The last report stated that we needed to increase our valorisation activities. But to what extent does that influence the*

[53] Research assessment NanoLab 2 1994-1998, VSNU and research assessment NanoLab 2 1999-2004, QANU.
[54] Research assessment NanoLab 2 1994-1998, VSNU.
[55] Research assessment NanoLab 2 1999-2004, QANU.

department? I think that it is not significant. We are willing to collaborate with industry and to valorise knowledge but we always do research and not development work."(NL2.1)

The production of other research outputs, such as patent applications and prototypes, did not increase because of relationships with NANO4 and NANO5. From 1998 onwards, the research department applied for 14 patents. After 2002, patent applications increased approximately from one patent application to two annually. Joint development of patents with industrial research partners did not occur on a frequent basis. NANO5 engaged in only one patent application together with the department. Respondents indicated that the patenting activities fitted with the activities of the department and that the spin-off companies did not influence the norms of the department in this respect.

Instead of focussing the activities of the department on producing other types of research output, the spin-offs actually enabled the department to outsource certain development activities that it preferred not to engage in. *"When it is experimental, I first make a chip of my own. That involves a lot of research to get it working. And we publish that. After that we sometimes need a hundred of those chips and that I occasionally outsource. It costs us manpower and you can't write publications based on it. This kind of work is now directed to a spin-off. Outsourcing costs us some money but it keeps us focussed on research."*(NL2.2) So, the spin-off companies helped the research department to focus on its research activities since the spin-off companies could engage in development work for the research department.

11 Comparative analysis

In this chapter we compare the empirical material that was presented in the previous five chapters. We first discuss the environment of the investigated research departments and pay particular attention to the motivations of public research organisations to support the creation of spin-off companies. Subsequently, we compare the relationships between research departments and spin-off companies, and the impacts of these relationships on the research portfolios of the research departments. At the end of this chapter, we will revisit the propositions that were postulated in Section 3.6.

In the empirical chapters we dealt with five research institutes: MedLab, PharmLab, ICTInstitute, ICTLab and NanoLab, and eight of their research departments. The research departments were referred to as MedLab 1, MedLab 2, PharmLab 1, etc. In total, 16 relationships between 8 research departments and 15 spin-off companies were investigated.[56] The spin-off companies of the research departments were categorised as either biomedicine, computer science or nanoscience and technology companies. We referred to them as BIO1, BIO2, ICT1, NANO1, etc. A detailed explanation of the sampling logic, the data collection and the data analysis can be found in Sections 4.3 and 4.4.

11.1 The support of spin-off companies by public research organisations: motivations and responses

The data that are presented in this study shows that public research organisations in the Netherlands have responded to demands in their environment to engage in knowledge transfer activities. They responded to these demands, among other ways, by creating support structures for spin-off companies. We showed, in Chapter 5, that the norms in the environment of public research organisations have increasingly stressed involvement in knowledge transfer and commercialisation. Policymakers in the Netherlands started to introduce funding instruments, from the 1980s onwards, that encouraged public research organisations to engage in such activities. As a result of an environment

[56] One of the investigated spin-off companies maintained relationships with two of the selected research departments.

in which norms changed, and in which incentives were provided to engage in knowledge transfer activities, the overwhelming majority of public research organisations started to offer various types of support for the creation of spin-off companies. Between 1996 and 2005, a large majority of public research organisations started, or had already started, to support the creation of spin-off companies. We believe the support for spin-off companies by public research organisations in the Netherlands was an isomorphic process. The creation by public research organisations of support structures for spin-off companies occurred for two reasons. For public research organisations, the creation of support structures, and the spin-off companies they helped to create, were clear and appealing examples that could show that the public research organisations were acting in good faith and adhering to the dominant norms in their environment. When it became clear that the creation of support structures for commercialisation activities by public research organisations had become a legitimate activity, with some public research organisations already having created technology transfer support structures, the bulk of the public research organisations in the Netherlands followed suit (cf. Figure 5.3). This isomorphic process of creating support structures for spin-off companies was facilitated by the character of these support structures. Most technology transfer support structures operated relatively independently from the research activities of public research organisations, i.e., they would not interfere in the daily activities of the researchers at the public research organisations. This substantially limited the risks of internal conflicts and tensions, and made it rather unproblematic for public research organisations to introduce these support structures.

When looking at the public research organisations in our study, we conclude from the interviews with their representatives that the types of motivations to start supporting the creation of spin-off companies correspond with the findings of van Tilburg and Kreijen (2003). Based on the theoretical framework that was introduced in this thesis, we can conclude that both resource-based motivations as well as institutional motivations played a role in supporting spin-off companies although institutional motivations appear to dominate (Section 5.4).

Table 11.1 displays the various motivations for the research institutes to start supporting spin-off companies and shows whether they were relatively early or late in creating their support structures. The provision of spin-off support activities by three research institutes, MedLab, PharmLab and especially the ICTInstitute, can be characterised as responses to changing norms in their environment. The two other research institutes, ICTLab and NanoLab, were much earlier in creating support structures for spin-offs and displayed resource-based as well as institutional motivations.

Table 11.1. Motivations of the selected research institutes in supporting the creation of spin-off companies.

Name of the research institute	**Main motivations for engaging in the support of spin-off companies**	**1st year of spin-off support**
MedLab (Comprehensive research university)	Not to be out of step with other public research organisations. Showing that research at the medical centre has societal relevance.	1996
PharmLab (Comprehensive research university)	To show that research of the institute is societally relevant. Organisations in its environment demanded a re-specification of the activities of the research institute.	1998
ICTInstitute	Changing norms in the environment triggered the research institute to show to its main sponsor that it too was engaging in research with societal relevance.	2000
ICTLab (Technical University)	Creating research partners that could provide resources. To follow its mission to contribute to the development of the regional economy.	1984
NanoLab (Technical University)	Creating research partners that could provide resources. To follow its mission to contribute to the development of the regional economy.	1984

The Technical University, and its two research institutes, NanoLab and ICTLab, had clear resource-based motivations for engaging in the support of spin-off companies. Located in a region without a substantial high-tech industry, the university created support structures to encourage the creation of new high-tech enterprises. In so doing, it was a frontrunner in the Netherlands. The idea was that these companies would be able to become research partners of the university and invest in research activities. The university managed to create a large number of spin-off companies. However, institutional motivations to create support structures also played a role. In the formation of the university it was stipulated that the university was expected, by its sponsors, to contribute to the economy of the region. Thus, the support of private enterprises was also motivated by a desire to meet the expectations of policymakers who had sanctioned the creation of the university. Disregarding the regional function of the university would have damaged the legitimacy of the Technical University.

MedLab, PharmLab and ICTInstitute were largely motivated to start supporting spin-off companies because they had noticed that organisations in their environment had started to pay increasing attention to the societal relevance of scientific research. MedLab and PharmLab followed the majority of public research organisations in the Netherlands by creating support structures, while the ICTInstitute was relatively late in creating support structures. The mission of these organisations stresses basic research over applied research and this can be regarded as the main explanation why they were not among the first research organisations in the Netherlands support research commercialisation. Traditionally, these research institutes had been successful in acquiring funding from research councils that primarily funded basic research. Before the 1990s, there was little incentive to support commercialisation activities such as spin-off companies because their principal sources of funding did not expect them to interact with industry. Before 1990, the prevailing belief within these organisations was that scientific researchers should engage in basic research and education, rather than devoting valuable resources to commercialisation and innovation. During the 1990s, these three research institutes attempted to maintain their basic research profiles while accommodating processes in their environment that called for engagement in knowledge transfer and commercialisation. The responses of MedLab, PharmLab and ICTInstitute should be seen as an adaptation to processes in the Dutch research system that required public research organisations to show that they were engaging in knowledge transfer. These research institutes were mainly motivated by a need to maintain their legitimacy in an environment that increasingly expected public research organisations to complement their missions with commercialisation activities. In the case of PharmLab we found that, at a later stage, resource-based motivations, i.e., enhancing relationships with industry and attracting additional funding, became an important motivation in further developing support structures.

11.2 The environments of the research departments

One of the aims of this study has been to understand the role of the environment of research departments in the establishment of relationships between research departments and industry. In order to understand the role of the environment, we compare the characteristics of the immediate organisational environment, i.e., the larger organisation that the research departments are part of, and the external environment, i.e., government agencies that provide project-based research funding to the departments. Table 11.2 provides an overview of the environments of the eight research departments.[57]

The immediate organisational environment of a research department may affect its propensity to engage in relationships with spin-off companies. The (funding) structure of the direct organisational environment may also affect the extent to which research departments are affected by demands from external organisations, such as research funding agencies, evaluation committees, industry and spin-off companies. In the Netherlands, research departments receive part of their funding from the larger organisational unit they are part of. Such so-called institutional funding may act as a buffer to demands from external organisations. For instance, research departments that receive large amounts of non-earmarked institutional funding have considerable freedom to set their own research agendas.[58] We found, however, that the trend in all the research institutes was to make institutional funding increasingly dependent on the ability of research departments to acquire external funding. So, non-earmarked institutional funding decreased, making research departments more dependent on their ability to acquire external research funding. In addition, strategic budgets were used for co-funding externally financed research projects when sponsors only paid part of the full cost of research. The result of this was that research departments were encouraged to acquire additional external funding to finance their research portfolios. Moreover, diminishing non-earmarked institutional funding decreased the ability of research departments to buffer external demands. ICTLab and NanoLab, both part of the Technical University, were the two research institutes where the research departments received the least amount of non-earmarked institutional funding. From 2002 onwards, departments in these institutes started to receive institutional funding primarily on the basis of achievements such as the acquisition of government funding and the number of publications and patents.[59] In such an environment, the ability to conduct scientific research becomes dependent on the ability of research departments to persuade external

[57] This table is based on the descriptions of the environments of the research departments in the period 1990 to 2007 in Chapters 6 to 10.

[58] Earmarked institutional funding, as opposed to non-earmarked institutional funding, concerns institutional funding whose acquisition and use are not free but depend upon criteria such as the acquisition of external funding.

[59] NanoLab 2 is an exception here because it was able to acquire strategic budgets from the NanoLab institute.

organisations to provide them with resources. Research departments in MedLab, PharmLab and ICTLab received somewhat more non-earmarked institutional funding. However, in these research institutes, non-earmarked institutional funding also decreased in favour of institutional budgets that were dedicated to co-finance externally funded research projects.

Looking at the differences between the research departments and their immediate organisational environments we see the following. The universities in which the investigated biomedical research departments reside, have traditionally emphasised basic research. This changed, especially during the 1990s, when engagement in knowledge transfer activities and commercialisation activities became more important. At the time of our data collection, the MedLab research institute still lacked extensive research commercialisation support structures. The PharmLab research institute, on the other hand, did create institutional support for research commercialisation. ICTInstitute 1 was relatively unique compared to the other research departments since it was part of an NWO-funded research institute. The research institute had a basic research focus and did not have elaborate structures to support research commercialisation. ICTLab and NanoLab, in comparison, were part of the Technical University, and thus had a long standing tradition of supporting commercialisation activities. The support structures of the Technical University, and its research institutes, were well-developed. In their missions, the research institutes paid explicit attention to the commercialisation of their research activities, specifically the creation of spin-off companies. This indicates that the organisational environment of the ICTLab and NanoLab departments was very supportive of collaboration with industry.

Table 11.2. Overview of the environments of the research departments.

Research institute **Research department**	Scientific focus of the institute	Attention to commercialisation in the mission of the institute	Extent of knowledge transfer support by the institute	Principal external research funders
MedLab				
MedLab 1	Basic research	Small	Minor	ZonMW, STW, Charities, Industry, TIPharma
MedLab 2	Basic research	Small	Minor	ZonMW, STW, SenterNovem, TIPharma, Industry
PharmLab				
PharmLab 1	Basic research	Small	Medium	STW, NWO, TIPharma, Industry
ICTInstitute				
ICTInstitute 1	Basic research	Small	Minor	NWO, SenterNovem, EU, Telematics Institute
ICTLab				
ICTLab 1	Mostly applied	Large	Major	STW, Senternovem, EU, NWO
ICTLab 2	Mostly applied	Large	Major	STW, EU, Industry, NWO
NanoLab				
NanoLab 1	Basic & applied	Large	Major	STW, SenterNovem, EU
NanoLab 2	Basic & applied	Large	Major	STW, NWO, SenterNovem, EU, FOM

Looking at the external sources of research funding, we see that the investigated research departments received external research funding from several different organisations. The most important funding sources of each of the research departments are displayed in Table 11.2 in order of decreasing importance. Overall, the research departments received most of their external funding from STW, SenterNovem, the EU and NWO. Research funding was also acquired from ZonMW, charities, industry and FOM. A considerable proportion of the funding environment of the research departments consisted of research funding organisations that preferred research departments to involve industry in research projects. As a result, research departments had a significantly lower chance of acquiring research funding if they did not include industrial research partners, and were therefore interested in attracting industry to their funding proposals. This meant that spin-off companies, which were often personally, geographically and cognitively close to their parent research departments, were potentially valuable research partners for these research departments. Moreover, government agencies have made no secret of their love for research-based spin-off companies, entities that epitomise commercialisation of research and knowledge transfer (Jongbloed & Zomer, 2011). This has made them even more valuable for the departments in legitimising the acquisition of government-funded research projects.

For the biomedical research departments, MedLab 1 and 2, and PharmLab 1, a range of organisations provided external funding. NWO and ZonMW, a subsidiary of NWO, as well as STW, charities, SenterNovem, the EU and industry were all important sources of funding. Although NWO and ZonMW have increasingly preferred research proposals that show clinical relevance, they do not require industry to be part of project proposals. The other sources of research funding, TI Pharma, STW, SenterNovem and industry, imply or explicitly require industrial participation in research proposals and projects. The computer science and nanoscience and technology departments relied mostly on STW, SenterNovem and EU subsidies, while NWO also provided funding. Looking at the government research funding of the computer science and nanoscience and technology research departments, ICTInstitute 1 and NanoLab 2 received significant funding from NOW, whereas the other research departments, ICTLab 1, ICTLab 2 and NanoLab 1 were predominantly dependent on research funding from STW, SenterNovem and the EU.

Industrial research partners were important sources of research funding for the biomedical research departments. For the computer science and nanoscience and technology research departments, industry was not a principal source of research funding. The companies that collaborated with the computer science and nanoscience and technology research departments were, on average, much smaller and did not have significant research budgets or research interests that required research projects with long time horizons.

11.3 Relationships between research departments and their spin-off companies

We now compare the types and the intensities of the relationships between the research departments and their spin-off companies. Tables 11.3 and 11.4 provide an overview of the relationships.[60] The tables are based on the data that were presented in Chapters 6 to 10.[61]

We found that in all cases the research departments maintained relationships with their spin-off companies for some time. All but a few respondents, from both the research departments and the spin-off companies, expressed their interest in maintaining relationships with each other. Overall, the interests of the departments matched quite well with the knowledge-intensive character of the product development activities undertaken by the spin-offs.. The main reason for the overlap is the fact that the companies originated from research that was being conducted at the research departments. Further, personal relationships were well-developed since, in most cases, some of the researchers of the research departments migrated to the spin-off companies. This facilitated relationships between the research departments and their spin-off companies.

11.3.1 General observations

While most relationships were of a rather modest intensity, some spin-off companies maintained intensive contacts and invested substantial amounts of monetary resources in the research departments from which they originated. The creation of a spin-off company in all cases led to informal relationships where test data, facilities and instruments, or prototypes, were exchanged or shared (Table 11.3). This was supported by informal meetings between employees of the departments and the spin-offs. For the research departments, informal contacts serve as a ‘reality check’ to inform researchers about the relevance of their

[60] These tables are an updated version of the tables presented in (Zomer et al., 2010).
[61] The method of data aggregation is explained in Section 4.4.

research interests for industrial organisations and the feasibility of their potential solutions.

Table 11.3. Intensity of the exchanges of information, people and physical resources between the research departments and their spin-off companies[62]

Spin-off company	Joint publications	Joint patent applications	Research staff employed by spin-off company	Personnel with simultaneous affiliations	Bachelor and master theses supported by spin-off company	Test data, facilities, instruments and prototypes obtained from spin-off company
BIO1	+++	++	+++	+	0	+++
BIO2	0	++	0	+	0	+
BIO3	0	0	+	+	0	+
BIO4	++	++	++	+	0	++
ICT1	+	0	+++	0	0	+
ICT2	++	0	+	0	0	++
ICT3	0	0	+	0	++	+
ICT4	0	0	0	0	+	+
ICT5	++	0	+	++	++	+++
ICT6	++	0	+	+	+	++
NANO1	0	0	+	0	+	+
NANO2	+	0	0	0	+	++
NANO3	++	0	+	+	<missing>	+
NANO4 (NL1)	+	+	+	+	0	++
NANO4 (NL2)	+	0	+	0	++	++
NANO5	0	+	0	+	+++	+

0 = no exchange occurred, + = minor intensity, ++ = significant intensity, +++ major intensity

We found that most spin-off companies engaged in joint publications with research departments, and that personnel from the departments migrated to the spin-off companies (Table 11.3). Some spin-off companies provided research departments with contract research projects. However, none of the companies donated money to the departments they originated from (Table 11.4). Most respondents from the spin-off companies and the departments stated that a lot of goodwill existed between the spin-offs and the departments. Providing favours to

[62] NANO4 maintained relationships with both NanoLab 1 and NanoLab 2. Hence the two rows.

each other included being able to freely use each other's research equipment, giving access to materials and prototypes, testing, sharing developments in research projects and sharing new ideas and problems that spin-off companies and the research departments faced in their research and development activities.

In most cases, researchers of the department or the research institute held shares in the spin-off company (Table 11.4). This created a formal linkage between the spin-off company and the research department. In cases where no capital stock was owned, the policies of the research institutes and universities appear to have played a large role. Research institutes in our sample particularly started to pay attention to ownership of capital stock in companies after 1995. The Comprehensive Research University created a holding company in 1996 while the holding company of the Technical University did not start owning capital stock until after 2000. The spin-offs ICT 3 and 4 were created rather independently of the research activities of the research departments, which explains the absence of capital stock ownership. The ICTInstitute, which was relatively late in creating knowledge transfer structures, dealt with capital stock ownership on an ad hoc basis prior to 2000.

In terms of contract research commissioned by spin-off companies, most spin-off companies are not interesting for research departments (Table 11.4). Spin-off companies, especially early in their existence, are very much pre-occupied with attracting sufficient monetary resources to ensure their own survival. Most of the time, the spin-off companies are depending on the research departments and research institutes to provide them with advice, technical support and facilities during the early stages of their existence. In biomedicine however, we found that the research departments were able to acquire substantial to large amounts of contract research (Table 11.4). Except for the biomedical departments, support for PhD research projects was almost entirely absent. This indicates that smaller, less affluent spin-off companies do not invest in long-term research projects. Despite this, the funding of PhD research projects is very valuable for research departments since PhD research projects are long-term projects that allow the departments to create valuable research outputs and focus on basic research.

Table 11.4. Intensity of the exchanges of monetary resources and legitimacy between the research departments and their spin-off companies

Spin-off company	Contract research commissioned by spin-off company	Jointly acquired government-funded research projects	Financial support of PhD projects	Does research institute or its staff own capital stock of spin-off company?	Funds from spin-off company in exchange for knowledge from research department	Donations received
BIO1	+++	+	+++	Yes	0	0
BIO2	+++	+++	+++	Yes	+++	0
BIO3	0	+	0	Yes	0	0
BIO4	++	+++	++	No	++	0
ICT1	0	+	0	Yes	0	0
ICT2	0	+	0	Yes	0	0
ICT3	0	+	0	No	0	0
ICT4	0	0	0	No	0	0
ICT5	+	++	+	Yes	0	0
ICT6	0	+	0	Yes	0	0
NANO1	+	++	0	No	0	0
NANO2	+	+	0	No	0	0
NANO3	0	++	0	No	0	0
NANO4 (NL1)	0	++	0	Yes	0	0
NANO4 (NL2)	+	+	0	Yes	0	0
NANO5	0	0	0	Yes	0	0

0 = no exchange occurred, + = minor intensity, ++ = significant intensity, +++ major intensity

Government funding was widely by spin-off companies and research departments to intensify their relationships. Most spin-off companies lacked the resources to directly commission large research projects. Government funding allowed spin-off companies to participate in research projects without having to invest monetary resources in the research departments they originated from. Almost all spin-off companies collaborated with their parent research departments in government-funded research projects (Table 11.4). Only two spin-off companies did not participate in such research projects. NANO5 had not participated in government-funded research projects because it had existed for less than a year, while collaboration between ICT4 and the ICTLab 1 research department in government-funded projects had been proposed but not funded. Eight out of the fifteen spin-off companies engaged in up to three government-funded research projects, while five spin-off companies had engaged in at least four government-funded research projects prior to 2007. All the government projects in which the spin-off companies had participated with the departments had required an industrial research partner. As such, the spin-off companies enabled the acquisition of research funding by the department. However, to meet this condition, research departments could also have used other industrial research partners. Nevertheless, since the spin-off companies are cognitively as well as personally closer to the research departments, they are attractive research partners for the departments when it comes to applying for government-funded research projects.

In this study, we are specifically interested to what extent the environment and the scientific fields in which the research departments reside affect the relationships they maintain with their spin-off companies. We found that the relationships differ by scientific field. Overall, the biomedical research departments' relationships with their spin-off companies were of a higher intensity than those of the computer science and nanoscience and technology research departments. The differences appear to arise mainly from the different characteristics of the spin-off companies in the various scientific fields. Intrinsic field characteristics, such as research costs and dependence on research equipment, may also have had an impact on the relationships. The organisational environment does not appear to significantly affect the relationships between the research departments and their spin-off companies. In the subsequent sections we will address these issues in greater dept.

11.3.2 Relationships in biomedicine

The relationships of the biomedical departments with spin-offs BIO1, BIO2 and BIO4 were the most intensive in our study. BIO3 is a relatively young and small spin-off company that had neither the time, nor the personnel and resources, to engage in intensive relationships. Except for BIO3, the biomedical spin-off companies were relatively large, with significant R&D budgets, compared with the smaller and less affluent computer science and nanoscience and technology spin-off companies. Given their size, the biomedical spin-off companies had the capacity to absorb knowledge more effectively. The companies were also interested in long-term basic research. As a result of the matching preferences and the large research budgets of BIO1, BIO2 and BIO4, intensive relationships between the spin-off companies and the research departments were established. These spin-off companies accounted for three of the four companies in our sample that did provide financial support for PhD research projects (Table 11.4). This is a clear sign that, more than in the other research fields, biomedical spin-off companies were willing to directly finance research activities with a long-term and more basic research focus in research departments. Only one other company, ICT5, provided financial support for PhD research projects as well. BIO1, BIO2, and BIO4 commissioned several large contract research projects, which is rather unique in our sample (Table 11.4). The biomedical research departments and their spin-off companies were also very successful in acquiring government projects (Table 11.4). Only in the biomedical research departments did we find that departments had received money from spin-off companies in exchange for their knowledge (Table 11.4). BIO2 and BIO4 possessed the monetary resources to acquire patents that were owned by the research departments. BIO1 commissioned contract research based on an agreement that it would own the knowledge from the research projects.

Given the fact that most biomedical companies in our sample have large R&D budgets and have personnel with academic training, one would expect that joint publications would occur frequently. However, BIO2 and BIO3 did not report joint publications because BIO2 did not conduct development activities and BIO3 had existed for only a short time. Co-patenting occurred with three of the four spin-off companies, which is a high proportion in comparison with the other scientific fields in this study (Table 11.3). In all the biomedical cases we found personnel with simultaneous affiliations to the spin-off companies and to the research departments. Support of bachelor and master theses on the other hand did not occur at any of the biomedical research departments (Table 11.3). Respondents from the spin-off companies attributed the absence of such support to the nature of their research and development activities, which often involved expensive research facilities.

11.3.3 Relationships in computer science

The relationships between computer science research departments and their spin-off offs were much less intense. The computer science spin-off companies in our sample were companies of relatively modest size, with a strong preference for short-term R&D, and with budgets far more limited than those of the biomedical spin-off companies. The computer science research departments regarded the spin-off companies as potential research partners but, at the same time, maintained contacts with numerous other industrial organisations as well. None of the spin-off companies contributed significant amounts of monetary resources to the research portfolios of the research departments, neither directly nor indirectly through participation in government-funded research projects (Table 11.4). Only one spin-off company financed part of a PhD research project. Overall, the computer science spin-off companies were not convinced that commissioning contract research projects to the research departments would yield results that would be useful in the short-term. For the ICTLab research departments, collaboration through bachelor and master theses of students was an important, inexpensive and easy form of knowledge transfer (Table 11.3). Supporting bachelor and master theses provided the spin-off companies with direct access to the latest developments in the research departments while the students would take part in translating research outcomes into knowledge that would be directly relevant for the spin-off companies. The mission of the ICTInstitute limited the relationships between ICTInstitute 1 and ICT1 and ICT2 in this respect since the research institute does not engage in education, and hence lack of interaction in this respect. Four of the six ICT spin-off companies co-published with the research departments from which they originated (Table 11.3). The joint publications occurred because some of the employees coming from academia continued to be interested in contributing to academic papers. The companies as such, however, were mostly not that interested in producing publications.

The relationships of ICTInstitute 1 and ICTLab 1 with their spin-off companies can be characterised as rather detached. The spin-off companies benefitted to some extent from knowledge produced in the research departments, but most of the spin-off companies were focussed on product development. The knowledge that was developed at the research departments from which they originated was not vital for their survival and therefore the relationships were of a low intensity, and had a rather loose character. The spin-off companies of ICTLab 2, on the other hand, were more interested in scientific developments. Further, ICTLab 2 personnel maintained simultaneous affiliations with ICT5 and ICT6, while ICTInstitute 1 and ICTLab 1 did not have such connections.

11.3.4 Relationships in nanoscience and technology

The relationships in the nanoscience and technology research departments were more intense than in the computer science research departments. However, the relationships were viewed as not significant in terms of the direct resources they provided to the research departments (Table 11.4). We found that three companies made small financial contributions, but this support was not sufficient to fund PhD or postdoc positions (Table 11.4). The largest amount of funding that was obtained by a research department from a spin-off company was €10,000. As with the computer science spin-off companies, all but one of the companies focused on short-term development activities and did not possess significant research budgets. By participating in at least 16 government-funded research projects, spin-off companies from NanoLab 1 legitimised government funding and thereby contributed significantly to the research capacity of the department. NanoLab 2 spin-off companies, on the other hand, participated in only two government projects, making their role much less significant in terms of providing access to government funding.

In the two nanoscience and technology departments, personal relationships were well-developed and informal exchanges occurred frequently in the laboratories where NanoLab 1 and 2, and the spin-off companies, conducted experiments and created computer chips (Table 11.3). These informal encounters were valued by both the research departments and the spin-off companies. In addition to the exchanges of information that arose from interactions, the spin-off companies paid for access to the laboratory of NanoLab. These contributions have significantly reduced the operating costs to be shouldered by the research departments. Four of the five investigated NANO spin-off companies co-published with the research departments from which they originated (Table 11.3). Mostly, these few joint publications amounted to former research staff of a research department contributed to publishing an article. NANO3 was an exception: this spin-off company contributed to at least ten publications because of the academic aspirations of its CEO. At least four of the five NANO spin-off companies supported bachelor and master theses of students from the research departments (Table 11.3). Similar to the computer science companies, the nanoscience and technology companies used the support of bachelor and master students to gain access to the departments. Supporting such projects was attractive for the companies since it was relatively inexpensive, while the students translated the knowledge of the departments into directly applicable knowledge.

11.3.5 Conclusions

Most spin-off companies do not directly contribute significant amounts of resources to the research departments from which they originated. Informal relationships between the research departments and the spin-off companies were valued by most respondents as they provided both types of organisations with information on new developments and solutions to technical or scientific issues. Government-funded research projects that involved spin-off companies were a common feature in the research departments' research activities. The participation of the spin-off companies in such projects legitimised the acquisition of the projects. However, participation in government-funded research projects would not necessarily lead to more knowledge transfer activities. Mostly, the relationships in government-funded research projects would be rather loose, and research departments and spin-off companies would update each other on progress that was made during the project.

Across the scientific fields, the relationships differed. Given the their relatively large R&D budgets, biomedical spin-off companies were able to commission some large contract research projects. They also legitimised government-funded research projects that significantly contributed to the research capacities of the biomedical research departments. The computer science and nanoscience and technology research departments were not able to benefit from their offspring to the same extent. More often, the spin-off companies in this field themselves were in need of money and other resources to survive. Informal relationships and exchanges of information and equipment were one of the main channels of knowledge transfer in these situations.

The national funding environment was important in encouraging the relationships between the spin-off companies and the research departments. Since most of the spin-off companies could not afford to commission contract research, government funding provided the necessary means for these spin-off companies to collaborate in research projects. The role of the spin-off companies in acquiring government projects was however limited. Mostly, research departments were the lead applicants for research projects and the departments could select industrial research partners from a broad range of private companies including their spin-offs.

Looking at the effects of the organisational setting on the relationships, we conclude that although the NanoLab and ICTLab research institutes had aimed to create spin-off companies as long-term industrial research partners, their spin-off companies had not been able to invest substantial monetary resources in the research institutes. In terms of providing legitimacy for the acquisition of government-funded research projects, they were more helpful. The biomedical research departments, with their more basic research focus and less elaborate technology transfer structures were able to acquire large amounts of funding from and with their spin-off companies. Whether or not research institutes and universities had technology transfer support structures in place, or had a tradition of university-industry interaction, did not appear to influence the intensity of the relationships.

11.4 Impacts of the relationships with spin-off companies on the research portfolios of research departments

We will now assess the extent to which relationships between research departments and their spin-off companies have affected academic research portfolios and whether differences can be observed due to organisational and disciplinary settings. We deal with the impacts on the research portfolios in three sub-sections: contributions to the resources for research; impacts on the research agendas; and impacts on research outputs.

11.4.1 Contributions to the resources for research

In Section 11.3 we discussed the similarities and differences among the relationships. In this section, we examine the extent to which these relationships have contributed to the resources of the investigated research departments. Table 11.5 displays the impacts of the relationships on the resources available for research. Overall, the biomedical research departments benefitted significantly from their relationships with spin-off companies, whereas the spin-off companies in the other research fields neither had the resources nor the immediate need to invest significant sums of money in the research departments. Exchanges of ideas, data and equipment, and legitimising government research funding through spin-off company participation in government-funded projects, on the other hand, were pervasive elements in the contributions of spin-off companies to the resources for research.

11.4.1.1 Contacts with other industrial research partners

Through their relationships with spin-off companies, research departments may be introduced to organisations they were not previously acquainted with. Such new contacts in turn may lead to the acquisition of additional resources. We found that, in most cases, the relationships with spin-off companies did not expand the contacts the research departments maintained with other industrial research partners. In all cases, spin-off companies were part of the larger environment in which multiple industrial research partners already maintained contacts with the investigated research departments. Three research departments benefitted from their contacts with the spin-off companies, indicating that spin-off companies can help to increase the networks of research departments and possibly open up new funding opportunities for them. On the other hand, the case of MedLab 1 clearly illustrates that relationships that lack clear agreements about personnel and intellectual property may also lead to conflicts. Such conflicts can inhibit future knowledge transfer activities by making departments hesitant to engage in new relationships with industry.

11.4.1.2 Income from industry

In Section 11.3 we showed that spin-off companies contributed, albeit mostly only modestly, to the research activities of the research departments by providing information and research equipment, mostly through informal interactions. In terms of monetary resources, the biomedical spin-off companies were able to engage in intensive relationships with the research departments from which they originated. The MedLab and PharmLab research departments profited significantly from their spin-off companies. MedLab 1 and 2 witnessed a large expansion of their research activities thanks to research funding from BIO1 and BIO2. PharmLab 1 also benefitted from contract research commissioned by one of its spin-off companies. The ICT and NANO research departments did not experience changes in their income from other industrial research partners as a result of their relationships with spin-off companies. The direct investments of the spin-off companies were small or non-existent. NanoLab 1, on the other hand, had engaged in collaborative research projects at least 16 times with its spin-off companies. By participating in these projects, the spin-off companies facilitated their acquisition.

We did not find that the research departments based in research institutes ICTLab and NanoLab, with their well-developed technology transfer functions, were any more successful in acquiring research funding from their spin-off companies. The biomedical research departments residing in research institutes with less elaborate technology transfer structures, have been far more successful in acquiring funding from their spin-off companies. If we look at two research institutes in the same scientific field, we see that the monetary contributions to research departments at ICTInstitute and ICTLab do differ somewhat, but that these differences are not significant. This suggests that the scientific field in which a research department resides has a stronger influence on the resources it will receive than the support structures that are in place in the research institute.

In addition to the resources that the spin-offs directly contributed, we were also interested to see whether the spin-off companies indirectly affected the resources available for research. Relationships with spin-offs may lead to additional contacts and, as a result, additional research funding. Relationships with spin-offs may also lead to changing practices and perceptions that translate into a more benign, or hostile, attitude towards contract research for industry. We found that in the two research departments with the most intensive relationships such impacts occurred (Table 11.5). After a conflict with BIO1, MedLab 1 became cautious about engaging in collaborations with new industrial research partners. This limited their activity in terms of contract research. MedLab 2 managed to re-license patents and collaborate with another company thanks to its relationship with BIO2. The six other research departments that had less intensive relationships with their spin-off companies did not report any such impacts.

11.4.1.3 Income from (inter)national government agencies

Spin-off companies participated in government-funded research projects together with their research departments and, in so doing, supported the research departments in the acquisition of research funding. Spin-off companies provide legitimacy for the acquisition of public research funding. In addition, research departments would also mention in their grant proposals that spin-off companies had originated from their ranks, thus using their spin-off companies to show to research funding agencies that their research activities had economic relevance.

Since many public research sponsors encourage collaboration with industry (Table 11.2), spin-off companies are attractive research partners for research departments. All the research departments had acquired government funding with the help of their spin-off companies. Given their origin, spin-off companies were cognitively close to ‘their’ research department’s research portfolio, the personnel were acquainted with each other, most spin-off companies remained geographically close and, more than other SMEs spin-offs, had a greater capacity to absorb knowledge from scientific research departments. Nevertheless, spin-off companies were only a part of a larger environment from which research departments could select partners to collaborate with. To a large extent, the research departments were able to pro-actively select organisations from their environment with whom to participate in government-funded research projects. While spin-off companies could be attractive for gaining access to public research funding, they do not perform an exclusive role, since spin-off companies are often small organisations that exist the alongside many other organisations with which research departments maintain contact. The environment of the investigated Dutch research departments is similar uniform in terms of public research funding opportunities: in all three scientific fields most of the funding agencies encourage science-industry collaboration. The preferences of the research departments did not appear significant since all research departments were open to collaboration with spin-off companies. What matters more with respect to the acquisition of government-funded research projects that require partnerships with industry is how many other industrial research partners, alongside the spin-off companies, qualify as potential partners for a research department on a specific topic.

Table 11.5. Impacts of the relationships with spin-off companies on the resources for research of research departments (shaded cells indicate an impact)

Research institute		*MedLab*		*PharmLab*	*ICTInstitute*	*ICTLab*		*NanoLab*	
Research department		**MedLab 1**	**MedLab 2**	**PharmLab 1**	**ICTInstitute 1**	**ICTLab 1**	**ICTLab 2**	**NanoLab 1**	**NanoLab 2**
Overall picture		Major contributions to the research capacity through contract research and participation in government-funded research projects.		Significant contributions to research capacity but spin-offs made up a relatively small part of the environment.	Insignificant contributions.	Insignificant contributions.	Small contributions to research capacity due to participation in government-funded projects.	Significant contributions to research capacity due to participation in government funded-projects.	Insignificant contributions.
Number of contacts with industrial research partners		Conflict with BIO1 led to hesitation in creating new contacts with industry.	Some additional contacts.	No impact reported.	No impact reported.	No impact reported.	Some additional contacts of limited importance.	No impact reported.	No impact reported.
Share of income from public and private research partners	Direct effects	Major contract research projects commissioned by BIO1.	Major contract research projects commissioned by BIO2.	Significant contributions to research capacity in exchange for patents.	No impact reported.	No impact reported.	Small contributions.	Small contributions.	Small contributions.
	Indirect effects	Hesitance to create new contacts with industry limited the potential for additional contract research.	Patents of BIO2 were re-licensed to another company with whom MedLab 2 started to collaborate.	Composition of research projects changed significantly but not due to spin-off companies.	No impact reported.	No impact reported.	Rise in research funding from industry was not related to spin-off companies.	No impact reported.	No impact reported.
Share of income from national government agencies and international funding agencies	Direct effects	BIO1 supported the acquisition of a large government project. After the departure of the spin-off company, the group struggled to acquire external funding.	Contacts with BIO2 led to the acquisition of a large government-funded project. Discontinuation of BIO2 led to a funding crisis.	BIO4 helped to acquire at least 9 government-funded research projects.	ICT1 and ICT2 participated in 4 government research projects and thus had a very limited impact.	Very limited impact: ICT3 participated in 1 government research project.	ICT5 and ICT6 helped to acquire at least 6 government research projects.	Spin-off companies helped to acquire at least 16 government-funded research projects.	NANO4 helped to acquire 2 government funded-research projects.
	Indirect effects	BIO1 contributed to research capacity, resulting in output that was used to acquire government funding.	Based on increased research output, the group was able to acquire large government-funded projects.	Composition of research projects changed significantly but not due to spin-off companies.	No impact reported.	No impact reported.	No impact reported.	No impact reported.	Presence of spin-offs enhanced reputation and helped to acquire projects independently of the spin-offs.

In addition to the direct effects of the relationships on income from government agencies, the research portfolios of MedLab 1 and 2, and of NanoLab 2 also experienced indirect effects (Table 11.5). The MedLab departments were heavily funded by their spin-off companies. MedLab 1 struggled to acquire government research funding after the departure of BIO1. Respondents stated that this was due to the departure of the professor which was replaced by another staff member and the relatively basic research orientation of the research portfolio of the research group after BIO1 departed. Funding from BIO2 to MedLab 2 led to a large increase in research capacity and publication output. Based on this output, the department was able to acquire large amounts of additional government funding. NanoLab 2 used the prestige that the spin-off companies provided, in combination with its excellent research quality, to acquire research funding for projects in which the spin-offs did not participate. In the other five research departments no indirect impact was reported on the income from government research projects.

11.4.2 Impacts on the research agenda

We will now focus on the impacts of the relationships between the research departments and their spin-off companies on the research agendas of the research departments. Table 11.6 displays the impacts on the research themes covered by the research departments, and the impacts on the balance between basic and applied research.

Table 11.6. Impacts of the relationships with spin-off companies on the research agendas of research departments (shaded cells indicate an impact)

Research Institute	*MedLab*		*PharmLab*	*ICTInstitute*	*ICTLab*		*NanoLab*	
Research department	**MedLab 1**	**MedLab 2**	**PharmLab 1**	**ICTInstitute 1**	**ICTLab 1**	**ICTLab 2**	**NanoLab 1**	**NanoLab 2**
Research themes covered	In consultation with BIO1, research topics were agreed upon.	No changes due shared preferen-ces. Funding of BIO2 greatly supported growth of one reseach line.	Minor changes in the research portfolio of the department.	At most, spin-off companies inspired the research portfolio.	No impact reported.	Certain reseach lines became important. Demands of spin-offs fit with mission of the department.	Minor changes in the research portfolio. Research lines were supported by spin-off presence.	No significant impacts. At most, spin-off companies inspired the research portfolio.
Balance between basic and applied research	Demands of BIO1 corresponded with the preferences of MedLab 1. After the departure of BIO1, focus on basic research.	No impact reported.	No impact reported.	No impact reported.	No impact reported.	No impact reported.	No impact reported.	No impact reported.

11.4.2.1 Shifts in research themes

In general, the research themes of the research departments were influenced only slightly by their relationships with their spin-off companies. Looking more closely, we see that intensive relationships with spin-off companies led to significant contributions to specific research lines. The research portfolio of MedLab 1 was heavily funded by BIO1 and its predecessor. In consultation with BIO1, the professor chose which research lines to pursue. The research lines he would work on for BIO1 would however still fit with his interests. Without the company, he might nevertheless have chosen to pursue other research themes. Similar to MedLab 1, MedLab 2 received large amounts of monetary resources from its spin-off. The investments of BIO2 steered the research activities towards one specific line of research. Large amounts of funding went into that research line, making it the most prominent research line of the department. Respondents from PharmLab 1 stated that contract research, participation in government-funded research projects, as well as informal meetings gave spin-off companies the opportunity to influence the research themes. The contacts with the companies did influence the research themes of the research department, but within the scope of its general mission: the design of drug delivery systems. Other research departments, which had received far less or no direct monetary resources from their spin-off companies, reported some impacts on their research portfolio but far less so than in the biomedical research departments.

Most spin-off companies simply did not possess the resources to significantly influence research themes. The impacts of the spin-off companies were from their onset very limited. The fact that research departments needed to take account of multiple organisations in their environment and, at the same time, followed research lines that they themselves preferred, limited the potential impact of the spin-off companies. As a consequence, research departments from ICTInstitute, ICTLab and NanoLab reported no impacts, or reported that their research themes were, at most, inspired by ideas or problems that the spin-off companies had shared with them. In the case of NanoLab 1, its spin-off companies had participated in at least 16 government-funded research projects and a small number of contract research projects of modest size. Nevertheless, the spin-off companies still were not able to steer research activities, simply because, in those government-funded projects, the research departments were the ones that carried out the research and had the ultimate responsibility. Spin-off companies could articulate their wishes ex-ante, but research departments enjoyed a relatively autonomous position in such government projects. Industrial research partners reported that they were able to inspire the topics that were addressed in the government-funded research projects, but that research departments had the final say in the research projects. Not surprisingly, most respondents from the spin-off companies stated that their participation in research projects occurred because it enabled them to witness the progress made by the research departments. They never expected the research projects to deliver results that would be of direct use to them. On the other hand, respondents from all the research departments stated that taking no account of the wishes of the spin-off companies would lead to a situation in which future legitimatising support for collaborative research projects would become difficult to obtain. Thus, research departments, if they are dependent on their spin-off companies for the acquisition of large amounts of resources, do need to take some account of their demands. In practice however, most research departments considered spin-off companies to be a source of inspiration, not a major driver of change in their research agendas.

11.4.2.2 Balance between basic and applied research

None of the research departments reported that their relationships with spin-off companies led to changes in the balance between basic and applied activities in their research portfolios. The research focus of a research department appears to be a core characteristic that is very difficult to influence by organisations that are often only loosely coupled to the department. In the cases of MedLab 1, MedLab 2 and PharmLab 1, significant to large amounts of monetary resources were provided by the spin-off companies, but the departments chose to continue conducting relatively basic research. Interestingly, we found that MedLab 1 and PharmLab 1 chose to focus more on basic research during or after the relationships with spin-off companies. MedLab 1 did so because of the conflict with BIO1 and the appointment of a new executive leader. PharmLab 1 shifted to a more basic research portfolio because it anticipated a certain research line being very promising. Most of the spin-off companies that possessed large amounts of resources were in a position to conduct applied research themselves, and preferred the research departments to focus on relatively long-term and basic research. To the research departments, conducting basic research is very important in order to maintain their scientific reputation. In turn, this type of reputation is key for the acquisition of research funding from government agencies.

Although we did not find that the relationships had an impact on the basic versus applied research focus of the research departments, it could be that, over a longer period, the pressures in the funding environment stressing knowledge transfer, and the increased dependence on resources from industry, may eventually lead to more applied research portfolios. In Chapter 5, we showed that the environment of research departments was increasingly emphasising knowledge transfer, relevance and the commercialisation of scientific research, with funding instruments encouraging such behaviour. Thus, one might expect research departments to gradually gear their activities towards the needs of industry in order to acquire resources. Spin-off companies and other industrial research partners, that may be interested in more-applied research results from research departments, would see their bargaining position improved from such a development since it would confront research departments with multiple constituents in their environment wanting them to conduct more-applied research.

11.4.3 Impacts on research output

The impacts of the relationships with the spin-off companies on the research output were investigated by inspecting the scientific publications, patents, prototypes and clinical applications, and the research quality of the research departments. The impacts on the research outputs are displayed in Table 11.7.

Table 11.7. Impacts of the relationships with spin-off companies on the research outputs of research departments (shaded cells indicate an impact)

Research institute		*MedLab*		*PharmLab*	*ICTInstitute*	*ICTLab*		*NanoLab*	
Research department		**MedLab 1**	**MedLab 2**	**PharmLab 1**	**ICTInstitute 1**	**ICTLab 1**	**ICTLab 2**	**NanoLab 1**	**NanoLab 2**
Scientific publica-tions	Direct effects	Major contributions by spin-offs to the research capacity led to an increase in publications.	Major contributions by spin-offs to the research capacity led to a number of high quality publications.	Contributions to the research capacity supported the publication output.	No impact reported.	No impact reported.	Contributions to the research capacity supported the publication output.	Contributions to the research capa-city supported the publication output.	No impact reported.
	Indirect effects	Departure of BIO1 led to a major decline in research funding and scientific output.	High-quality publica-tions based on BIO2 funding contributed to the acquisition of government projects.	No impact reported.	No impact reported.	No impact reported.	No impact reported.	No impact reported.	No impact reported.
Other research output	Patent applications	No increase in patenting activities. Scientific activities remain central concern.	Department was already involved in patenting. Patenting behaviour did not change because of BIO2.	Department was already involved in patenting. Paten-ting behaviour did not change due to BIO3 and 4.	Patenting does not occur. Publications remained a key output.	No impact reported.	No impact reported.	No impact reported.	No impact reported.
	Prototypes, demonstrators and clinical applications	No impact reported.	No impact reported.	No impact reported.	No impact reported.	No impact reported.	Part of the prototype creation was outsourced to spin-off companies.	Part of the proto-type creation was outsourced to spin-off companies.	Part of the prototype creation was outsourced to spin-off companies.
Research quality		Resources from BIO1 helped to provide basis for high quality research output.	Resources from BIO2 provided basis for high quality research output.	Department was credited for research alliances with companies. Research quality was not affected.	Department was credited for contacts with industry. Research quality was not affected.	Department was credited for contacts with industry. Research quality was not affected.	Department was credited for strong connections with industry. Research quality was not affected.	The department was credited for its spin-off companies. Research quality was not affected.	Spin-off companies were not mentioned in the assessments. Research quality was not affected.

11.4.3.1 Impacts on scientific publications

Most spin-off companies did not contribute directly to an increase in scientific publications by engaging in joint publications with their parent research departments. Overall, the computer science, and nanoscience and technology spin-off companies were not interested in writing scientific articles. The biomedical spin-offs on the other hand were interested in publishing articles. The spin-off companies that participated in writing scientific publications had, in many cases, employees that also held positions at public research organisations.

The substantial numbers of research projects that were commissioned by spin-off companies in some cases and the participation of spin-off companies in government-funded research projects did lead to an increase in the number of publications. Increases in research capacity enabled the research departments to publish scientific publications. Collaboration between research departments and spin-off companies in government research projects did not crowd out the writing of scientific articles. In the relationships, the departments were able to maintain significant autonomy over their core activities, including the publishing of scientific articles.

In the two cases with the most intense relationships, MedLab 1 and 2, the relationships had unforeseen consequences that did not occur in the other departments. The conflict between MedLab 1 and BIO1 led to a major decline in contract research, which subsequently resulted in a decline in scientific output. MedLab 2 found itself in a difficult position after research funding from BIO2 stopped. Fortunately for MedLab 2, based on the results from its contract research projects, it was able to develop high-quality publications that convinced government agencies to finance several new large research projects.

11.4.3.2 Impacts on other research outputs

When looking at the number of prototypes, demonstrators, clinical applications and patent applications that were produced, only three of the research departments reported changes due to their relationships with spin-off companies. ICTLab 2 and NanoLab 1 and 2 reported that the design activities for computer chips were occasionally outsourced to spin-off companies. For the research departments, outsourcing these design activities was attractive since the spin-off companies were able to produce these chips more inexpensively and it allowed researchers of the departments to focus on original research activities instead of routine work, such as designing computer chips for testing.

One could have expected that relationships with spin-off companies would lead research departments to produce outputs that were of particular interest to these companies, or that their relationships with spin-off companies would change their attitudes towards the creation of prototypes or the application for patents. However, we did not find evidence of such tendencies, and did not find that the relationships led to an increase in patent applications, prototypes or clinical applications by research departments. The reason for this was that the spin-off companies were predominantly interested in informal exchanges of knowledge such as the exchange of test results, expertise and information on developments in the departments' research projects. In the biomedical departments, spin-off companies often commissioned contract research on the condition that results arising from the contract research projects would be owned by the companies. Researchers who conducted contract research for these spin-off companies shared their information with the companies, but this left the actual results and direction of the research unaffected. Subsequently, the companies themselves mostly filed patent applications based on findings that originated from these projects. Hence the collaborations did not affect the patent output of the research departments. Where patent applications were filed by the research departments (MedLab 2, PharmLab 1, ICTLab 2, NanoLab 1 and NanoLab 2), we found this was already the case before the spin-off companies were founded. The frequency of patent applications did not change. Moreover, the computer science and nanoscience and technology departments were largely not interested in applying for patents and preferred leaving this to their spin-off companies.

The professor of MedLab 2 reported that, as a result of the discontinuation of BIO2 and the subsequent termination of research funding, his department became reluctant to engage in further commercialisation activities. The uncertainty that the discontinuation of the spin-off company had created induced MedLab 2 to focus on the acquisition of government funding and to re-assess the benefits and drawbacks of engaging in the creation of spin-off companies and conducting contract research for them. Firms that sought to collaborate with the department after the discontinuation of BIO2 were treated cautiously as the department preferred to create a stable research portfolio based on government-funded research projects.

11.4.3.3 Impacts on research quality

Overall, we found that the relationships with spin-off companies did not affect the research quality of the research departments. According to the respondents, it is primarily the research staff that contribute to the research quality of a research department. Spin-off companies can provide monetary resources to enhance research capacity and provide information, research equipment or test data but, in general, this did not affect the research quality of the research departments. When spin-off companies provide, or help to provide, large amounts of monetary resources which research departments are able to use at their own discretion, research departments appear to be able to conduct high-risk research that has the potential to create scientifically innovative output. This is illustrated by the case of MedLab 2. In research assessments, three out of the eight research departments were credited for their connections with industrial research partners, which implies that societal relevance and collaboration with industry is becoming important in research assessments. Only NanoLab 1, from which four spin-off companies originated, was explicitly credited for the creation of spin-off companies.

11.4.4 Conclusions

In this section we have investigated the extent to which the relationships between eight research departments and their spin-off companies affected the research portfolios of these research departments. Table 11.8 shows the relation between the intensity of the relationships between the research departments and their spin-off companies and the impacts on the research portfolios of the research departments.

Table 11.8. Relation between the intensity of the relationships and the impacts on the research portfolios of the research departments.

	Intensity of the relationships	Impacts on		
		Resources for research	**Research agenda**	**Research output**
Biomedicine departments	Medium / High	- Significant contribution to research capacity	- Particular research lines grow and become important for the departments - Bargaining with spin-off companies about topics. Topics inspired by spin-off companies	- Significant increase in number of publications - No impact on other research outputs - No impact on research quality
Computer science departments	Low	- No/small contribution to research capacity	- Research topics inspired by spin-off companies	- No/small contribution to publication output - No impact on other research outputs - No impact on research quality
Nanoscience & technology departments	Low / Medium	- Small contribution to research capacity	- Research topics inspired by spin-off companies	- Spin-off companies add to publication output as they legitimise government projects - Some design activities are outsourced to spin-off companies - No impact on research quality

In Section 11.2, we showed that the investigated research departments depend on many organisations in their environment to provide them with information, physical resources, monetary resources and legitimacy (Table 11.2). Spin-off companies, we found, often make up only a small part of that environment. Generally, the relationships with other organisations in the environments were far more important for the survival than the relationships with the spin-off companies. Since the dependence on spin-off companies was, in most cases, low, the impacts of the exchange relationships with the spin-off companies were also limited (Table 11.8). Spin-off companies mostly lacked the power to influence the research portfolios of the departments since they had insufficient resources. However, when the relationships with spin-off companies did involve the exchange of significant amounts of resources, i.e., in the case of our biomedical research departments, impacts on the research portfolios were more significant.

Relationships with spin-off companies led to additional contacts with industry in only a few instances. Most spin-off companies did not enhance the networks of research departments with industry. Poorly managed relationships even inhibited the desire to maintain contacts with industry. In the government-funded research projects that research departments acquired partly by having spin-off companies on board in the project proposals, the demands of the spin-off companies were balanced by the preferences of the research departments. Further, since the research departments operated rather autonomously in most government projects, the spin-off companies did not dictate, and at most inspired, the research agendas of the research departments. The spin-off companies were not able to force the research departments to choose certain topics. The balance between applied and basic research in the research departments appears to be a core characteristic of the research departments and is very difficult to change. We did not find any evidence that the relationships with the spin-off companies led to more applied research portfolios.

The biomedical spin-off companies did commission large contract research projects. In two cases, research departments became very dependent on their spin-off companies to supply them with research funding. The large amounts of research funding from the biomedical spin-off companies were, however, not accompanied with strict constraints on their use since the companies were mostly interested in basic research. In these situations, the research departments bargained with the spin-off companies in order to agree on research topics of common interest. As a result, the acquisition of these large amounts of research funding from the spin-off companies did not lead to a loss of control over the research agendas. The contributions to the research capacity led to a significant rise in publications. Further, the relationships that funded large parts of a research portfolio had significant, and unforeseen effects such as a hesitance to engage in new collaborations with industry. It even led to an increase in high quality research output that enabled the acquisition of large government-funded research projects. The biomedical spin-off companies did not require the research departments to change their outputs. Also, we found no changes in the number of patents the research departments applied for.

The computer science and nanoscience and technology spin-off companies in our sample did not possess the monetary resources or an interest in long-term research to commission research projects. These companies contributed only to a very limited extent to the research departments' resources for research by enabling them to acquire government-funded research projects. In these government projects, research departments were able to control the research and they managed to buffer their research interests against demands coming from the spin-off companies. As a result, the research agendas of the computer science and nanoscience and technology departments were not affected, nor did the relationships lead to an increase in the number of prototypes, demonstrators or clinical applications that were created, or the number of patents applied for.

11.5 Revisiting the propositions

Our research model, based on resource dependence theory and on new institutional theory, helped us to formulate a set of five propositions (Section 3.6). In this section we assess the plausibility of these five propositions, in light of the empirical material we collected.

11.5.1 Motivations of public research organisations to support the creation of spin-off companies

The first two propositions concern the motivations of public research organisations in starting to support the creation of spin-off companies. The propositions are as follows:

Proposition Ia:

A public research organisation that is situated in an environment that values knowledge transfer will support the creation of spin-off companies in order to adhere to the dominant rules and norms in its environment.

Proposition Ib:

A public research organisation that is situated in an environment that values knowledge transfer will support the creation of spin-off companies in order to mobilise resources from its environment.

The two propositions expect public research organisations to display one of two possible types of motivations for engaging in the support of spin-off companies. While new institutional theory stresses that organisations will follow dominant rules and norms in their environment in order to maintain legitimacy, resource dependence theory expects organisations to be mainly interested in managing their relationships in order to mobilise vital resources. When looking at the selected public research organisations in our study we find that both resource-based as well as institutional motivations have contributed to the research departments' support of spin-off formation. Institutional motivations, though, appear to dominate.

We found that the behaviour of the MedLab, PharmLab and ICTInstitute corresponded with the new institutional variant of the first proposition: Proposition Ia. MedLab, PharmLab and ICTInstitute adapted to rules and norms in their environment that were increasingly stressing the engagement of public research organisations in knowledge transfer activities. In order to maintain their legitimacy, the research institutes started to support the creation of spin-off companies. The research institutes initially lacked sufficient intrinsic, resource-based, motivations to engage in the support of spin-off companies since they preferred to focus on basic research and were able to acquire significant research budgets from their traditional research sponsors, i.e., government ministries, research councils and their own organisation. As a result, their interest in commercialising research results was rather limited prior to the 1990s. The engagement of MedLab, PharmLab and ICTInstitute in the support of spin-off company creation was intended to maintain their legitimacy in the eyes of key constituents in their environment. The creation of the support structures allowed the research institutes to maintain their basic research profiles while accommodating processes in their environment that called for research commercialisation. In so doing, they buffered their core activities from environmental processes that demanded that their research produce more economic gains.

Proposition Ib states that public research organisations are motivated to support the creation of spin-off companies in order to mobilise resources from their environment. Only in the case of the Technical University, and its two research institutes, did we find this to be valid, although new institutional motivations also appeared to play a role there. Located in a region that did not have any large-scale high-tech industry, the university sought to create support structures to encourage the creation of new high-tech enterprises. These actions preceded national policy initiatives aimed at promoting commercialisation activities by public research organisations. The Technical University envisaged that companies would become research partners of the university, and be prepared to invest in the research activities of the university. The Technical University managed to create a large number of spin-off companies. The creation of the support structures for spin-off companies was also rooted in the fact that the Technical University was expected by its sponsors to boost the regional economic climate. Thus, the support for the creation of private enterprises was also motivated by a need to meet the expectations of policymakers who had sanctioned the founding of the university. Disregarding the supposed regional function of the university would have damaged its legitimacy. This latter point shows that, in the case of the Technical University and its research institutes, motivations are not always clearly traceable to either resource dependency theory or new institutional theory. Expectations from constituents in its environment as well as resource-based motivations on the part of the Technical University induced it to start supporting spin-off companies, even before other public research organisations did so.

11.5.2 Responses of research departments to an environment that encourages science-industry interactions

Proposition II focuses on the consequences of the attempts by government agencies to increase science-industry relationships. Research departments may positively respond to such attempts and engage in relationships with their spin-off companies in order to acquire additional resources.

Proposition II:

A research department that resides in a funding environment which makes resources available to encourage science-industry relationships will employ the *relationships with its spin-off companies to mobilise such resources from its environment.*

Research departments may pro-actively identify and target organisations in their environment in order to mobilise resources from them. As a result, one would expect that when research departments are promised rewards for engaging in relationships with industry, they will enlist their spin-off companies and other industrial research partners to acquire resources from their environment. We found that all the selected research departments engaged with their spin-off companies in government-funded innovation-oriented research projects. We found that the departments utilised their spin-off companies to legitimise the acquisition of government-funded research projects. Spin-off companies were mentioned in project proposals, and spin-off companies also participated as research partners in research projects. MedLab 2 carried out a government-funded research project that involved a large amount of monetary resources for the research department. PharmLab 1 and NanoLab 2 engaged in a total of respectively 11 and 16 government-funded research projects together with their spin-off companies. The other research departments each engaged in up to six government-funded research projects with their spin-off companies.

Although spin-off companies collaborated with their parent research departments in government-funded research projects, they were not the only industrial research partners that could be enlisted to legitimise government research funding. As shown in Chapters 6 to 10, the investigated research departments maintained contacts with many industrial research partners. These industrial research partners could all be invited to join proposals, thus increasing the chances of success in applying for government funding. Respondents from the research departments indicated that only on a few occasions the spin-off companies actually filled a gap which could not be filled by existing industrial partners because of differences in research preferences. In the case of MedLab 2, the research department's research interests were heavily interwoven with those of BIO2. In the cases of ICTLab 2 and NanoLab 1, the spin-off companies ICT5, ICT6 and NANO2 were companies that worked in a specific technology domain that was of interest to the research departments. Therefore, the spin-off companies were an attractive partner, although other industrial partners could have been enlisted to help legitimise the acquisition of research projects. In relation to industry in general, respondents indicated that spin-off companies are a preferred partner for research departments since they are geographically, personally, as well as cognitively, close to the research departments. Further, employees of the spin-off companies and researchers at the research departments tend to be well-acquainted with each other, often having worked together in the same research department.

Coming back to Proposition II, we conclude that research departments indeed enlist their spin-off companies to increase their likelihood of success in applying for government grants. Other industrial research partners of the research departments often participated in such projects as well, so the role of the spin-off companies was not unique in this respect.

11.5.3 Managing the demands of spin-off companies

Regarding Proposition III, we expected that, when engaging in relationships with external organisations, research departments would need to deal with the demands and expectations of these organisations. Resource dependence theory expects that, when a research department engages in exchange relationships with external organisations, it will attempt to buffer the demands of these organisations if the demands are not in line with its own preferences. This allows the research department to retain control over its research agenda and research outputs, and thereby protect its legitimacy with other organisations in its environment. Thus, we would expect a research department to limit the influence of spin-off companies on its research portfolio, especially in situations where the preferences of the research department and the demands of spin-off companies are not compatible. Thus, the third proposition states that:

Proposition III:

When engaging in relationships with its spin-off companies, a research department will seek to avoid influences on its research portfolio if the demands of the spin-off companies are not in line with its own preferences.

We found that research departments were able to avoid influences on their research agendas and research outputs. In most cases, the core research activities of research departments remained unaffected, while research departments allowed spin-off companies only little say in the research projects they were collaborating in. This only led to marginal changes in the research agendas of research departments. However, in some cases, we found that the research outputs and research agendas were significantly affected by the relationships with spin-off companies.

All the research departments had a strong opinion about what kind of research they wanted to conduct. Most research departments preferred to conduct more basic research than they were able to because of limited research funding opportunities. Our investigation of the research departments found that each research department sought to limit the influence of its spin-off companies as far as possible whenever the spin-offs' demands were not in line with its own preferences. In most cases, research departments were able to do so because they selected only those organisations in their environments that had demands that were in line with their own preferences.

For monetary resources, the research departments we investigated relied upon the university or research institute they were part of, as well as government funding agencies and a range of research partners. In addition, industrial research partners and peers also provided the research departments with information and physical resources, while legitimacy was acquired by producing publications and engaging in collaboration with industry. Therefore, for the research departments, spin-off companies were one of many organisations in the environment that provided the research departments with resources. We found that in the cases of ICTInstitute 1, ICTLab 1 and NanoLab 2, the resources from the spin-off companies were of little significance in relation to the overall research portfolios of the research departments. Other organisations, such as government agencies and other industrial research partners were of much greater importance for these research departments, while the spin-off companies were of peripheral importance. Nevertheless, government agencies expect research departments to collaborate with industrial research partners. Most spin-off companies do not have a significant impact on the research output and research agendas of research departments. Spin-off companies form only a small part of the larger institutional environment of research departments and any influence coming from spin-off companies is consequently relatively small. Although scientific researchers often collaborate with companies, our findings indicate that their core activities are largely unaffected. Researchers utilise the presence of spin-off companies to demonstrate to the outside world that relevant and applicable knowledge is being produced. They strategically present their spin-off companies to legitimise the acquisition of public funds and stress their engagement in science-industry interactions. In so doing, they often de-couple their core research activities from such activities in order that their research activities remain unaffected.

In the cases of ICTLab 2 and NanoLab1, the spin-off companies participated in at least 6 and 16 government-funded research projects respectively, while spin-off company ICT5, that originated from ICTLab 2, also commissioned a small amount of contract research. In these cases, research departments could avoid impacts on their research agenda and outputs because other organisations in their environment were much more important in terms of resources than the spin-off companies. When we look specifically at NanoLab 2, we see that spin-off companies collaborated in at least 16 government-funded research projects. This in principle gives the spin-off companies an important position. However, in these research projects, the spin-off companies did not provide resources to the research department. The spin-off companies helped to acquire government funding for projects in which the spin-off companies were allowed to witness developments in research projects. Therefore, the potential influence of spin-off companies was very limited.

Given that research departments are able to select organisations in their environment, they can choose not to collaborate with organisations that have demands that are not in line with their own preferences. Research departments and spin-off companies will not engage in certain collaborative activities if either of them is not satisfied with the conditions under which the collaboration will take place. We found this to be the case at MedLab 1 and NanoLab 1. After the departure of BIO1, the new executive leader chose to adopt a basic research profile whereas the spin-off company was interested in more applied research. NANO2, that spun out from NanoLab 1, would have liked to collaborate more intensively with the research department but felt it was not possible to steer the research projects in a way that it would benefit. Because multiple organisations existed in their environments, research departments were able to maintain relationships with those spin-off companies and other organisations whose demands overlapped with their own preferences. In all our cases, respondents from the research departments stated that the spin-off companies and the research departments chiefly shared the same research interests, thereby limiting the pressure for research departments to change their research agenda. Organisations that do not operate in the same field of expertise as a research department will not choose to collaborate with the research department, while the research department will choose only the ones that fit with its preferences. At the same time, most spin-off companies stated they did not expect research departments to change their research agendas and research outputs. For the research departments, the scientific community remained one of the most important constituents. Moreover, research agendas cannot be changed overnight, and developing an expertise and acquiring the right research equipment may take many years.

To summarise, we found that the research departments indeed sought to avoid influences on their research portfolios if the demands of the spin-off companies were not in line with their own preferences. Research departments have been able to do so by selecting other organisations in their environment, only engaging in relationships with spin-off companies that have similar preferences as the research departments, and by rejecting demands when these spin-off companies were not of central importance to the research departments. However, the discussion on the empirical material in the light of proposition IV, in the text below, will show that what looks like research departments maintaining stability, research departments in the long run may need to take into account the demands of spin-off companies in cases where the spin-off companies become important for their survival.

Proposition IV states that a research department will attempt to protect itself from external pressures that it is confronted with when mobilising resources. However, in circumstances where this is not possible, and the potential resources at stake are high, a research department will change its behaviour. It will do so in order to acquire these resources, either to ensure its survival or to expand its research portfolio.

Proposition IV:

> *A research department will only allow changes to its research portfolio in response to a relationship with a spin-off company if this relationship will provide the research department with access to a significant amount of resources, but the research department will change in a way that is closest to its own preferences.*

In the light of this proposition, we discuss the impacts on the research agendas and the research outputs of the research departments. In discussing proposition III, we already showed that exchange relationships of a minor intensity do not significantly change the research portfolios of the research departments since other organisations are far more important for the survival of these research departments. We therefore exclude the ICTInstitute 1, ICTLab 1 and NanoLab 2 research departments from the following discussion. Instead, the following five research departments are discussed: MedLab 1 and 2, PharmLab 1, ICTLab 2 and NanoLab 1.

The research themes of these research departments were only influenced marginally by their relationships with the spin-off companies. Research departments that engaged in relationships of medium intensity with their spin-off companies, at most, adjusted the research topics they were active on, but remained close to their own preferences. The spin-off companies were based on knowledge from the research departments, implying that the areas both organisations were be active in, often had large overlaps.

In the cases of MedLab 1 and 2, large investments were made by BIO1 and BIO2. The commissioned projects were very interesting for MedLab 1 and 2. The spin-off companies were able to steer the research activities in the research projects they were involved in to some extent. The other three research departments, PharmLab 1, ICTLab 2 and NanoLab 1 reported that the relationships with the spin-off companies inspired their research themes and increased the prominence of certain lines of research. This was the result of direct support by the spin-off companies, or due to, participation of the spin-off companies in government-funded research projects. For PharmLab 1, contract research, the participation in government-funded research projects and informal meetings gave BIO3 and BIO4 the opportunity to influence the research topics. The relationships with the spin-off companies had an impact on the research agenda of the department but only within the scope of its general mission. Other research departments, which received far less or no direct monetary resources from their spin-off companies, reported that research lines were inspired by the spin-off companies, but far less than seen in the biomedical research departments. Here, spin-off companies simply did not possess the resources to considerably influence the research themes. The fact that the research departments stayed close to their original research course should also be attributed to their investments in personnel and research equipment. Since the expertise of personnel takes years to change, research departments could only make small adjustments. Further, staying close to their own research agendas did not endanger their legitimacy with the scientific community and other industrial research partners.

None of the research departments reported that their relationships with spin-off companies led to direct changes in the basic or applied nature of their research portfolios. Even in cases where large amounts of resources were acquired by the research departments, they maintained largely the same balance between basic and applied research. In the cases of MedLab 1, MedLab 2 and PharmLab 1, significant to large amounts of monetary resources were provided by the spin-off companies. However, the research departments were allowed by the spin-off companies to conduct relatively basic research projects. Nevertheless, research departments were not willing to change their research focus, given their own preferences and the threat of endangering their legitimacy within the scientific community. The BIO spin-off companies, with large amounts of resources, preferred the research departments to focus on longer term basic research rather than applied research. In the case of ICTLab 2, we did not find any changes in the research portfolio in this respect because the focus of the research departments was already relatively applied, while the spin-off companies that originated from the research departments employed former researchers from the research department.

Regarding the scientific output, we found that all five research departments that had relatively intense relationships with one or more of their spin-off companies reported that this led to increased research capacity, which in turn resulted in a larger number of publications. Thus, the relationships contributed to the research portfolios of these research departments, in ways that were in line with the preferences of the research departments. Respondents stated that publishing remained a core activity of the research departments. Overall, the number of patent applications, and the creation of prototypes and clinical applications, did not change, even when significant exchange relationships occurred. None of the research departments changed their patenting activities due to their relationships with the spin-off companies. Research departments were either already engaged in patenting and did not change the frequency of patent applications, or were not interested in patenting and left applying for patents to their industrial research partners. Only one of the five research departments reported that the production of prototypes and demonstrators changed. NanoLab 1's spin-off companies enabled the research department to outsource development activities that would otherwise have been conducted at the research department, freeing up more time and resources for scientific research projects.

To summarise, we found that research departments that acquired significant resources from their spin-off companies allowed some minor changes to their research themes. The support contributed to the research output of the research departments, but did not significantly affect the research quality or the type of research outputs produced by the research departments. Since most of the research departments had several potential research partners, the research departments were in the position to select those research partners in their environment that were closest to their own preferences.

12 Conclusions and reflections

In this chapter, we will provide answers to the research questions, discuss the contributions of the empirical findings to the existing body of literature and reflect on the results of this study in the light of policies devoted to knowledge transfer activities of public research organisations.

12.1 Answering the research questions

The aim of this study has been to contribute to the existing body of knowledge on the knowledge transfer activities of public research organisations and the impacts of these activities on the production of scientific knowledge. We investigated spin-off companies since these entities are among the most prominent examples of research commercialisation. For research departments, the creation of spin-off companies may yield benefits such as access to additional resources. However, relationships with spin-off companies may also lead to an overreliance on commercial organisations and a redirection of research, or changes in research outputs. The main research question that we postulated in Chapter 1 is as follows:

> *When research departments engage in the creation of spin-off companies, do they maintain relationships with these spin-off companies and, if so, what effect do the relationships have on the research portfolios of the research departments?*

In order to answer this research question, we investigated five research institutes and eight of their research departments. We selected three scientific fields: biomedicine, computer science, and nanoscience and technology. These fields were selected because academics working in these fields have been at the centre of attention from policymakers concerning the commercialisation of scientific research. We conducted 39 semi-structured interviews with employees of research institutes, research departments and spin-off companies, and carried out a detailed investigation of the relationships between research departments and 15 of their spin-off companies. In addition to the interviews, we drew on data from financial reports and financial administrative systems, strategic plans and research evaluations. Our goal was to study the impacts of the relationships with spin-offs on the research portfolios of research departments.

12.1.1 Literature

The first sub-question focuses on what existing empirical studies can tell us about the impact of knowledge transfer and commercialisation activities on the research portfolios of research departments. Knowledge transfer and commercialisation activities include collaborative research projects with industry, applying for patents, the creation of prototypes, demonstrators and clinical applications, the creation of companies, and, further, industry funding may also be an indicator of knowledge transfer activities.

R1. What can the empirical literature tell us about the impact of knowledge transfer and commercialisation activities on the research portfolios of research departments?

The review of the literature in Chapter 2 showed that collaboration with industry creates additional research capacity for researchers and provides them with access to resources such as information and research equipment (Crespo & Dridi, 2007; Gulbrandsen & Smeby, 2005; Harman, 1999; Lee, 2000; Meyer-Krahmer & Schmoch, 1998; Seashore-Louis et al., 2001; Slaughter & Leslie, 1997; Welsh et al., 2008). Patenting and licensing on the other hand do not lead to an increase in resources for most public research organisations (Geuna & Nesta, 2006; Nelson, 2001). While empirical studies show that collaboration with industry and engagement in commercialisation activities are overall not detrimental to the open communication of science, studies specifically in the life sciences do provide less reassuring results (Allen & Norling, 1990; Blumenthal et al., 1997; Blumenthal, Gluck, Seashore-Louis, Stoto, et al., 1986; Crespo & Dridi, 2007; Davidson, 1986; Friedberg et al., 1999; Harman, 1999; Lee, 2000; Martinson et al., 2005; Stelfox et al., 1998; Ylijoki, 2003). A majority of the studies conclude that in the disciplines of our interest, industrial funding and commercialisation activities are related to applied research, and that industrial funding and commercialisation activities may even steer public sector research into more applied directions (Blumenthal, Gluck, Seashore-Louis, Stoto, et al., 1986; Godin & Gingras, 2000; Gulbrandsen & Smeby, 2005; Harman, 1999; Zucker & Darby, 1996). With some exceptions, industrial funding and patenting are correlated with larger numbers of publications and citations, and thus to a higher research quality (Blumenthal, Gluck, Seashore-Louis, Stoto, et al., 1986; Gulbrandsen & Smeby, 2005; Harman, 1999; Lebeau et al., 2008; Ranga, 2003; Seashore-Louis et al., 2001;

Senker & Senker, 1997; Zucker & Darby, 1996). Based on our literature review, we can conclude that studies addressing the impacts of spin-off company creation and collaboration with spin-off companies on scientific research are still scarce. Preliminary evidence from the few available studies indicates that the presence of spin-off companies is correlated with higher research productivity but it remains unclear in these studies whether spin-off companies actually contribute positively to the productivity of researchers or whether successful researchers are, on average, more often associated with spin-off companies (Buenstorf, 2009). Chapter 2 concludes that studies on the impacts of knowledge transfer and commercialisation activities will benefit from the use of explicit theoretical perspectives, thereby providing insights into the causes of change and stability in the production of scientific knowledge. Additionally, research on the impacts of spin-off companies could benefit from broadening the range of impacts considered by paying attention to the impacts on academic research agendas and on the research department's resources as well.

12.1.2 Making sense of inter-organisational relationships and their impacts

The second sub-question focuses on the organisational theories that may assist us in conceptualising the relationships between spin-off companies and research departments, and help us understand under which circumstances these relationships may have an impact on the research portfolios of research departments.

> **R2.** What can we learn from organisational theory to conceptualise the relationships between spin-off companies and research departments, and the impacts of these relationships on the research portfolios of research departments?

Since research departments depend to a large extent on their environment to provide them with resources, we characterise them as open systems that support themselves by exchanging resources with their environment (J. W. Meyer & Scott, 1992). Organisational choice is constrained by a range of external pressures, and organisational survival depends on the responsiveness of the organisation to external demands and expectations. Organisations seek stability, predictability and legitimacy, since these will enable them to obtain vital resources. At the same time, organisations are capable of choosing strategies in response to demands and expectations from their environment (Oliver, 1991), while this environment shapes the conditions of dependency relationships, and their impacts (Tolbert, 1985).

Two organisational theories provide a basis for the research model formulated in this study: resource dependence theory (Pfeffer & Salancik, 1978) and new institutional theory (J. W. Meyer & Rowan, 1977). These organisational theories can assist in conceptualising what factors play a role in establishing the relationships between research departments and their spin-off companies, and the impacts these relationships may have on the research portfolios. When research departments maintain relationships with their spin-off companies, these relationships may affect the research portfolios of the research departments. Relationships with spin-off companies, combined with the preferences and resources of a research department, will shape a department's research portfolio. In addition, other organisations in the environment of a research department may also shape the relationships with spin-offs and the research portfolios of research departments. Relationships with spin-off companies may bring about changes in the research portfolio of a research department, but a research department may also avoid influences, for instance by ignoring demands or by symbolically complying with the demands of external organisations whilst keeping its core research activities unchanged.

The research model that was developed (Figure 12.1) distinguishes between the preferences and resources of a research department (box I), the potential resources and demands of organisations in its environment (boxes II and III), the relationships that a research department engages in (box IV) and the research portfolio of the research department (box V).

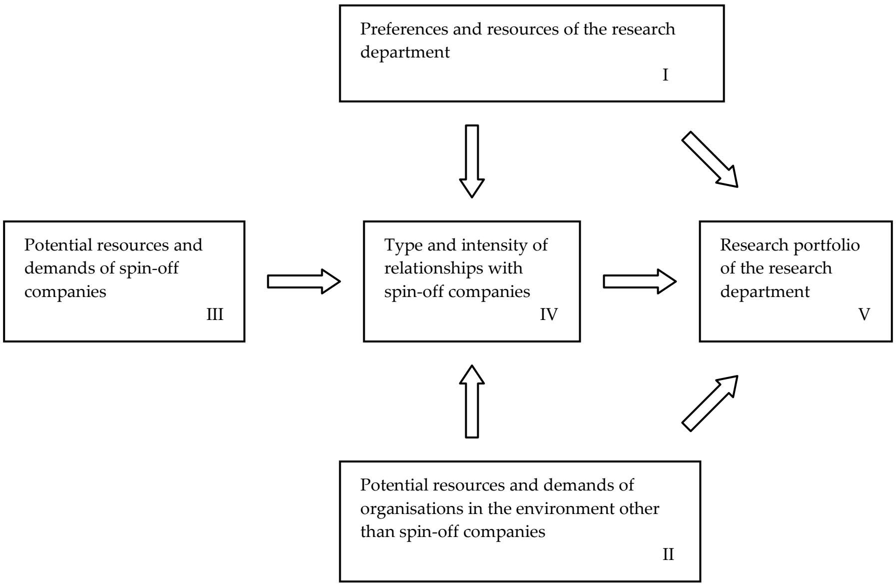


Figure 12.1. The research model restated

12.1.3 Relationships between research departments and their spin-off companies

Sub-questions 3 and 4 concern the type and intensity of the relationships between research departments and spin-off companies, and the roles that the national and organisational environments play in shaping these relationships.

R3. What role does the environment of research departments play in shaping the relationships between spin-off companies and research departments?

R4. Do research departments maintain relationships with the spin-off companies they helped to create and, if so, what is the type and intensity of these relationships?

12.1.3.1 The environments of research departments

In Chapter 5 we showed that the environment of public research organisations in the Netherlands has become increasingly supportive of researchers' engagement in knowledge transfer and commercialisation activities. Funding agencies and governmental policymakers have increasingly demanded from public research organisations that researchers pay attention to the societal relevance of their research, that they collaborate with industry and that they commercialise their findings. In terms of funds available for research, changes occurred as well. Numerous project-based funding instruments have been introduced by public national and supranational authorities with the aim of having researchers contribute to innovation and produce societally relevant research outputs. Starting in the 1980s, funding schemes increasingly started to pay attention to societal relevance and commercialisation of research during the 1990s. Today, scientific researchers in the technical sciences who apply for research grants have to justify the societal relevance of their intended research and are increasingly encouraged to show how research results may be transferred to industry. Researchers in the technical sciences, when applying for project-based funding, have to specify which societal partners will participate in their projects and whether they have industrial research partners that will co-fund their research projects. This means that private enterprises, including spin-off companies, have become attractive partners for researchers trying to acquire research funding from government agencies.

In total, we investigated the relationships between research departments and spin-off companies in eight research departments based within five research institutes in the Netherlands. Most research departments in our sample received funding directly from the Dutch research council NWO. The dominant part of externally acquired funding of most research departments originated from research funding agencies in the public sector that were encouraging researchers to interact with industry, such as STW, SenterNovem and the EU. As a result, the research departments sought to involve industry in their research projects in order to qualify for public funding.

Comparing the organisational environments of the research departments, we found that the research institutes that they are part of all had support structures in place to facilitate commercialisation activities. This signifies to organisations in their environments that they are engaging in societally relevant research that could result in commercial outputs. All the research departments saw the funding they received from their parent institution decline during the period under investigation: 1990 to 2007. Additionally, for research institutes and universities, this institutional funding became a means to stimulate their staff to acquire external funding. Previously, institutional funding was principally a way to pay tenured staff.

There were also some notable differences in the organisational environments of the research departments. The support structures of two of the investigated research institutes, ICTLab and NanoLab, were the most extensive in our case studies. ICTLab and NanoLab are part of a Technical University which has a long tradition of supporting commercialisation activities. The research institutes give explicit attention to knowledge transfer in their missions, specifically the creation of spin-off companies. At the same time, research departments in these research institutes received relatively little non-earmarked funding from their parent institution. As a result, compared to other research departments in our sample, the organisational environments of the research departments in ICTLab and NanoLab were the most active when it came to engaging in relationships with external organisations such as industry.

The organisational environments of the investigated research departments that are part of MedLab, PharmLab and ICTInstitute were also supportive of commercialisation and collaboration with industry, but to a lesser extent. These research institutes also came late in responding to societal demands to show societal relevance and to commercialise research results. They were also later than the Technical University in setting up support structures for the creation of spin-off companies. The organisational environments of these research departments traditionally had a stronger emphasis on basic research. Even though non-earmarked institutional funding declined in these institutes as well, the overall amount of non-earmarked institutional funding was still relatively high compared to that of the ICTLab and NanoLab research departments. This meant that the research departments in these institutes had more possibilities to conduct research projects in which no external organisations, such as industry, were involved.

12.1.3.2 The relationships between the research departments and their spin-off companies

Overviewing the results from our empirical analyses, we conclude that most spin-off companies remain close to their parent research departments, and maintain contacts in various ways and intensities. For the research departments we investigated, spin-off companies can have different meanings. Some departments regarded spin-off companies as entities that commercialise research results and that leave the institute for good. However, most departments in our sample were very interested in continuing to collaborate with their offspring because spin-offs had valuable resources to offer, and were instrumental in giving the department access to project funding from government agencies.

A large majority of the research departments and their spin-off companies were interested in maintaining relationships with each other. Research themes matched relatively well, personal relationships were well-developed, and spin-off companies and research departments were often geographically close to each other. This contributed to the intensity of the relationships. Informal relationships were valued by most respondents as they provided both research departments and spin-off companies with updates on developments, know-how and access to physical resources, such as computer chips and biochemical materials. This finding corresponds with other studies that have found that researchers are motivated to gain access to equipment and materials from the business sector (Crespo & Dridi, 2007; Lee, 2000; Meyer-Krahmer & Schmoch, 1998; Slaughter & Leslie, 1997) and collaborate with industry in order to identify funding for some of their basic research questions, introduce new research topics and gain access to unpublished data (Meyer-Krahmer & Schmoch, 1998; Senker & Senker, 1997). A study by Meyer-Krahmer & Schmoch (1998) identified the acquisition of research funding as the main advantage of engaging in relationships with industry. In our study, we found that most spin-off companies, compared to industry in general, had very little monetary resources to dispense to their parent research departments, although there were some exceptions.

In our study, the creation of a spin-off company always led to informal relationships in which test data, instruments or prototypes were exchanged between a research department and its spin-off company. We also found that most spin-off companies worked on joint publications with their parent research departments, and that personnel from the departments had migrated to the spin-off companies. Some spin-off companies even provided the departments with contract research projects. However, none of the companies simply donated money to the departments they had originated from without expecting something in return. Commissioning research projects did not occur frequently because most spin-off companies did not have the financial capacity to directly invest in research projects. Conversely, especially early in their existence, we found that spin-off companies were pre-occupied with attracting sufficient monetary resources to ensure their own survival and were not interested in research projects that would not produce outcomes that were of immediate relevance to them. In the cases of MedLab and PharmLab, spin-off companies were able to commission large contract research projects. Except for the biomedical departments, support of PhD research projects, which is very valuable for research departments, was almost entirely absent. Government funding, on the other hand, was a reason for spin-off companies to intensify relationships with their parent research departments. Almost all spin-off companies participated with research departments in government-funded research projects.

Across the scientific fields, the relationships differed in type and intensity. The relationships between the biomedical spin-offs and their parent departments were the most intense in our study. Most of the biomedical spin-off companies possessed relatively large research budgets and were willing to directly finance research activities, provided they had a long-term and relatively basic research focus. Only in the case of the biomedical research departments we found that departments received money from spin-off companies in exchange for their knowledge once that they had been created. Co-patenting in the biomedical departments occurred more frequently compared to the other research fields. The number of joint publications with biomedical spin-off companies varied significantly because of the differing characteristics of the companies. In all biomedical research departments, simultaneous affiliations of personnel occurred. Support of bachelor and master theses by spin-offs on the other hand did not occur at all in the biomedical research departments. This is probably because research activities in this discipline are more expensive due to the higher costs of research facilities and materials.

The relationships between computer science research departments and their spin-off companies were of a low intensity and can be characterised as rather loose. The spin-off companies that originated from the computer science departments were of a relatively modest size, and they had a stronger preference for short-term development activities. Additionally, their research budgets were far more limited than those of the biomedical spin-off companies. None of the spin-off companies contributed significant amounts of monetary resources to the research portfolios of the departments, either directly or indirectly through participation in government-funded research projects. Only one spin-off company financed part of a PhD research project. For the ICTLab research departments, collaboration through bachelor and master theses of students was an important low-cost means of knowledge transfer. Joint publications and patents were not important for these companies. Joint publications were mostly produced because personnel from the spin-offs were interested in contributing to academic papers.

The relationships between the nanoscience and technology spin-off companies and their parent departments were of a low to medium intensity. The, mostly small, companies did not possess the monetary resources to engage in long-term, large-scale research projects. As a result, the relationships between the spin-off companies and the nanoscience and technology research departments were not significant in terms of the direct resources they provided to research departments. One department collaborated with its spin-off companies in a large number of government-funded research projects. The participation in these projects contributed significantly to the research capacity of the department. Personal relationships were well developed and informal exchanges occurred frequently in the clean-room facilities of the research institute. In addition, the spin-off companies paid for access to the clean-room facilities. Joint publications and the support of bachelor and master theses of students from the research departments were a common phenomenon, while co-patenting occurred only sporadically.

12.1.3.3 The role of the environment

Looking at the impact of the organisational backgrounds of the research departments on the relationships between research departments and spin-offs, we find that the NanoLab and ICTLab research institutes explicitly aimed to create spin-off companies in order to establish long-term industrial research partners. However, the spin-off companies they created have not directly invested significant monetary resources in the research departments from which they originate. These research institutes have, nevertheless, created more spin-off companies than the other institutes in our study. The biomedical research departments with their relatively basic research focus and less elaborate technology transfer structures were able to acquire large amounts of funding from their offspring. So whether or not research institutes and universities operated extensive technology transfer support structures, or had a tradition of university-industry interaction, did not appear to matter. Larger spin-off companies, with significant R&D budgets and long-term research interests, were able to commission large research projects whereas smaller companies were mostly pre-occupied with their survival and more practical development activities. Firm size and industrial sector are major factors in explaining the type and the intensity of collaborations between researchers and industry. These findings correspond with studies by Laursen and Salter (2004); Mohnen and Hoareau (2003); Fontana et al. (2006). We can conclude that the presence of support structures for knowledge transfer and commercialisation does not necessarily increase the intensity of the relationships between spin-off companies and research departments, nor does this increase the resources that research departments might receive from their offspring. Mustar et al. (2008) come to the same conclusion and argue that despite knowing this, many public research organisations continue to sustain elaborate support structures. From an institutional point of view, the support of knowledge transfer activities can be explained as a process of isomorphism since, regardless of the actual results of support structures, public research organisations will support such structures in order to maintain their legitimacy with other organisations in their environment. Discontinuing such knowledge transfer support structures would lead to a decrease in the legitimacy of public research organisations since their environment increasingly expects them to engage in the commercialisation of research results.

With regard to the influence of the national funding environment, we found that in five of the eight research departments, government funding led to an increase in collaborative research projects between research departments and their offspring. However, the influence of publicly funded research and innovation projects on the intensity of the relationships between the departments and their spin-offs should not be exaggerated. Research departments were already maintaining informal relationships with their spin-off companies before they started to collaborate in government-funded research projects. Since the relationships between the research departments and the spin-off companies already existed, we conclude that government-funded research projects were instrumental in providing a platform for collaboration. Collaboration in these government projects enhanced the research capacities of research departments and the development capacities of industry. Although government-sponsored research projects provided a basis for more extensive collaboration, very often the relationships between the departments and their offspring would have existed without government funding, albeit in a less intensive form.

12.1.4 Do spin-off companies make academics' heads spin?

Research sub-question 5 looks at the impacts of the relationships with the spin-off companies on the research portfolios of research departments.

R5. What impacts do the relationships between research departments and spin-off companies have on the research portfolios of the research departments?

So, to what extent did the relationships have an impact on the research portfolios of the research departments? Spin-off companies can 'turn the heads of academics' by supporting their research activities, contributing to ideas and pointing to potentially valuable lines of research. However, spin-off companies may also make the academics' heads spin by forcing them to conduct research on topics they are less interested in. The spin-offs may also seek to delay or prohibit publications, or even force scientific researchers to adjust their results.

We found that relationships with spin-off companies generally did not make academics' heads spin. For most research departments, the relationships with the spin-off companies amounted to a fraction of their total set of activities. Although spin-off companies were attractive partners to collaborate with, these companies were not the only potential research partners for research departments. The departments could select industrial research partners from a broad range of private enterprises. According to resource dependence theory, when organisations can rely on multiple organisations in their environment, they have more control over the external criteria they encounter by selecting organisations that best meet their preferences. This limited the potential for spin-off companies to collaborate with research departments, and restricted their influence on the departments' research agendas and research outputs.

The ability of spin-off companies to have an impact on the research portfolios of research departments depended largely on their capacity to fund research projects. Most spin-off companies participated in government-funded projects with research departments and inspired the research agendas of departments, but they did not force research departments to comply with their demands. Research departments principally sought to protect and increase their scientific reputation, which is still their most important asset. Without their scientific reputation and publications, departments would have found it difficult to acquire government funding and many private companies would not have been interested in knowledge from the departments in the first place. As a result, even in cases where large amounts of monetary resources were acquired from spin-off companies, research departments protected their scientific interests and continued to conduct scientific research and produce scientific outputs that were key to advancing their reputation in the specific fields in which they were active.

12.1.4.1 Contributions of spin-off companies to the resources for research

We found that spin-off companies contributed in several ways to the research capacities of the research departments they originated from. We have already shown that spin-off companies, amongst other things, provided the research departments with test data, inspiration for new and relevant research problems, and research equipment. This corresponds with findings in the literature (Crespo & Dridi, 2007; Lee, 2000; Meyer-Krahmer & Schmoch, 1998; Senker & Senker, 1997; Slaughter & Leslie, 1997). At this point, we would like to discuss in more detail the contributions of spin-off companies in terms of monetary resources. Most spin-off companies in our sample contributed only in a modest way to the financial resources of the research departments. Mustar et al. (2008) have suggested that most spin-off companies are not a source of revenue for the public research organisations they originate from. On the level of the research institutes, we found evidence that supports this conclusion. As with revenues from academic patenting activities (Mowery, 2001), only a small number of spin-off companies in our sample generated significant returns for the research institutes. At the same time, our findings suggest that, on the level of the research departments, spin-off companies can make significant contributions. Some, mostly larger, spin-off companies may possess significant amounts of resources, and may be willing to make direct contributions to the research capacities of a research department, as the MedLab and PharmLab cases clearly illustrate. This observation corresponds with findings by Blumenthal, Gluck, Seashore-Louis and Wise (1986, p.242) who found that *"larger firms give more money to universities than smaller ones and also tend to give larger amounts per grant."* So, while in general, the direct contributions of spin-offs to the research capacity of research departments are limited, some research departments may find that their offspring can significantly boost their research capacities.

Direct contributions to the research capacity of departments were not the only way in which spin-off companies proved beneficial to research departments. Spin-offs supported research departments in acquiring research funding from government sources, as funding agencies have increasingly required researchers to collaborate with industry and show their research has commercial potential. Spin-off companies enhance the prestige of their parent organisations by adding to their legitimacy and create a justification for public funds being invested in research departments. While spin-off companies are not inherently favoured over other types of enterprises in government-funded research projects, we found that spin-off companies can be a preferable research partner for research departments given their geographical, social and cognitive proximity. As a result, spin-off companies are valuable assets for researchers competing for research grants for which the participation of industry is preferred. By engaging spin-off companies as partners in research projects, or by mentioning them in their project proposals, the research departments may strengthen their proposals with ideas from industry and enhance the urgency of their proposals by adding SMEs as project partners. In so doing, they ultimately increase their chances of obtaining public funding. So, while most spin-off companies do not directly contribute financial resources to their parent research departments, their presence enables research departments to be more successful in acquiring government funding.

12.1.4.2 Impacts of spin-off companies on the research agendas of research departments

Based on the literature, we expected the research themes in academia to be inspired by relationships with spin-off companies. A study by Gulbrandsen and Smeby (2005), for instance, reported that industrial funding introduces new research topics. We found that spin-off companies inspire the research themes that research departments work on. However, in most cases, research departments disregard the demands of spin-off companies when these demands do not align with their own research interests. They can do so because other organisations are far more important for their survival. Furthermore, changing research themes of departments would require alternative expertise from staff. We found that, over time, the presence of spin-offs can promote certain lines of research. When significant amounts of resources are at stake, we saw that research themes are influenced by spin-off companies as this enables certain lines of research to grow and inspires the direction of research projects. In such cases, research departments often bargain with the spin-off companies about the exact research topics and involve spin-off companies in decision-making processes during the research. Given the fact that most spin-off companies participated in government-funded research projects, one could expect these companies to directly affect the research agendas of the research departments. However, spin-off companies hardly contributed monetary resources to these projects and are usually one of several industrial partners participating. As a result, the research departments are able to operate relatively autonomously in these projects.

While existing empirical studies have found that relationships with industry and engagement in commercialisation activities are, overall, not detrimental to the norms and values and the open communication of science, we also came across empirical studies in the life sciences that provided less reassuring results (Section 2.3). Studies that reported conflicts of interest and delays in publications predominantly concerned studies that investigated the outcomes of clinical trials (e.g., Davidson, 1986; Friedberg et al., 1999; Stelfox et al., 1998). We found in our study that, in some instances, contract research for spin-offs leads to the postponement of research results in order to enable the spin-offs to secure intellectual property rights. The contract research projects that the departments conducted for the spin-offs did not however prevent the publishing of the outcomes of the research that was conducted in the departments. The difference between our findings and other findings in the literature may be explained by the fact that, in our study, there were no instances where clinical trials were conducted for the spin-off companies.

A majority of the existing empirical studies found a correlation between knowledge transfer activities of academic researchers and applied research (e.g., Crespo & Dridi, 2007; Godin & Gingras, 2000; Gulbrandsen & Smeby, 2005; Senker & Senker, 1997; Zucker & Darby, 1996). In the literature, it is unclear whether science-industry relationships lead to applied research agendas or whether it is that researchers who engage in science-industry relationships are those who on average conduct more applied research. In this study, we aimed to shed light on the causal relationship between knowledge transfer activities and applied research. We did not find evidence that having relationships with spin-off companies actually induced academic researchers to engage in applied research activities. When engaging in relationships with industry, research departments choose to collaborate with organisations that fit with their preferences. In so doing, research departments reduce the likelihood of having to accommodate demands from organisations that do not fit with their preferences. Additionally, spin-off companies that do have the potential to impact on the research agendas of the departments, due to their possession of large amounts of resources, still prefer research departments to focus on longer-term basic research. Spin-off companies may even enable research departments to outsource certain development activities, enabling them to focus on core research activities. Our findings suggest that knowledge transfer activities may be related to applied research simply because research departments that engage in relationships with industry already have more-applied research portfolios than research departments with few connections to industry. If changes towards applied research are to occur due to relationships with industry, these will likely take a considerable time to manifest themselves and will take place only when multiple external organisations and the departments themselves are interested in making such changes.

12.1.4.3 Impacts of spin-off companies on the research output of research departments

We found that spin-off companies in most cases contributed only small amounts of monetary resources to their parent research departments, but in other ways did help to enlarge the research capacity of the research departments. This additional research capacity led to increases in the number of publications. Our findings correspond with most of the existing studies that also come to a moderately positive conclusion: industrial funding and patenting are related to greater numbers of publications (Blumenthal, Gluck, Seashore-Louis, Stoto, et al., 1986; Gulbrandsen & Smeby, 2005; Harman, 1999; Lebeau et al., 2008; Ranga, 2003; Seashore-Louis et al., 2001; Senker & Senker, 1997; Zucker & Darby, 1996). Research departments that maintain relationships with spin-off companies, and that have relations which involve large amounts of resources, are able to significantly increase their publication output. However, we also find that when research departments predominantly rely on these companies, the research capacity of these departments can be threatened and publication output may decrease once the funding from the spin-off companies ceases. This corresponds with findings in the literature that show that overdependence on industrial funding can lead to fewer publications (Blumenthal et al., 1996).

We did not find that relationships with spin-off companies led to an increase in patent applications or the creation of prototypes or clinical applications. In two instances, we actually found that the presence of spin-off companies enabled research departments to outsource development activities to their spin-off companies. This enabled them to focus on research activities instead of on routine work that did not have a research-intensive character. Existing studies have shown that industrial support of academic research is correlated with a higher amount of commercial products and consultancy activities, and the creation of spin-off companies (Azagra-Caro et al., 2006; Blumenthal, Gluck, Seashore-Louis, Stoto, et al., 1986; Gulbrandsen & Smeby, 2005). We found that most research departments that engage in relationships with their spin-off companies are already active in knowledge transfer activities and that the relationships with the spin-off companies do not increase their propensity to engage in such activities. We therefore conclude that relationships with spin-off companies, and industry in general, will not necessarily lead to more patents, prototypes or other types of research output, but that research departments that collaborate with industry are typically already more active in producing such kinds of outputs.

For research departments, producing scientific publications remains the most important type of research output, despite the increased attention for research commercialisation and the increased engagement of research departments in collaboration with industry. Patent applications, prototypes and clinical applications overall makes up only a small part of the total research output. Relationships with spin-off companies are not detrimental to the research quality of research departments. Relationships with spin-off companies provided a basis for publications, but did not contribute directly to research quality. Research quality can be said to depend primarily on the quality of the staff in the departments. The current body of empirical literature supports the same line of argument. High quality researchers receive more industrial funding, while industrial funding does not have impacts on research quality (Blumenthal et al., 1996; Lowe & Gonzalez-Brambila, 2007). Moreover, researchers at public research organisations who do create spin-off companies are, on average, more likely to have been high impact scientists, even before they started a firm (Lowe & Gonzalez-Brambila, 2007).

12.1.5 Relationships with spin-off companies, their impacts on research portfolios and the role of disciplinary and organisational backgrounds

The sixth and final sub-question deals with the disciplinary and organisational backgrounds of the research departments and whether these are important in explaining differences in the relationships with spin-off companies and the impacts of the relationships on the research portfolios of research departments.

> **R6.** What differences can be observed across the relationships between research departments and their spin-off companies, and the impacts of such relationships on the research portfolios? Can the variations be explained by disciplinary and organisational backgrounds?

We found that, across the research institutes and scientific fields we investigated, there is a difference in the type and the intensity of the relationships with spin-off companies and the impacts on research portfolios. Biomedical research departments reported the most intense relationships and the largest impacts on their research portfolios. The other research departments were engaged in less intensive relationships, and these relationships have very little impact on the research portfolios. Three of the four biomedical spin-off companies engaged in significant to large exchanges of resources with the research departments from which they originated. These companies possessed relatively large research budgets and had a preference for long-term and basic research compared to the spin-off companies in the computer sciences and nanoscience and technology fields. Disciplinary characteristics as such do not appear to matter. Rather it is the characteristics of the companies that shape the relationships with the research departments.

We did not find that the organisational backgrounds of the research departments influenced the intensity of the relationships and the impacts of these relationships on the research portfolios. Research departments that resided in the MedLab and PharmLab institutes maintained the most intense relationships with spin-off companies in our sample. However, these research institutes had a relatively short tradition of supporting knowledge transfer activities and had been focused on relatively basic research until recently. NanoLab and ICTLab, which have relatively well-developed knowledge transfer and commercialisation support structures, maintained less intense relationships with their spin-off companies, whereas one could have expected that relationships here would have been more intensive. Apparently, factors other than the organisational environment are more important in determining the intensity of the relationships between research departments and their offspring. The most important factors in this respect seem to be the characteristics of the spin-off itself, i.e., its R&D budget, its time horizon, and its absorptive capacity.

12.2 Reflections

In this section we reflect on the use of new institutional theory and resource dependence theory, our research model, and how the results from our empirical investigations relate to current debates on research commercialisation.

12.2.1 Usefulness of the organisational theories

We made use in this study of resource dependence and new institutional theories to identify the motivations for public research organisations to start supporting the creation of spin-off companies. The theories were also used to describe how relationships between research departments and their spin-off companies are shaped, and how the latter can impact on the research portfolios of research departments.

We found both resource dependence theory and new institutional theory to be helpful in explaining the motivations of public research organisations to support the creation of spin-off companies. Both theories assume that organisational survival depends on responsiveness to external demands and expectations (Oliver, 1991). New institutional theory expects organisations to adhere to norms and beliefs in their environment in order to secure their legitimacy (DiMaggio & Powell, 1983; J. W. Meyer & Rowan, 1977; Scott, 1987b). Resource dependence theory, on the other hand, focuses on visible interdependencies between organisations and expects organisations to respond to their environment in order to mobilise resources (Pfeffer & Salancik, 1978). When engaging in supporting spin-offs, most public research organisations in the Netherlands cited motivations that reflect an adherence to norms and rules, i.e. institutional type motivations. Resource-based motivations for engaging in the support of spin-off company creation were also mentioned, as public research organisations were also interested in expanding their resource base. We found that the motivations of public research organisations could not always be interpreted from either a resource dependency or a new institutional perspective. In some cases, both logics prevailed. Public research organisations try to adhere to norms and rules in their environment that stress knowledge transfer and commercialisation activities. At the same time, they have become aware of the potential resources that spin-off companies can offer as research partners, and have set up support structures to encourage the creation and growth of spin-offs. The idea that organisations may behave based on either resource-based motivations or on motivations arising from habits and conventions in their environment is thus oversimplistic. This study shows that, in responding to processes in their environment, organisations will look for opportunities to acquire new resources, they will copy the behaviour of other organisations, and they will symbolically comply with demands from organisations they depend upon. These responses may occur simultaneously or separately, and be premeditated or unintended.

While investigating the exchange relationships between research departments and their offspring, and the impacts of these relationships, both resource dependence and new institutional theory proved to be useful. New institutional theory assumes that organisations need to maintain exchange relationships with other organisations in their environment, and focuses on the adherence to norms and rules in the environment (DiMaggio & Powell, 1983; J. W. Meyer & Rowan, 1977; Scott, 1987b). Resource dependence theory focuses on how organisations manage their access to resources and under which circumstances they are willing to adapt their behaviour to acquire resources (Pfeffer & Salancik, 1978). Both theories show that organisations will persist in their behaviour if this is allowed by organisations in their environment. Complying with demands from spin-off companies, which generally offer only little in terms of resources, could have induced changes in the research departments' core activities. From a resource dependence perspective, this would have endangered the acquisition of resources by departments from other, more important, organisations in the environment. This explains why the research agendas, and also the research outputs, of research departments have not been significantly affected by the relationships with spin-off companies except in situations where significant amounts of resources were acquired from spin-off companies, because in such cases, spin-offs did become important resource sources. The institutional perspective can also explain the stability of the research portfolios. Research departments risk endangering their reputation if they take account only of industrial demands, and communicate to organisations in their environment that their goal is to solely produce scientific knowledge. We have seen, in our study, that there may be occasions when resource dependencies become so strong that research departments will change their outputs and agendas in order to remain eligible for funding from industry. In such cases, earlier motivations of stability and persistence make way for resource-based motivations so that significant amounts of resources are acquired, and research agendas and research outputs change.

12.2.2 Implementation of the research model

The research model we developed, proved to be useful in providing a framework to explain how research portfolios of research departments can be affected by external organisations such as spin-off companies. The research model distinguishes between the preferences and resources of research departments on the one hand, and the potential resources and demands of organisations in their environment on the other. In so doing, the research model helped us to show how research departments balance their own preferences with the demands of other organisations in their environment.

The research model provided indications of how scientific knowledge production could be affected by relationships with industry. We found in our empirical investigations that such relationships can impact on the research portfolios of research departments through various mechanisms. Research departments may anticipate demands and respond pro-actively to expected demands from spin-offs and other organisations. Departments may also be forced to change their research agendas because of the direct demands of companies involved in research projects, or departments may be inspired by new ideas and incorporate them into their research agendas. Other mechanisms also exist. Companies may support a research line of a research department, thereby disregarding other lines of research in which they are not interested. Equally, when spin-offs are created, research departments may need to let go of researchers that are of interest to these spin-off companies, thereby losing expertise in one or more of their research lines. Outsourcing of development activities to industry is yet another mechanism through which research agendas and outputs may be altered. Looking at publication outputs, relationships with industry affect the research portfolio in various ways. Relationships with industry may lead to additional research capacity and, as a result of that, to additional publications. The presence of spin-offs may lead to greater chances of success when applying for government grants, thus indirectly contributing to additional publications. Further, collaborations with spin-off companies may give departments access to valuable information as input to the research process leading to higher research quality, thereby improving the likelihood of success when submitting publications.

12.2.3 Contributions to scholarly debates

In Chapter 1 we showed that notions such as the New Production of Knowledge (Gibbons et al., 1994) and the Triple Helix Model (Leydesdorff & Etzkowitz, 1996) claim that scientific knowledge production is increasingly motivated and steered by societal demands, and that collaboration between science and industry is intensifying. While the Triple Helix Model suggests that public research organisations will retain their core research and teaching activities and supplement these with knowledge transfer and commercial activities, the New Production of Knowledge expects boundaries between scientific researchers and societal actors to disappear and knowledge production to become increasingly application-oriented. As researchers are increasingly interacting with industry, the New Production of Knowledge view also expects research outputs to change and that research agendas will become increasingly influenced by industrial research partners, especially when they collaborate directly with industrial organisations. The Triple Helix Model, on the other hand, expects that even though the academic system has significantly increased its communication and interaction with other subsystems in society, core academic activities such as publishing will be chiefly untouched by these activities. In this view, research commercialisation and collaboration with industry will supplement traditional activities.

Our investigations found that the impact of relationships with industry on research agendas and research outputs, i.e., the core characteristics of academic life, is limited. Even though industrial research partners have become more important for research departments, other organisations in the environment are generally far more important for the departments' survival. Only in cases where large amounts of resources are at stake are core characteristics, such as research agendas and research outputs somewhat affected. For most research departments, it is evident how they should advance their interests, and this is by conducting excellent research that has a degree of societal relevance, either directly by engaging in research projects with industry, or indirectly because of the societal problems that the research addresses. In so doing, research departments are accommodating the demands for societal relevance within their research activities. Even in cases where spin-off companies do fund a large part of research portfolios, traditional scientific criteria are still paramount and are likely to remain so as long as funding agencies as well as industry itself attributes importance to traditional scientific criteria and as long as scientific criteria remain one of the key criteria for promotion in a scientific career.

Boundaries between academia and other parts of society are only partially blurring. On the one hand, this study shows that research departments and public research organisations have increasingly engaged in research commercialisation, and are very open to funding from industry in order to supplement their increasingly strained research budgets. The majority of the researchers we spoke to, felt that interactions with industry had become a normal part of life. On the other hand, this study shows that scientific knowledge production has not become a process in which the activities of industry and scientific researchers have become fully integrated. In other words, we still find a distinct division of labour in cases where research departments collaborate with industry. Industry focuses on development activities that add commercial value to their activities, while research departments largely focus on basic and long-term research problems. Most departments use their spin-offs to acquire and legitimise the acquisition of funding, or to acquire test data or access to materials and research equipment. In so doing, research departments make clever use of their spin-offs to enhance their research capacity, to enhance their publication outputs, and to advance their research activities in directions they think are of importance for their future survival. So, while boundaries may be blurring as regards the additional activities in which scientific researchers and research institutes are engaging, on the shop-floor, activities of industry and the research community still appear to be very much delineated. In some cases, spin-offs sometimes actually help to once more delineate the boundaries between the academic system and industry by taking over development activities that research departments believe should not be conducted at universities. Boundaries may be blurring somewhat, but institutional spheres remain intact and scientific researchers remain principally committed to the production of scientific publications.

Taking these aspects into account, this study provides perhaps a somewhat sobering message for proponents of the New Production of Knowledge who expect increasingly interactive forms of knowledge production, the disappearance of boundaries between the academic system and other parts of society, and a shift towards application-oriented research. The findings outlined above make the Triple Helix Model a more convincing approach for understanding the changes that the academic system is going through. Even though scientific researchers and public research organisations are stepping outside the traditional academic boundaries and are increasingly interacting with other organisations in society, the core characteristics of academic research are hardly affected when we look at science-industry relationships. Additionally, we find that there is still a distinct division of labour when it comes to collaboration in research projects. The academic system, as a subsystem of society, still enjoys a high degree of autonomy. Academia, industry and government, i.e., systems with different goals, logics and practices, are increasingly communicating and interacting with each other. However, this has not forced scientific researchers to capitulate to demands from other societal sub-systems. Additional checks and balances have been introduced that allow demand articulation and a better insight into the taxpayers' money that is spent on scientific research

The fact that we did not find evidence of significant changes in either the core characteristics of research departments or in the division of labour, does not mean that, in the long term, some changes will not occur. Given the expectations generated by resource dependence theory and new institutional theory, one could suppose that the academic system, over time, will need to take account of the needs and wishes of other subsystems in society if these subsystems come forward with more explicit and stringent demands. As such, research departments that are active in fields that have funding structures that encourage science-industry interaction may, in the long run, be induced to change their research outputs and their basic versus applied research balance in order to maintain their long-term viability. Typically, these types of changes occur very gradually. In the past twenty to thirty years we have witnessed such long-term change processes. For instance, thirty years ago it was still uncommon for most academic researchers to file a patent based on publicly-funded research. The current generation of researchers, who are in their early-careers, receive their scientific education in a world with different values than those from twenty years ago. Patenting by scientific researchers has become a common phenomenon (Baldini, 2006). As a result of the changed environment in which they now conduct research, researchers will be less hesitant in following the demands of companies, especially when government rewards them to do just that.

12.3 Openings for further research and implications for policy

This study aimed to provide a detailed look into the relationships between research departments and spin-off companies and the impacts of such relationships on the production of scientific knowledge. We now know more about the type and the intensity of the relationships, the barriers and the enablers for academics to engage in relationships with their offspring, and the impacts of these relationships on the research portfolios of research departments.

12.3.1 Future research

The two organisational theories employed in this study, resource dependence theory (Pfeffer & Salancik, 1978) and new institutional theory (J. W. Meyer & Rowan, 1977), were helpful in describing how research portfolios of research departments may be affected by relationships with organisations in their environment and why research agendas and research outputs remain relatively unaffected under most circumstances. This study demonstrates that future investigations into the research activities of public research organisations and research departments could benefit from the use of organisational theories since these enable one to hypothesise about causes of change and stability in the behaviour of research organisations. The research model that we employed provides a basis on which to investigate under what circumstances the behaviour of research organisations will or will not change, and when research organisations will adapt or will not adapt their behaviour to address processes in their environment.

Studies into knowledge transfer activities and research commercialisation, and their effects on scientific knowledge production may benefit from investigating other countries and different scientific fields. From the ProKnow-Project we already know that, across different European countries, the relationships between research departments and spin-offs are of a low intensity.[63] Further, the impacts of the relationships with spin-offs across the countries in this study were also very small. Future cross-national studies could provide greater insight into the effects of different governance structures on the establishment of relationships

[63] This study was conducted under the aegis of the EU sixth-framework project ProKnow. In addition to the Netherlands, data were collected in six other countries: Bulgaria, Finland, France, Germany, Switzerland and the United Kingdom.

between research departments and spin-offs, and the impacts of these relationships on the production of scientific knowledge. As observed in the empirical chapters, the biomedical cases differed significantly from the computer science and nanoscience and technology cases. Investigations in other scientific fields may produce additional insights because of the epistemic characteristics of these fields, the business sectors that they are connected with, or the science policies and funding instruments that govern them.

12.3.2 Implications for policy

In recent decades, policymakers have presented public research organisations with an increasing number of checks and balances in order to increase the capacity to steer scientific research and to obtain more insight into the performance of the academic system. Government research funding is increasingly geared towards stimulating knowledge transfer between academia and society as a way of increasing the innovative potential of private enterprises. Government policies encouraging knowledge transfer and research commercialisation have led to mixed results. Public research organisations and government agencies have invested considerable resources and time in supporting research commercialisation, specifically the creation of spin-off companies. Still, most of the public research organisations do not benefit financially, or only in a limited way, from the creation of spin-off companies. Other studies also point to the fact that the benefits for public research organisations, in terms of resources, do not cover the expenses of most technology transfer activities (Mowery, 2001; Mustar et al., 2008). At the same time, our findings show that although the benefits for research institutes may be limited, researchers in these institutes can use their spin-off companies to persuade funding agencies to provide them with research funding. Our research also shows that relationships that are not well-managed can lead to conflicts. Such conflicts will inhibit the willingness of researchers to engage in future collaborations with industry.

In stimulating knowledge transfer and research commercialisation, the EU and most of its member states take a different approach from the US. The US research system is relatively decentralised and science and innovation policies in the US are chiefly focused on getting the incentives right for researchers to commercialise their results and by letting them experiment. EU member states, the Netherlands including, in contrast, attempt to create the mechanisms through which commercialisation of research is to occur. Such an approach may hamper harvesting the full potential of research output in EU member states (Goldfarb &

Henrekson, 2003). In the EU, more than in the US, the believe exists that the government should provide policies for knowledge transfer mechanisms top-down. The question is to what extent this is useful. In the Netherlands, for instance, policymakers aimed to increase knowledge transfer through science-industry research programmes and programmes targeted directly at research commercialisation. More and more, it looks like science-industry collaboration has become a goal on its own for policymakers, thereby superseding the goal of actually increasing the absorption of academic knowledge by industry in order to create innovations in products and services. In the long term, substantial goal achievement should be achieved with concern to the policy instruments that aim to encourage science-industry knowledge transfer. This implies that policymakers should be aware of the mechanisms of how incentives do work or do not work with regard to science-industry knowledge transfer. Too often, large-scale government-initiated research programmes, that finance researchers and private enterprises to create public-private partnerships, lead to symbolic collaboration and ad hoc consortia whose lifespan is limited to period in which such consortia receive funding. Additionally, creating top-down roadmaps that invest in research themes popular with industry limit the abilities of scientific researchers to find funding for 'innovative' research topics that are not yet interesting for industry. In enhancing collaboration with industry it is probably far more effective to get the incentives right at the level of the individual researchers and the research organisations they are part of. Looking from an industrial perspective, the existing literature also provides evidence that policymakers should be careful in stimulating science-industry collaborations top-down. First of all, this study shows, as do studies from Laursen and Salter (2004), Mohnen and Hoareau (2003), and Fontana et al. (2006), that firm size and industrial sector are dominant factors as regards the type and the intensity of science-industry collaborations. This implies that when industry is interested in knowledge from academia it should be supported in its capacity to absorb that knowledge and be supported in setting up sustainable long-term innovation trajectories. This will especially help SMEs that have, on average, smaller capacities and smaller amounts of resources to put academic knowledge to commercial use. Further, for national instruments to be effective in creating science-industry collaborations, the characteristics of public research organisations and industry that exist locally need to be taken into account. This implies that different strategies should be applied when dealing with different business sectors. A 'one size fits all'-approach in subsidising large-scale thematic research programmes, in which industry should participate, often will not work.

Policymakers tend to emphasize the production of patents, licensing of patents and the creation of spin-off companies when supporting science-industry collaboration and research commercialisation. However, most knowledge within public research organisations cannot be patented (Geuna & Musico, 2009), and only 17% of R&D performing companies consider patents an at least moderately important source of knowledge (Cohen et al., 2002). Companies rely on a variety of sources as regards knowledge from public research organisations, and none of these sources play a dominant role (Arundel & Geuna, 2004; Cohen et al., 2002). In addition, it is not evident that creating spin-off companies is a more efficient way of knowledge transfer than licensing knowledge from public research organisations to existing industry. On the contrary, mobility of researchers, informal contacts within professional networks and the flow of graduates to industry are far more important ways of knowledge transfer with industry (OECD, 2002). As a result, policymakers who want to enhance the contribution of public sector research to the economy, should invest more into more informal, less easily standardised ways of science-industry collaboration.

Nederlandstalige samenvatting

Wetenschappelijke kennis wordt vandaag de dag gezien als een belangrijke basis voor economische vooruitgang en maatschappelijke welvaart. Publieke kennisinstellingen in Nederland zijn in toenemende mate actief om kennis over te dragen aan de maatschappij en om hun wetenschappelijke kennis commercieel te exploiteren. In Nederland wordt dit proces ook wel kennisvalorisatie genoemd. In de afgelopen jaren zijn publieke kennisinstellingen in Nederland en in het buitenland in toenemende mate hun kennis gaan valoriseren. De toegenomen kennisvalorisatie door kennisinstellingen wordt door beleidsmakers over het algemeen als zeer positief ervaren. Kennisvalorisatie is een blijk van interactie met de maatschappij en uitwisseling van kennis die tot innovatie leidt. Voor wetenschappers kan kennisvalorisatie extra inkomsten betekenen. Ook kan het leiden tot een grotere onderzoekscapaciteit en toegang tot informatie die waardevol is in het wetenschappelijk onderzoek. Tegelijkertijd heeft de toegenomen kennisvalorisatie ook geleid tot een debat over de mogelijke negatieve effecten. Kennisvalorisatie door wetenschappers, zoals contractonderzoek voor het bedrijfsleven zou de autonomie van het wetenschappelijk onderzoek kunnen aantasten. Financiering van onderzoek door bedrijven zou kunnen leiden tot overmatige vraagsturing door het bedrijfsleven, geheimhouding van resultaten en uiteindelijk een verslechtering van de kwaliteit van onderzoek.

Om meer inzicht te krijgen in de mogelijke effecten van kennisvalorisatie op wetenschappelijk onderzoek, richt deze studie zich op bedrijven die zijn ontstaan uit wetenschappelijke onderzoeksgroepen, zogeheten spin-off bedrijven. Vaak blijven deze bedrijven relaties onderhouden met de onderzoeksgroepen waaruit ze zijn ontstaan. Deze studie is specifiek geïnteresseerd in de impacts van de relaties tussen onderzoeksgroepen en spin-offs op de onderzoekscapaciteiten, onderzoeksagenda's en onderzoeksresultaten. Deze drie onderwerpen vormen samen het onderzoeksportfolio van een onderzoeksgroep.

De centrale onderzoeksvraag in deze studie luidt als volgt:

> Als onderzoeksgroepen spin-off bedrijven helpen te creëren, blijven ze dan relaties onderhouden met deze bedrijven en wat zijn de impacts van deze relaties op de onderzoeksportfolios van onderzoeksgroepen?

Deze centrale onderzoeksvraag is verder uitgewerkt in de volgende zes deelvragen:

R1. Wat kan de literatuur ons vertellen over de impact van valorisatie activiteiten op de onderzoeksportfolios van onderzoeksgroepen?

R2. Welke theorieën kunnen ons helpen om de relaties te beschrijven tussen spin-off bedrijven en onderzoekgroepen, alsmede de impacts van deze relaties op de onderzoeksportfolios van onderzoeksgroepen?

R3. Wat is de rol van de omgeving in het tot stand komen van de relaties tussen spin-off bedrijven en onderzoeksgroepen?

R4. Onderhouden onderzoeksgroepen relaties met hun spin-off bedrijven en zo ja, van welke type en intensiteit zijn deze relaties?

R5. Wat is de impact van de relaties tussen onderzoekgroepen en hun spin-off bedrijven op de onderzoeksportfolios van deze onderzoeksgroepen?

R6. Welke verschillen kunnen worden waargenomen in de relaties tussen onderzoeksgroepen en hun spin-off bedrijven en de impacts van dergelijke relaties op de onderzoeksportfolios? Kunnen de variaties verklaard worden door disciplinaire en organisatorische achtergronden?

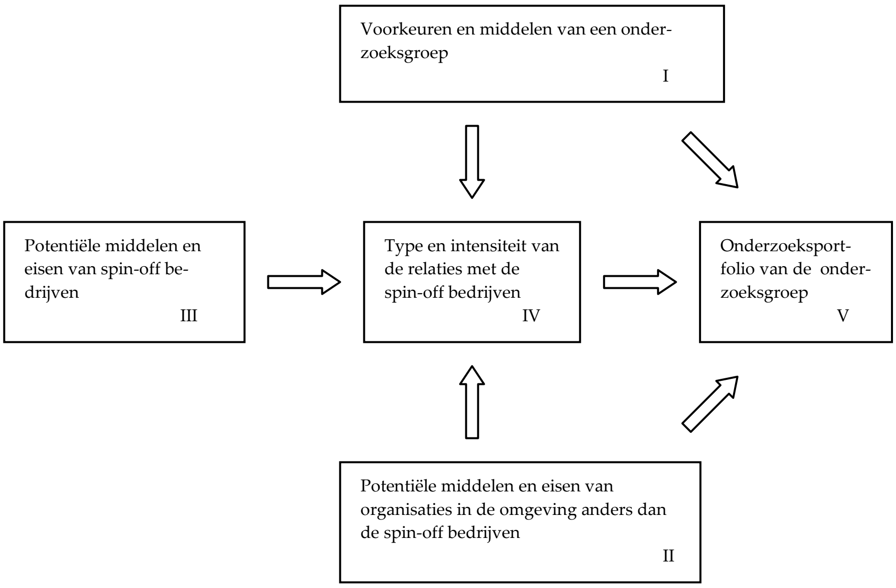
Deze onderzoeksvragen zijn beantwoordt door acht onderzoeksgroepen binnen vijf onderzoeksinstituten te onderzoeken. In deze studie is gekozen voor drie wetenschappelijke disciplines: biomedische wetenschappen, informatica, en nanowetenschap en-technologie. De relaties tussen vijftien spin-off bedrijven en hun onderzoeksgroepen zijn onderzocht alsmede de impacts van deze relaties op de onderzoeksportfolios. Er is data verzameld door interviews te houden met vertegenwoordigers van de spin-off bedrijven en onderzoekers van de onderzoeksgroepen. Tevens zijn er financiële gegevens verzameld, interne documenten en onderzoeksevaluaties.

Literatuur

De bestaande literatuur stelt dat samenwerking met industrie bijdraagt aan de onderzoekscapaciteit van wetenschappers en wetenschappers voorziet van informatie en onderzoeksapparatuur. Het aanvragen van octrooien lijkt niet te leiden tot een vergroting van de financiële middelen van de meeste wetenschappers. De meeste studies stellen dat kennisvalorisatie niet schadelijk is voor de open communicatie van uitkomsten van wetenschappelijk onderzoek. Studies binnen de medische wetenschappen laten echter minder geruststellende resultaten zien; onderzoek leidt in sommige gevallen tot geheimhouding. Financiering door industrie lijkt samen te hangen met toegepast onderzoek. Verder hangt financiering door industrie samen met een hoger aantal publicaties en een hogere onderzoekskwaliteit. Eerdere studies hebben zich nagenoeg niet gericht op de gevolgen van het creëren van spin-off bedrijven en de samenwerking met spin-off bedrijven op wetenschappelijk onderzoek. De weinige studies op dit gebied wijzen er op dat spin-off bedrijven gerelateerd zijn aan een hogere onderzoeksproductiviteit. Het is echter nog onduidelijk of spin-off bedrijven daadwerkelijk bijdragen aan de productiviteit van onderzoekers of dat succesvolle onderzoekers al succesvoller waren voor het ontstaan van de spin-off bedrijven. Bovendien zou onderzoek naar de impacts van spin-off bedrijven verbreed kunnen worden naar impacts op onderzoeksagenda's en onderzoekscapaciteiten. Verder zouden bestaande studies naar de impacts van kennisvalorisatie kunnen profiteren van theoretische perspectieven die nu nog nagenoeg geheel ontbreken in deze studies.

Theorie en onderzoeksmodel

Twee theorieën vormen de basis voor het onderzoeksmodel dat is ontwikkeld voor dit onderzoek: 'resource dependence theory' (Pfeffer & Salancik, 1978) en 'new institutional theory' (J. W. Meyer & Rowan, 1977). Het onderzoeksmodel dat is ontwikkeld (zie onderstaand figuur) maakt ten eerste een onderscheid tussen de voorkeuren en de middelen van een onderzoeksgroep (vak I), de potentiele middelen en eisen die organisaties in de omgeving van de onderzoeksgroep hebben (vakken II en III). Op basis van deze factoren gaat een onderzoeksgroep relaties aan met spin-off bedrijven (vak IV). Een onderzoeksgroep zal relaties aangaan met spin-off bedrijven om toegang te krijgen tot middelen zoals informatie, geld en onderzoeksapparatuur. Tegelijkertijd zal de spin-off hier iets voor terug vragen, bijvoorbeeld kennis uit de onderzoeksgroep. Omdat een onderzoeksgroep afhankelijk is van meerdere organisaties in haar omgeving om te overleven, zal de onderzoeksgroep niet zondermeer altijd relaties aangaan met een spin-off bedrijf. Een onderzoeksgroep kan namelijk kiezen uit verschillende bedrijven en de eisen van andere bedrijven zijn wellicht makkelijker in te willigen dan die van de spin-off bedrijven. De relaties met de spin-off bedrijven kunnen een impact hebben op het onderzoeksportfolio van een onderzoeksgroep (vak V), maar vinden altijd plaats in een groter geheel waarin ook de voorkeuren en middelen van een onderzoeksgroep, alsmede de potentiële middelen en eisen van andere organisaties een rol spelen.



Het onderzoeksmodel

Relaties tussen onderzoekgroepen en hun spin-off bedrijven

In deze studie zijn de relaties tussen acht onderzoeksgroepen en vijftien van hun spin-off bedrijven onderzocht. De resultaten uit dit onderzoek laten zien dat de meeste spin-off bedrijven in de buurt blijven van de onderzoeksgroepen waaruit ze zijn voortgekomen en dat ze op uiteenlopende wijze en met verschillende intensiteit samenwerken.

De oprichting van een spin-off bedrijf leidde altijd tot informele relaties waarin de testgegevens, instrumenten of prototypes worden uitgewisseld. Een kleine minderheid van de spin-off bedrijven in onze studie voorzag de onderzoeksgroepen van financiering middels contractonderzoek. Echter, geen van de bedrijven doneerde alleen maar geld om hiervoor vervolgens niets voor terug te eisen. Over het algemeen komt contractonderzoek weinig voor omdat de meeste spin-off bedrijven niet de financiële middelen hebben om rechtstreeks te investeren in langlopende wetenschappelijke onderzoeksprojecten. In het geval van drie onderzoeksgroepen in de biomedische wetenschappen, waren spin-off bedrijven wel in staat om grote financiële bijdragen te leveren omdat de spin-off bedrijven de beschikking hadden over aanzienlijke hoeveelheden financiële middelen. Overheidsfinanciering is een wijdverbreide manier voor spin-off bedrijven om de relaties met onderzoeksgroepen te intensiveren. Nagenoeg alle spin-off bedrijven nemen deel aan overheids-gefinancierde onderzoeksprojecten samen met de onderzoeksgroepen waar ze uit voort zijn gekomen.

Spin-off bedrijven uit de biomedische hoek hadden de meest intense relaties met de onderzochte onderzoeksgroepen. Het merendeel van de biomedische spin-off bedrijven bezitten relatief grote onderzoeksbudgetten en zijn bereid om directe investeringen te maken in wetenschappelijk onderzoek. De relaties tussen de informatica onderzoeksgroepen en hun spin-off bedrijven waren van een lage intensiteit. De spin-off bedrijven, die ontstaan zijn uit de informatica onderzoeksgroepen hebben over het algemeen een bescheiden omvang, en hebben een sterke voorkeur voor korte termijn onderzoek en concrete ontwikkeling van producten. Bovendien zijn hun onderzoeksbudgetten veel beperkter dan die van de biomedische spin-off bedrijven. De relaties met de nanowetenschap en-technologie spin-off bedrijven waren van een lage tot gemiddelde intensiteit. De veelal kleine bedrijven beschikken niet over de financiële middelen om te investeren in langlopende onderzoeksprojecten. Als gevolg daarvan, waren de relaties tussen de spin-off bedrijven en de nanowetenschap en-technologie onderzoeksgroepen niet significant in termen van de directe middelen. De participatie in overheids-gefinancierde projecten was daarentegen veelvoorkomend.

De rol van de omgeving in het aangaan van relaties met spin-off bedrijven

Kijkend naar de effecten van de organisatorische achtergronden van de onderzoeksgroepen op de relaties, kan geconcludeerd worden dat de onderzoeksgroepen met de meest uitgebreide ondersteuning voor kennisvalorisatie niet per definitie ook de meest intensieve relaties hebben met spin-off bedrijven. De grootte van een bedrijf en de onderzoeksbudgetten van een bedrijf zijn veel belangrijker als het gaat om de intensiteit van de relaties. Grotere bedrijven met aanzienlijke onderzoeksbudgetten en een lange termijn onderzoeksvisie konden zich veroorloven om grote investeringen te maken, terwijl kleinere bedrijven vooral bezig waren met overleven en meer praktische ontwikkelingsactiviteiten. Ondersteunende structuren voor kennisvalorisatie leiden niet noodzakelijkerwijs tot een hogere intensiteit van de relaties, noch een stijging van de financiële middelen die onderzoeksgroepen tot hun beschikking hebben doordat ze spin-off bedrijven hebben gecreëerd.

In vijf van de acht onderzoeksgroepen heeft overheidsfinanciering geleid tot een toename van de geformaliseerde relaties tussen onderzoekgroepen en hun nakomelingen. Toch moet de invloed van overheids-gefinancierde onderzoeks- en innovatieprojecten op de intensiteit van de relaties niet worden overdreven. Onderzoeksgroepen onderhielden al informele relaties met hun spin-offs voordat ze begonnen samen te werken in de overheids-gefinancierde projecten. Daarom kan gesteld worden dat de brede deelname van spin-off bedrijven in de overheids-gefinancierde onderzoeksprojecten instrumenteel was in het creëren van een platform voor samenwerking. Samenwerking in deze projecten verbetert de onderzoeks- en ontwikkelingscapaciteit van beide typen organisaties en creëert een basis voor een meer uitgebreide samenwerking. Maar meestal zouden de relaties tussen de onderzoeksgroepen en hun spin-off bedrijven toch hebben bestaan, zij het wellicht in een minder intensieve vorm.

De impacts van spin-off bedrijven op wetenschappelijk onderzoek

Welk effect hebben spin-off bedrijven op onderzoeksgroepen? Spin-off bedrijven leveren op verschillende manieren een bijdrage aan de onderzoekscapaciteit van de onderzoeksgroepen waar ze vandaan komen. Spin-off bedrijven voorzien onderzoeksgroepen onder andere van testgegevens, inspiratie voor nieuwe en relevante onderzoeksproblemen en onderzoeks-apparatuur. Slechts een klein aantal spin-off bedrijven genereert aanzienlijke rendementen voor kennisinstellingen. Aan de andere kant laat deze studie wel zien dat op het niveau van de onderzoeksgroepen, spin-off bedrijven belangrijke financiële bijdragen kunnen leveren. Bepaalde, veelal grotere, spin-off bedrijven die beschikken over aanzienlijke financiële middelen, kunnen significante bijdragen leveren aan de onderzoekscapaciteiten van wetenschappelijke onderzoeksgroepen. Maar de directe bijdragen aan de onderzoeksgroepen zijn niet de enige manier waarop spin-off bedrijven gunstig zijn voor onderzoeksgroepen. Spin-offs steunen onderzoeksgroepen bij het verwerven van overheidsfinanciering. Voor de overheid zijn spin-off bedrijven een teken dat onderzoeksgroepen kennis produceren met commerciële potentie. Dus terwijl de meeste spin-off bedrijven niet rechtstreeks bijdragen aan de financiële middelen van onderzoeksgroepen, is hun aanwezigheid in overheids-gefinancierde zeer lonend voor wetenschappers.

Spin-off bedrijven inspireren de onderzoeksthema's van onderzoeksgroepen. Echter, in de meeste gevallen, dienen onderzoeksgroepen geen sterke rekening te houden met de spin-off bedrijven waar ze mee samenwerken. Andere organisaties en mensen in de omgeving van onderzoeksgroepen, zoals andere bedrijven, NWO, en de 'peers' van wetenschappers zijn veel belangrijker voor onderzoeksgroepen in de meeste gevallen. Echter, in gevallen waar aanzienlijke hoeveelheden financiële middelen ontvangen worden door onderzoeksgroepen, worden onderzoeksthema's weldegelijk beïnvloed door spin-off bedrijven. In dergelijke gevallen, onderhandelen onderzoeksgroepen met spin-off bedrijven over de exacte onderzoeksthema's. Spin-offs zijn dan ook vaak betrokken bij de besluitvorming tijdens onderzoeksprojecten. In sommige gevallen kan contractonderzoek voor spin-off bedrijven leiden tot uitstel van onderzoeksresultaten om de spin-off bedrijven in staat te stellen om intellectuele-eigendomsrechten te waarborgen. Het contractonderzoek dat de onderzoeksgroepen uitvoerden voor de spin-off bedrijven leidde echter niet tot geheimhouding van bepaalde onderzoeksresultaten. Wat betreft de mogelijke verschuivingen naar toegepast onderzoek is er geen bewijs gevonden dat de relaties van onderzoekers met spin-off bedrijven leiden tot een verschuiving. Bij het aangaan van relaties met het bedrijfsleven, kiezen onderzoeksgroepen ervoor om organisaties te selecteren die passen bij hun voorkeuren. Derhalve zijn de impacts van de relaties op dit gebied zeer beperkt. In sommige gevallen geeft de creatie van spin-off bedrijven zelfs de mogelijkheid om ontwikkelingsactiviteiten buiten de onderzoeksgroep te laten plaatsvinden. Onderzoeksgroepen kunnen zich daarna meer richten op wetenschappelijk onderzoek. Als er verschuivingen naar meer toegepast onderzoek zullen optreden als gevolg van relaties met industrie, dan zullen deze verschuivingen waarschijnlijk pas over een langere periode zichtbaar worden en zal zoiets alleen plaatsvinden wanneer meerdere externe organisaties en de onderzoeksgroepen zelf geïnteresseerd zijn in het verschuiven van hun onderzoek naar meer applicatie-gerichte activiteiten.

Relaties met spin-off bedrijven, en industrie in het algemeen, leiden niet tot meer octrooien, prototypes of klinische applicaties. Onderzoeksgroepen die samenwerken met industrie zijn gemiddeld al actiever in de productie van dergelijke zaken. Onderzoeksgroepen die intense relaties met spin-off bedrijven onderhouden kunnen hun publicatie-aantallen aanzienlijk verhogen. Tegelijkertijd blijkt uit dit onderzoek dat als onderzoeksgroepen relaties aangaan met bedrijven, hun afhankelijkheid van het bedrijfsleven zeer bepalend is voor de eventuele invloed dat een bedrijf kan uitoefenen. Ondanks de toegenomen aandacht voor kennisvalorisatie en de samenwerking van onderzoeksgroepen met spin-off bedrijven, blijft voor onderzoeksgroepen het produceren van wetenschappelijke publicaties de belangrijkste vorm van onderzoeksresultaten. Relaties met spin-off bedrijven lijken niet nadelig te zijn voor de kwaliteit van onderzoek maar lijken veel eerder de kwaliteit van onderzoek te versterken.

Voor de meeste onderzoeksgroepen betreffen de relaties met spin-off bedrijven vaak slechts een fractie van hun totale set aan onderzoeksactiviteiten. Hoewel spin-off bedrijven aantrekkelijke partners zijn om mee samen te werken, zijn spin-off bedrijven niet de enige potentiële onderzoekspartners voor onderzoekgroepen. Onderzoeksgroepen kunnen kiezen uit een breed scala aan ondernemingen. Resource dependence theorie stelt dat wanneer organisaties kunnen kiezen uit meerdere organisaties, ze meer controle hebben over de eisen van de organisaties waar ze mee samenwerken door het selecteren van organisaties die het best voldoen aan hun voorkeuren. Dit beperkt de mogelijkheden van spin-off bedrijven om samen te werken met onderzoekgroepen en beperkt de invloed op de onderzoeksagenda's en de onderzoeksresultaten van de onderzoeksgroepen.

Het vermogen van spin-off bedrijven om een impact te hebben op de onderzoeksportfolios van onderzoeksgroepen hangen meestal af van het vermogen van spin-off bedrijven om onderzoek direct te financieren. Daarnaast zijn onderzoeksgroepen nog steeds hoofdzakelijk geïnteresseerd in het beschermen en uitbouwen van hun wetenschappelijke reputatie. Zonder hun wetenschappelijke reputatie en publicaties, zullen onderzoeksgroepen het moeilijk vinden om overheidsfinanciering te verwerven en zal het bedrijfsleven überhaupt niet geïnteresseerd zijn in de kennis van onderzoeksgroepen. Als gevolg hiervan is het, zelfs in gevallen waar grote hoeveelheden financiële middelen worden verkregen door onderzoeksgroepen, mogelijk voor onderzoeksgroepen om zich te richten op hun wetenschappelijke interesses en het uitvoeren van wetenschappelijk onderzoek.

Relaties met spin-off bedrijven, hun invloed op onderzoeksportfolios en de rol van de disciplinaire en organisatorische achtergronden

De relaties tussen de spin-off bedrijven en onderzoeksgroepen zijn uiteenlopend. Biomedische onderzoeksgroepen onderhielden soms zeer intense relaties met hun spin-off bedrijven en meldden ook significante impacts op hun onderzoeksportfolios. Andere onderzoeksgroepen, in de computerwetenschappen en de nanowetenschap en –technologie, onderhielden minder intensieve relaties en deze relaties had over het algemeen zeer weinig invloed op de onderzoeksportfolios. Biomedische bedrijven bezaten relatief grote onderzoeksbudgetten en hadden een voorkeur voor lange termijn onderzoek ten opzichte van de spin-off bedrijven in de computerwetenschappen en nanowetenschap en-technologie. Dus de disciplinaire kenmerken van de onderzoeksgroepen op zich zijn niet dominant in het bepalen van de intensiteit van de relaties en de impacts op de onderzoeksportfolios. Veel belangrijker zijn de kenmerken van de bedrijven in deze wetenschappelijke gebieden. Organisatorische achtergronden van de onderzoeksgroepen lijken geen invloed te hebben op de intensiteit van de relaties en de effecten van deze relaties op de onderzoeksportfolios. Onderzoeksgroepen in de twee geselecteerde biomedische onderzoeksinstituten onderhielden de meest intense relaties met spin-off bedrijven. Deze onderzoeksinstituten had een relatief korte traditie in het ondersteunen van kennisvalorisatie activiteiten en waren tot voor kort gericht op relatief fundamenteel onderzoek. Twee onderzoeksinstituten met relatief goed ontwikkelde structuren voor kennisvalorisatie onderhielden juist minder intense relaties met hun spin-off bedrijven. Blijkbaar zijn andere factoren dan de organisatorische omgeving belangrijker in het bepalen van de intensiteit van de relaties tussen onderzoeksgroepen en hun spin-off bedrijven. De belangrijkste factoren in dit opzicht lijken de kenmerken van de spin-off zelf te zijn.

Appendix I: List of abbreviations

AUTM	Association of University Technology Managers
AWT	Advisory Council for Science and Technology
BSIK	Successor of ICES/KIS programme
DLOs	Agricultural Research Institutes
EC	European Commission
EPO	European Patent Office
EU	European Union
FTE	Full-time Equivalent
GTIs	Large Technological Institutes
ICES/KIS	Economic Reinforcement Fund that promotes PPPs between public research organisations and business
IOP	Innovation Oriented Research Programmes
IP(R)	Intellectual Property (Right)
KNAW	The Royal Netherlands Academy of Arts and Sciences
KWF	The Dutch Cancer Society
LSBR	Landsteiner Stichting voor Bloedtransfusie Research
LTIs	Leading Technological Institutes
NFU	The Dutch Federation of University Medical Centers
NWO	The Netherlands Organisation for Scientific Research
OECD	Organisation for Economic Co-operation and Development
OTP	The Open Technology Programme administered by STW
PCT	Patent Cooperation Treaty
PNPs	Private non-profit organisations
PPPs	Public-private partnerships
QANU	Quality Assurance Netherlands Universities
R&D	Research and development
RAE	Research Assessment Exercise
SenterNovem	Agency of the Ministry of Economic Affairs
SME	Small- to Medium-Sized Enterprise
STW	Foundation for the Technical Sciences
TNO	Netherlands Organisation for Applied Scientific Research
TI Pharma	Top Institute Pharma
VNO-NCW	Confederation of Netherlands Industry and Employers
VSNU	Association of Universities in the Netherlands
WRR	Scientific Council for Government Policy
ZonMW	The Netherlands Organisation for Health Research and Development

Appendix II: List of interviewees

Cited interviewees in chapters 6-10

Code	**Function**	**Current employer**	**Formerly employed by:**
ML0.1	Technology transfer officer	MedLab	
ML0.2	Technology transfer officer	MedLab	
ML0.3	Technology transfer officer	MedLab	
ML1.1	Head of department	MedLab 1	
ML1.2	Group leader	MedLab 1	
ML1.3	Full professor and chief scientific officer	MedLab 1 and BIO1	
ML2.1	Full professor	MedLab 2	
PL0.1	Technology transfer officer	MedLab & PharmLab	
PL0.2	Business director	PharmLab	
PL1.1	Head of department	PharmLab 1	
PL1.2	Associate professor	PharmLab 1	
PL1.3	Post-Doctoral researcher	PharmLab 1	
BIO3.1	CEO	BIO3	PharmLab 1
BIO4.1	Chief scientific officer	BIO4	
II0.1	Technology transfer officer	ICT Institute	
II0.2	Scientific director	ICT Institute	
II1.1	Head of department	ICT Institute 1	
II1.2	Associate professor	ICT Institute 1	ICT1
ICT2.1	CEO	ICT2	
IL0.1	Business director	ICTLab	
IL0.2	Staff member accountancy	ICTLab	
IL1.1	Head of department	ICTLab 1	
IL1.2	Associate professor	ICTLab 1	
ICT3.1	CEO	ICT3	
ICT4.1	CEO	ICT4	
IL2.1	Head of department	ICTLab 2	
IL2.2	Associate professor, Chief Technology Officer	ICTLab 2, ICT5	

Cited interviewees in chapters 6-10 continued

IL2.3	Associate professor	ICTLab 2	
ICT6.1	CEO	ICT6	ICTLab 2
NL0.1	Technology transfer officer	NanoLab	
NL0.2	Scientific director	NanoLab	
NL1.1	Head of department	NanoLab 1	
NL1.2	Associate professor	NanoLab 1	
NANO1.1	Commercial director	NANO1	NanoLab
NANO2.1	CEO	NANO2	
NL2.1	Head of department	NanoLab 2	
NL2.2	Associate professor	NanoLab 2	NanoLab 1, NANO1, NANO5
NANO4.1	Commercial director	NANO4	
NANO5.1	CEO	NANO5	

Appendix III: Examples of interview protocols

IIIa: Example of interview protocol for scientific directors

Introduction: Aim and background of the study, aim of the interview

Spin-off companies

1. How many spin-off companies has the research institute helped to create?
2. Does the research institute support the creation of spin-off companies and knowledge transfer activities? How?
3. Which research departments have been active in the creation of spin-off companies in your institute?

Environment

4. Who are important stakeholders in the environment of the research institute?
5. What changes have occurred in the past twenty years in the environment of the research institute in terms of funding, the scientific field, and evaluation of the research institute by organisations in the environment?
6. Does the institute have board members from outside of academia?

Mission

7. How would you describe the culture within the research institute in respect to research and knowledge transfer activities?
8. What is the main mission of the research institute?
9. How important are knowledge transfer activities for the research institute in relation to research activities?
10. What changes have occurred in the mission, strategy and research focus of the research institute?
11. Did changes in the mission, strategy and focus of the research institute lead to changes in the research activities of the research departments?
12. What does the funding model of the research institute look like and what are the implications of this model for the research activities and knowledge transfer activities of research departments?

Research and knowledge transfer activities

13. What type of knowledge transfer and commercialisation activities has the research institute engaged in? And what has been the extent of these activities?
14. How would you describe position of the spin-off companies in relation to the total set of activities of the research institute?
    a. Central/peripheral
    b. Symbolic/vital
    c. Individual activity/ collective activity
    d. Tied to specific themes/omnipresent
15. What was the effect of the creation of spin-off companies on the reputation of the research institute?

IIIb: Example of interview protocol for technology transfer officers

Introduction: Aim and background of the study, aim of the interview

Spin-off companies

1. How many spin-off companies has the research institute helped to create?
2. Does the research institute support the creation of spin-off companies and knowledge transfer activities?
3. How has the support of knowledge transfer activities and commercialisation activities developed over time?
4. Which research departments have been active in the creation of spin-off companies in the research institute?

Mission, policies

5. Who are the most significant industrial research partners of the research institute?
6. Does the research institute maintain strategic partnerships with these organisations?
7. Does the funding model of the research institute facilitate and/or impede knowledge transfer and commercialisation activities?

IIIc: Example of interview protocol for researchers

Introduction: Aim and background of the study, aim of the interview

1. What is your function? And what are your daily activities as a researcher?
2. What research topics are you active on?
3. Would you describe your research department as focused on basic research, applied research or otherwise?

Preferences:

4. What kind of research would you prefer to conduct (basic vs. applied, as well as research topics)?
5. Are knowledge transfer activities important for you? Why?
6. What kind of research equipment do you need for your research and does this have an effect on the research topics you can choose to be active on?

The environment

7. Who are important stakeholders in the environment of the research department?
8. Could you briefly describe the relationships you have with these organisations and what they expect from your research department?
9. What does the funding model of the research institute look like and what are the implications of this model for the research activities and knowledge transfer activities of your research department?

Relationships with the spin-off companies

10. What kind of interactions does your research department have with spin-off x, spin-off y, …?
    a. Publications, patents, exchange of information, physical resources, prototypes, …
    b. Joint projects: contract research, government-funded projects
    c. Exchange of personnel
    d. Support of PhD projects, Master, and Bachelor theses
11. How often do employees of the spin-off company and the research department meet? What do they discuss and exchange?
12. Has the spin-off company paid for using the research institute's or research departments' laboratories, buildings and instruments?
13. What are the main reasons of the research department to collaborate with its spin-off companies?

   a. Is it to acquire money, information, to engage in joint publications, co-patenting, acquisition of physical resources, personnel, prototypes?
   b. Are they any other reasons?

14. To what extent does the environment of the research department facilitate and/or impede the relationship with the spin-off companies? (national and regional setting, regulations in and outside the research institute, institutional mission, funding allocation)
15. How would you describe the position of the spin-off companies in relation to the research activities of the research department?
    a. Central/peripheral
    b. Symbolic/vital
    c. Individual activity/ collective activity
    d. Tied to specific subjects/ omnipresent
16. Have there been moments of competition between the research department and the spin-off company?

Impact of the relationships on the research portfolio

17. Did the relationship with the spin-off companies have an impact on:

The direction of the research agenda

   a. Thematic and methodological shifts due to the relationship with the spin-offs
   b. Change in the research topics to more customer-driven or application oriented research

The composition of the research projects

   c. Number of research contacts
   d. Number of projects with public and private actors
   e. Amount of income from public and private research partners (did the presence of spin-off companies increase the participation in government-funded projects?
   f. Amount of income from national research councils and the EU

The academic output

   g. Number of publications in peer-reviewed journals (by increased capacity, better quality because of collaboration with so)
   h. Ratings in QANU research evaluations
   i. Reputation within relevant communities of research

Other research outputs

   j. Number of prototypes, demonstrators and clinical applications

k. Number of patent applications and rewards

If the relationships had an impact, please specify per impact-indicator through what ways the relationships had an impact.

18. Can you think of any other repercussions on the research activities of the research department?
19. Taking into account all the impacts, how would you, in general terms, describe the impacts of the spin-off companies on the research activities of your department?
20. Is there information present about the funding the research department receives and the output of the research department which I could have access to?

IIId: Example of interview protocol for representatives from spin-off companies

Introduction: Aim and background of the study, aim of the interview

1. What is your function? And what are your daily activities as a member of this company?
2. What products/services does the company offer?
3. Could you describe how the company came into existence?
    a. Who were the key persons involved during the start-up phase?
    b. What was the role of the research department during the start-up phase?
    c. Which personnel and what information and other resources were acquired by the company in this process from the research department?
    d. Did the company receive help from national and regional government, and from the research institute?
4. What is the current size of the company?
5. Does your company qualify as "research intensive"? Please provide a description.
6. What kind of research themes and types of knowledge are you interested in?

7. Could you name a person at the former department who has collaborated with the spin-off company?

Relationships with the research department

8. What kind of interactions does your company have with the research department?
    a. Publications, patents, exchange of information, physical resources, prototypes, …
    b. Joint projects: contract research, government-funded projects
    c. Exchange of personnel
    d. Support of PhD, Master, and Bachelor theses
9. Did you or do you currently pay for using the institute's laboratories, buildings and instruments?
10. Are you among the potential employers for the research departments' graduates?
11. How often do employees of your company and the research department meet? What do they discuss and exchange?
12. What do you think are the main reasons for the research department to collaborate with your company?
13. Has the research department become your customer and/or vice versa?
14. Have there been moments of competition between the research department and your company?
15. Do you have contacts with other research departments in the research institute? If so, what do they look like?

Impact of the relationships on the research portfolio

16. What is your impression about the impact that your company has had on the research department? Do you think the relationship with your company has had an impact on:

    The research agenda
    a. Thematic and methodological shifts due to the relationship with the spin-offs
    b. Change in the research topics to more customer-driven or application oriented research

    The composition of the research projects
    c. Number of research contacts
    d. Number of projects with public and private actors
    e. Amount of income from public and private research partners (did the presence of spin-off companies increase the participation in government-funded projects?
    f. Amount of income from national research councils and the EU

The academic output

g. Number of publications in peer-reviewed journals (by increased capacity, better quality because of collaboration with so)
h. Ratings in QANU research evaluations
i. Reputation within relevant communities of research

Other research outputs

j. Number of prototypes, demonstrators or clinical applications
k. Number of patent applications and rewards

If so, please specify what the influence has been.

17. Can you think of any other repercussions on the research activities of the research department?

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