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The motivations, organisation and outcomes of university-industry interaction in the Netherlands

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Abstract

This paper aims at analysing the impact of institutional and organizational factors on bridging industrial and university motivations for collaboration, as well as on the content, management and outcome of this relationship, in the Netherlands. In particular, we explore which type of projects, set up under specific industrial and university motivations, are more likely to face institutional barriers related to technology, market and organisational incentives frameworks. Moreover, we analyse the impact of technology transfer offices, research sponsoring, part-time professorships, and patenting on aligning university and industry motivations towards collaboration. To proceed empirically, thirty in-depth cases of successful university-industry knowledge transfer are analysed.

Keywords: university-industry interaction, innovation cooperation.
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1. Introduction

University-industry interaction is seen as the most efficient form through which university inventions can get into practice because university and industry join and overlap research efforts to develop innovations and solve complex problems (Pavitt, 1998 p.795). In particular, this collective effort for knowledge development creates space for user-developer relations between the partners, which facilitates experimenting and testing products and concepts under development as well as further problem-solving based on fundamental research (Kline and Rosenberg, 1986; Pavitt, 1998; Lee and Gaertner, 1994; Foray and Steinmueller, 2003 p.79). Moreover, it allows firms to become aware of new knowledge developments and to create new technological learning options on future technologies (Caloghirou *et al.*, 2003). Therefore, as technological interdisciplinarity and complexity, as well as competitive pressures to shorten product life, increased, university-industry interaction has become acknowledged as crucial for the competitiveness of firms (Hagedoorn, 1996; Pavitt, 1998; Caloghirou *et al.*, 2003).

Firms and policy-makers are willing to foster successful university-industry collaborations. However, despite sharing the national organisational and institutional context facilitating or constraining their interaction (i.e. laws, culture, organisations, and policies), university and industrial researchers face different prevalent incentive frameworks, (Nelson, 1993; Foray and Steinmueller, 2003). Hence, on the one hand, many empirical studies have analysed the importance of university-patenting laws in encouraging a more entrepreneurial attitude of university researchers towards interaction with industry, the relevance of technological transfer offices, spin offs, and of research sponsoring in facilitating knowledge transfer (Hall *et al.*, 2001; Colyvas *et al.*, 2002; Lowe, 2006). On the other hand, some authors have analysed the different motivations of university and industrial researchers in interacting and in transferring knowledge (Lee, 2000; Lam 2005; O'Shea *et al.*, 2005; Balcony and Laboranti, 2006).

Both types of studies provide insights on the role of institutions and incentive frameworks on the university-industry interaction, but they have focussed, almost in isolation, on the specific role of individual sets of factors. Therefore, the effective role of national institutions on bridging industrial and university motivations towards interaction; and on defining the content, form and outcome of university-industry collaboration is still quite uncertain (Heher, 2006). To shed light on the role and importance of a range of institutional factors in aligning university and industry motivations towards collaboration, in a national system of innovation, a horizontal investigation of how the process by which university knowledge is brought into use is required (Colyvas *et al.*, 2002).

This paper is an attempt to map university-industry interaction in the Netherlands by analysing the impact of prevalent institutions on the university and industry motivations to collaborate as well as on the content, management and outcome of this relationship. In particular, we explore whether and how the incentives of university and industry researchers in bringing innovations into practice are aligned towards projects with specific characteristics. Moreover, we investigate which type of projects, set up under specific industrial and university motivations, are more likely to face institutional barriers related to technology, market and organisational incentives frameworks. Additionally, we analyse the impact of technology transfer offices, research sponsoring, part-time professorships, and patenting on the bridging university industry motivations towards collaboration. To proceed empirically, detailed data on thirty cases of successful university-industry knowledge transfer are analysed.

The analysis suggests that the form, content and outcome of university-industry interaction depend on the motivations of university and industrial researchers to commit in bringing innovations into practice. In particular, specific industrial and university motivations seem to be complementary and bring along some particular forms of interaction, with particular organisation and technological goals. Moreover, different institutional factors facilitate or deteriorate diversely the alignment of motivations of university and industrial researchers to commit in bringing innovations into practice.

2. Institutions and Incentives

This section reviews the main motivations of university and industrial researchers in interacting and in transferring knowledge, as well as the role of some institutions (barriers and facilitators) on the university-industry collaboration.

2.1. Motivations for university-industry interaction

Cooperation with universities seems especially important for industrial firms to access new knowledge, ideas and technologies, as well as skilled labour, especially qualified engineers, whose capabilities can be tested during the collaborative project (Adams *et al..,* 2001; Feller *et al*., 2002; Balcony and Laboranti, 2006). In particular, firms seem to engage in collaborative projects with universities to access and develop interdisciplinary scientific capabilities for solving complex problems and for supporting product development (Lee, 2000; Feller *et al.*, 2002; Tether, 2002; Lam, 2005). Indeed, collaborative projects with university often focus on research related to existing product lines, exploratory research in search of new products, instrumentation and technical problem solving, and design of prototypes (Lee, 2000). Additionally, firms may collaborate with universities to maintain or to establish direct personal links with top professors (Lam, 2005; Balcony and Laboranti, 2006).

Benefits for firms from collaboration with universities tend to be in line with their objectives to participate. Benefits include access to new knowledge, ideas and technologies; development and maintenance of an ongoing relationship with university, as well as making progress toward the development of new products and processes (Lee, 2000; Feller *et al.*, 2002; Caloghirou *et al.*, 2003; Lam, 2005). It is unlikely that firms reorient their research agendas due to results from collaboration with university (Lee, 2000). In particular, the larger the number of R&D scientists and engineers a firm has, the less likely the firm is to acknowledge the university contribution to the development of new products and processes (Lee 2000).

University researchers are found to participate in collaboration with firms for accessing production technologies and getting prototypes manufactured, as well as for getting additional research funds (Lee, 2000; Balconi and Laboranti, 2006). Indeed, Lee (2000) shows that university researchers collaborate with firms mainly to advance and complement their own research agenda, rather than with the objective of supporting industrial development, which seems to be the least of their concerns. In particular, they seem mostly driven to secure funds for graduates students and lab equipment, to gain insights into their research, to test the practical application of their theory and research, and to get additional funds for their own research. University benefits from collaboration with industry were found to be strongly correlated with the early reasons for collaboration as well as with the length of the project (Lee, 2000). No university motivation affects negatively technology transfer (Bozeman, 1994).

Thus, university and firms seem driven to collaborate by very different reasons. However, the success of the collaborative university-industry projects depends on permitting both parties to achieve their specific goals. This requires that achieving ones' goals does not invalidate, but enhance the achievement of the other's goals (Lee, 2000; Lam 2005; O'Shea *et al.*, 2005; Balcony and Laboranti, 2006). Thus, some specific aligned motivational axes for university industry collaboration need to exist.

2.2. Institutional context of university-industry interaction

The process by which university knowledge gets into practice is complex, interactive and risky. Technological and market problems seem to be the biggest risks in the process of bringing university knowledge into industrial innovations, independent of whether this process can be characterized as supply-push or demand-pull (Kline and Rosenberg, 1986; Pavitt, 1998).

Moreover, the different incentive frameworks at the university and in industry are widely blamed for constraining university-industry interaction and their outcomes. Shortly and oversimplified, university researchers have incentives to concentrate on fundamental and theoretical research, publishing their research results, being recognised by their peers and assuring their tenure; while industrial researchers are driven to focus on applicability and appropriation of the generated knowledge, on commercially viable technologies, and on solving technological problems (Dasgupta and David, 1994; Rosenberg and Nelson, 1994). These differences in objectives, incentives and research focus may pose several types of problems to knowledge transfer between university and industry. In particular, they restrain the transfer of basic research results, especially if firms have low absorptive capabilities. Moreover, differences in research objectives and incentives reflect into organisational differences related to values, priorities, and time schedules, which pose further barriers to effective collaboration and technology transfer (Feller *et al.*, 2002). Prior experience in working with a university may decrease the difficulty of acquiring and assimilating basic knowledge and reduce the expectation of early commercialization (Hall *et al.*, 2001). Therefore, Fritsch and Lukas (2001, p.309) find that maintaining one R&D cooperation project with universities or research institutes necessitates additional effort, but maintaining a high number of collaborations might enhance substitution and specialization of firms' own research activities.

Furthermore, collective university-industry knowledge production and especially the attribution of its research results may be problematic because it requires finding a common agreement on a balanced level of appropriation by the participating firm and of public diffusion of results (Foray and Steinmueller, 2003, p.84). Therefore, some authors find that the lesser problems of knowledge appropriation between the partners and the higher the efforts put on learning from different channels, the more likely is the collaboration to be successful (Hagedoorn *et al.*, 2000; Caloghirou *et al.*, 2003).

Therefore, differences in the university and industry incentives can create difficulties for the alignment of the motivations and research objectives of the university and the industry. In other words, it might be difficult for both parts to be motivated for common types of research. However, besides pursuing their academic career, university researchers may also feel rewarded by solving puzzles, and technological insights also provide direction and meaning for academic research (Dietz and Bozeman, 2005; Balconi and Laboranti, 2006). Moreover, the industrial and university research worlds seem to become less and less dissimilar, in particular, from the 1990s, since they have been developing flexible organisational structures to facilitate knowledge development and transfer (Lee and Gaertner, 1994; Lam, 2005). According to Lam (2005), the boundaries between university and industry are increasingly loose and it becomes difficult to distinguish the roles and careers of industrial and university researchers.

Consequently, university-industry collaboration is gradually becoming a market in which academic researchers and firms bring their own research agendas and for which they are willing to commit time and resources. In this market, each party needs to recognise the objectives and agendas of the other party even though most of the time these are not formalised (Lee, 2000; Lam, 2005).

Given the difficulties inherent to the process of bringing inventions into practice as well as in bridging university and industrial motivations towards collaboration, policy measures are now widely present in developed countries. In particular, to encourage knowledge transfer between university and industry, policy-makers introduced public sponsoring to collaborative research projects, stimulated the establishment of university's Technology Transfer Offices (TTOs) and part-time professorships, and pushed for more active use of university property rights. Several studies have analysed the importance and impact of such policies in encouraging and facilitating knowledge transfer (Hall *et al.*, 2001; Colyvas *et al.*, 2002; Lowe, 2006).

Public research-sponsor grants, which in many cases are becoming more dependent on knowledge transfer conditions, also seem to support the increase in university-industry collaborative research (Lee and Gaertner, 1994; Laredo, 1995; Bozeman and Gaughan, 2007). Indeed, public research sponsoring may help bridging university and industry motivations for collaboration in R&D as well as for engaging in efficient translation of new scientific advances into commercially viable technologies and products (Lee and Gaertner, 1994). Researchers who collected more (public or private) research sponsoring were found to reveal a greater propensity for industrial involvement (Bozeman and Gaughan, 2007). University researchers may consider these funds as an opportunity for complementing their research activities and gaining technological insights for their research. On the other hand, firms are increasingly thought to consider collaboration with university as a form of getting public financing for carrying on their research agenda (Tether, 2002; Lam, 2005; Balcony and Laboranti, 2006).

In some countries, part-time professorships have been institutionalised with specific regulations as a form of knowledge transfer. Indeed, the exchange of industry and university positions, allowing the expansion of their social and industrial networks and market awareness, seems to make researchers more productive in developing industrial innovations (Dietz and Bozeman, 2005). Moreover, Zucker *et al.* (2002) show that employment by entrepreneurial start-ups of top university researchers positively influences the success of the spin off.

University TTOs are another form of knowledge transfer that has become increasingly widespread in the OECD countries. TTOS were conceived to encourage technology transfer to industry and the valorisation of university knowledge. The wide spread of university TTOs has been associated with clarification of university patenting rights as well as with campaigning for university entrepreneurship. Despite the fact that TTOs have generally been achieving their goal to increase pecuniary benefits to the university, the additionality of TTOs in terms of effective technology transfer to firms is difficult to prove (Bozeman, 1994; Colyvas *et al.*, 2002; Lowe, 2006; Bach and Llerena, 2007).

Finally, studies on the impact of the regulation of university patenting on the effectiveness of university-industry knowledge transfer are numerous, but they focused mainly on the US context. Colyvas *et al.* (2002, p.66) argue that the usefulness of university patents and exclusive licenses depends on the type of invention. In particular, university patents seem particularly important to induce firms to develop ‘embryonic’ inventions, but not the adoption of almost ‘ready-to-use’ innovations. Instead, Lee and Gaertner (1994) argue that encouraging universities to focus on the industrial value added, and especially in patenting and licensing, may not assure that firms will sequentially develop commercial products. Moreover, Henderson *et al.* (1998) find that the importance of university patents decreased after the mid-1980s, mainly due to the increase of ‘low-quality’ university patents. Additionally, Feller *et al.* (2002) argue that the industrial benefits from collaboration with university do not depend on the university's ability to establish intellectual property rights and obtain product-specific outcomes. In the long run, negative consequences for the quality of university basic research, and consequently its value added for industry, are expected from directing university towards industrial applied and short term oriented research as well as encouraging the publication of patents (Lee and Gaertner, 1994; Geuna, 2001).

Overall, this review of the literature suggests that university-industry collaborations are set under different unilateral objectives and motivations, and both need to be, at least partly, addressed and achieved for the taking off and success of the collaboration. Therefore, as Foray and Steinmueller (2003) argue, university-industry collaboration requires that a division of labour and respective organisation and co-ordination of the knowledge production and distribution process are agreed and set, as well as rules for accessing resources during development, and for appropriating and external diffusing knowledge generated. Most studies in the field have analysed individual aspects related to motivations, barriers and incentives to university-industry collaboration in isolation and without considering their impact on the project organisation and outcome. This paper aims at bridging this empirical gap.

3. Methodology and Data

The goal of this paper is to explore axes of alignment of university and industry motivations for collaboration, as well as to analyse whether and how the content, organisation and outcome of university-industry collaboration differs across the most common motivational factors under which industrial and university researchers cooperate. Moreover, it aims at exploring which type of projects set up under specific motivations are more likely to face certain institutional barriers or to benefit from some existing institutions. In particular, this paper focus on the role played by specific Dutch collaborative research grants, part-time professorships and PhD agreements, as well as more generic institutions such as university patents and TTOs.

For undertake this research, we collected in-depth information on thirty cases of university-industry collaboration. The unit of analysis in the case study is a piece of knowledge developed or co-developed at university and transferred to one or a group of industrial firms. Cases were selected on the basis of the actual taking place of knowledge transfer, not based on whether or not this knowledge was (subsequently) commercialised. Data were collected by means of a standardized protocol that contained many questions requiring short written answers. These answers were collected by engineering students at MSc level, on the basis of interviews with those involved in the project (both at firms and at university).

The protocol consists of around 200 questions focusing on the following elements of the process of knowledge transfer between university and firms (Kingsley *et al.*, 1996; Bozeman, 2000; Bercovitz and Feldman, 2006):

- The main characteristics of the innovation in terms of disciplinary origin, complementary characteristics, applications and potential benefits, and potential users;
- Identification of the origin of the project in terms of how the innovation relates to previous scientific and technological knowledge, as well as how and why the idea emerged and who had the idea;
- The main aspects of design and performance of the development project, in particular who designed, financed and performed the R&D project, the relative role of firms and universities in the design and performance of R&D, how the project was implemented, as well as the early goals and outcomes of the project and the major problems experienced during development;
- The degree and the forms of knowledge transfer between university and firms, in particular the forms used by firms to access, absorb and use that knowledge, as well the major problems during this process of knowledge transfer;
- Impact of the knowledge transfer process on the performance, productivity and research objectives of firms and of university departments;

- Identification and characterisation of the role of other organisations and institutions involved in the process of knowledge development and transfer process, as well as their relative importance according to firms and university;
- The main characteristics of university researchers, and their department, in terms of academic reputation and experience in collaborating with industry, as well as the motivations to participate in this R&D project;
- The main characteristics of the participating firms in terms of activity, products, market, R&D intensity, capital origin, motivations to participate in the project, and experience in collaborating with universities.

The main strategy to identify cases has been to interview chairs of some research departments in the faculties of mechanical engineering, biotechnology, chemistry, applied physics and electrical engineering in two universities of Technology in the Netherlands (Eindhoven and Delft). The chairs were asked to name relevant technology transfer projects, and to provide contacts to the people involved in the projects they mentioned. Additionally, we consulted national electronic libraries for PhD theses finished in the last 5 years, we interviewed the directors of the university's TTOs, and we identified professors with a large number of industrial patents.

The final 30 cases were chosen independently of their relative weight on the population of university innovations, following some criteria. Given our research design, which aims at studying motivations and the role of institutions on the process of knowledge transfer, we wanted a variety of cases across the following four axes. First, cases should have diverse disciplinary origin. Second, cases should show diversity in terms of the efforts of university and firms on the innovation development (university-driven research; the firm addresses the university with the idea; results from collaborative project). Third, we wanted some variety between formal and informal forms of knowledge transfer and university-industry interaction (i.e. we want only some cases in which start-ups or spin offs were created or university patents have been issued). Fourth, cases should show variety in terms of the forms of financing and design, i.e. we wanted some cases financed by the university, STW[1], other research sponsors, and others still financed by firms. Table 1 provides some information on the variety present on our sample of 30 cases collected. Out of these 30 projects analysed, only two did not achieve the expected outcomes, while four

[1] Created in 1981, the Technology Foundation STW mission is to stimulate technical scientific research and its utilisation, consequently to encourage public private knowledge transfer by allocating funds to cooperative research between industry and universities. Its main goal is to bring public and private organisations together into cooperative research arrangements, which can result in practical applicable results with patentable value.

had outcomes above the expected ones. Despite this good performance, university researchers evaluate twenty-six as fully successful projects, and firms only twenty-one.

(Table 1)

Using information on these thirty case studies, we analyse the motivations for and characteristics of university-industry interaction in the Netherlands. The first stage of our analysis is to standardise the information from the answers to the questions in the protocol into a number of binary variables. This allows us to compare the cases in a quantitative way, while keeping a set of information that is richer than what can be collected in a large-scale survey. In particular, we explore the alignment axes of university industry motivations as well as their association with specific projects with specific characteristics in terms content, organisation and outcomes. Similarly, we analyse the impact of prevalent institutions on encouraging or preventing the different alignment axes of university-industry motivations.

Given the type of data and the limited number of observations, we build on results from the non-parametric Mann-Whitney T-test, correlation coefficients and cross tabs on the main aspects of the cases. Additionally, principal component analysis is used to identify the alignment axes of university and firm motivations, as well as the role of institutional facilitators in facilitating the different alignment axes. In the principal component analysis, we use a *polychoric* correlation matrix to calculate the principal components, to better account for the fact that our variables are binary. Finally, we conduct a *K*-means cluster analysis to visualise and understand differences in objectives, motivations and design of university-industry projects.

4. Analysing university and industry motivations to collaborate

In this section, we analyse the motivations of university and firms for participating in collaborative projects, and we relate these motivations to the organisational characteristics of the projects. Table 2 provides information on the frequencies and the polychoric correlation coefficients among industrial and university motivations for collaboration. Table 3 provides a short summary description of these motivations, along with other variables on various aspects of the knowledge transfer process that will be introduced in the discussion and analysis.

[Tables 2 and 3 about here]

4.1. University motivations

In all thirty cases, university researchers were interested in participating in the specific project in order to undertake high-quality scientific research and in developing knowledge. Among the more specific reasons, we singled out particular motivations for university researchers (in order of frequency observed in the thirty cases): (i) obtaining insights into the industrial applicability of previous research, (ii) maintain collaborative industrial contacts, (iii) access to additional funding, and (iv) to increase future (collaborative) research opportunities (Table 2). Motivations to collaborate in knowledge development with industry are not exclusive (the sum of frequencies of the four university motivations is larger than 30); only the intention of maintenance of collaborative contacts seems, to a certain extent, to be opposite to other motivations.

When university researchers engaged in the project are motivated by the prospect to gain insights on the **industrial applicability of research results,** this is likely to lead to the development of innovations that substitute existing technologies, rather than leading to technologies that are complementary to existing ones. This is one of the two variables that measure the nature of the innovation projects in our sample (see Table 3). Thus, the prospect of industrial application often leads to the development of new or significantly more efficient products or processes. Projects in which the applicability motive plays a role are less likely to apply for competitive public funding; only six cases out of the sixteen applied benefit from public research sponsoring (variable *Research sponsoring*).[2] Moreover, they are often developed in an environment of frequent interaction between university and industrial researchers, both through formal and informal means (variables *Frequency* and *Informal*). They tend to aim at developing applied proof of concepts as well as to face several technological problems during development and adoption (variable *Technical problems*). These projects tend to be followed by similar projects before a plan for a product or commercialisation emerges.

When the motivation of university researchers to join a collaborative project with a firm is the **maintenance of collaborative contacts**, projects are more likely to be initiated by firms, e.g., firms look for university support for solving technological problems, for product development, or for public sponsoring. Consequently, these projects focus often on applied research and on the development of complementary to existing technologies (i.e., low on *Substitute innovation*), especially in the engineering fields. They tend either to lead to *Research sponsoring*, characterised by a low *Frequency* of interaction

[2] In two cases, the university designed the project and applied for STW research funding with industrial partners/users. In two other cases, firms, aware of university research patents set a research consortium to benefit from public financing on the topic.

during project development (mostly when a part-time professor is involved) or to a *Master* thesis on a topic of interest to the firm, usually characterised by a high *Frequency* of interaction. University researchers are more likely to perform all the required research in the project and to use firm's infrastructures. Knowledge developed tends to be transferred (and used by firms) through prototypes and interaction during the project rather than through independent further technological development of university developed knowledge in firms' labs. Mostly relying on public research funds or on university resources (i.e. master students), these projects are less likely to suffer from finance problems.[3] These projects are also less likely to suffer from technical problems or from cultural barriers, given the experience of parts in interacting and often the pre-existing personal contacts between the parts. Publications are less likely to be delayed. Both parts tend to be willing to engage in future collaborative projects.

Projects in which university researchers participated to **finance a particular research topic** or to **develop future research (collaborative) opportunities** are mostly those in which university and firms did not have previous collaborative research contacts. The firm and university often come together through indirect means, such as publications, conferences, policy networks, and research networks. They are more likely to focus on developing applications for university knowledge previously developed and patented (variable *Previous university patented knowledge*, owned by the university or the firm). Firms are more likely to participate in the design, finance and performance of R&D. Moreover, during the project, firms tend to integrate the knowledge developed by university through technological development independently from the university (sometimes in secrecy). IPR stipulations, assuring that all patentable results belong to the firm, are likely to be set in the beginning of such a project. Consequently, university researchers need to delay publications to allow firms to scrutinize the patenting possibilities of the results. In this context, the different incentives frameworks of industry and university, in terms of secrecy, direction of research, applicability, and appropriation may limit knowledge development and transfer. Still, the commercialisation of new products occurred or has been planned by the end of more than half of these projects (seven, variable *Commercialized or in process*).

In projects that university researchers joined to **finance a particular research topic**, participating firms are more likely to locate further from the university, often in a different country, and to have greater technical and research capabilities. In particular, we have two cases with an industrial partner in Germany and one with a partner in the US. Knowledge transfer is mainly done through formal interaction (low on variable *Informal*) and through the firm's in-house technological development. Severe *technical problems*

[3] Only two cases out of the fifteen cases were performed with great share of industrial funds.

in scaling up and making industrial applications of scientific knowledge are often experienced. Outcomes are more likely to affect the research objectives of participating firms than outcomes from projects without this university motivation.

Projects, in which university researchers collaborate with firms to **develop future research (collaborative) opportunities**, are often focused on innovations that support the design of systems and products. Knowledge transfer relies mostly on firms' in-house technological development, and on the use of specialised subcontractors (producing components or software, according to specifications) to support the translation of the research results produced at the university into technological knowledge. The impact of these projects on the research objectives of the university researchers tends to be smaller than in other projects where this motivation is not present.

4.2. Industrial motivations

We also identify four main industry motivations for firms to propose or engage in collaboration with university (Table 2): (i) support for product development (the most important motivation), followed by (ii) the desire to access public research sponsoring, (iii) to get support in solving technological problems, and (iv) the motivation also to explore a good research opportunity. Similar as university motivations, industrial motivations for collaboration are not exclusive. Still, the industrial motivation of accessing a research opportunity seems opposite to the motivations to resolve technological problems or to obtain support in their product development projects.

When getting **support to product development** is the motivation of the firm to propose or join the project, it aims mainly at using university knowledge, expertise and facilities. Knowledge transfer tends to occur at the end of the project, especially through labour mobility, as well as formal and informal meetings. Firms are likely to participate in the design and sometimes on the performance of the research work, to a lesser extent when part-time professors initiated the projects. When *part-time researchers* are involved, these projects are more likely to apply for *research sponsoring*, in particular for *STW* funds, than to be financed by the firm or to be performed by *Master* students. The four projects aimed at supporting *product development* and implemented by *Master* students, all accomplished their development objectives by the end, and two of these led to further collaboration.

When solving **technological problems** is the motivation of the firm to enter into the project, the development of products or methods tend to be early goals of the project. These projects tend to be developed and performed in a context of frequent university-firm interaction through both formal and informal means. Participating firms tend to locate in the Netherlands, so the average distance is smaller than in projects not motivated by firms' technological problems. Firm's infrastructures are more likely to be used in these projects. In four cases, knowledge transfer involved the employment of university researchers engaged in the project. Knowledge developed during these projects is likely to lead to *commercialisation* or plans for commercialisation of new products.

To **access public sponsoring** is often the motivation of firms to join or to propose a collaborative research project on complementary to existing technologies (low on *Substitute innovation*). These projects tend to be proposed by firms or by *part-time researchers*. Eight of these fifteen projects relied on previous research results. They tend to be implemented by *PhD* students, in a context of scarce interaction (low on *frequency*) and often do not encounter *technical problems*. Knowledge transfer tends to be done through reports, prototypes and testing (undertaken by the university or the firm). Participating firms frequently do not have their own R&D lab. The technological outcomes of the project often allow firms improving processes rather than developing new or more efficient products. By the end of the project, both parts are often willing to engage in future collaborative projects.

Research opportunity is the motivation of firms that participate in projects, set and designed by the university, aimed at developing proof of concepts rather than developed/crafted technologies. These projects often benefit from public *research sponsoring*, and mostly likely, they would not be developed without it. Only two of these six projects were performed without public financing. Compared with projects without this industrial motivation, the firm tends to locate further from the university, which is reasonable because the firm is more interested in being aware of the new knowledge developments than to get concrete immediate benefits from the project. Their research outcomes are likely to lead to the reorientation of the R&D objectives of firms, but not to an immediate sales increase. University researchers tend to benefit highly in terms of publications.

In sum, there is not a one-to-one match between the non-excusive motivations of university and firms to collaborate for R&D. Still, axes for alignment of their motivations towards the setting up of collaborative project with specific characteristics seem to exist. This issue will be further analysed in Section 6, before we analyse the institutional context of university-industry interaction.

5. Institutional facilitators and barriers to university-industry collaboration

In this section, we analyse in depth the institutional facilitators and potential barriers for the process of knowledge transfer between university and firms. Table 4 provides information on the number of cases that observed barriers to knowledge transfer or benefited from institutionalised facilitators as well as the correlation coefficients among these variables.

[Table 4 about here]

5.1 Barriers

Market dynamics

Projects that suffer from market problems, like a lack of customers, competition in the form of a technology race, or a change of market strategy of the industrial partner, are more likely to concentrate in projects that support *product development*. Firms tend to design and perform R&D in these projects, and test prototypes developed with the help of the university. The overall evaluation is not as good as in other projects because participants fell diluted by the fact that further innovation development and/or its effective commercialisation was obstructed by changes in markets rather than to technical problems. Still, these projects are likely to produce relevant results to feed further research at the university and lead to a large number of publications. Market dynamics, and consequently the change of the market strategy of firms affected four cases. In two of these cases, problems are also/instead attributed to the bad management of firms.

Technical problems in knowledge development and adoption

In twelve cases, technical difficulties in knowledge development as well as in making industrial use of scientific knowledge, e.g., scaling up university samples, applying knowledge to specific materials, or developing a user-friendly product, needed to be overcome. Great technical problems are more likely to occur in projects aimed at developing *substitute* to existing technologies, based on previous research results, especially on university-patented knowledge. Technical problems often occur in projects implemented in a context of frequent, even that sometimes formal, university-industry interaction. Firms are likely to perform research and test proof of concepts/ prototypes developed by/with the university. Effective knowledge transfer tends to require university advice, involvement of industrial research institutes to help with scaling up and on the development of technological knowledge from scientific results, as well as through in-house technological development. These projects tend to develop advanced product prototypes[4], and they tend to be evaluated as successful by both firms and universities. Technical

[4] Examples: decision-making system software, solar cells based on photovoltaic foil manufacturing technique, white-light Led products, fully integrated in-line solar cell manufacturing machine for high rate deposition, method

problems are less likely to occur in projects that benefited from public research sponsoring, in particular from STW. Technical problems occur mostly in longer projects which suffer also from financial problems to continue the research agenda.

Cultural differences

In six cases, university and industry find that their different attitude towards knowledge sharing, appropriability, and applicability create problems for the development and transfer of knowledge within the project. These differences may lead to the industrial partner withdrawing (or loss of interest in the project).[5] In these projects, firms and universities tend to not have previous common collaborative experience, and they come together for collaboration through indirect means, often in projects based on university-patented knowledge. Both the university and the firm are involved in the performance or R&D. University-industry interaction is often frequent but formal, and non-participating firms are less likely to use knowledge developed in these projects. University publications are delayed so that firms can scrutinise their potential for patenting. When compared with projects in which cultural differences are not reported as problematic, these projects involve often multinationals and firms located far from the university, except for two cases.[6] Moreover, university researchers tend to be less experienced in collaboration than in other projects. Evaluation tends to be less positive than in other projects, and usually there is no willingness to engage in further collaborative projects.

In sum, technical problems seem inherent of R&D projects that led to the development of advanced prototypes or products using substitute to existing technologies, through high university-industry

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to measure cardiovascular indicators, a medical rapid diagnostic test of drugs of abuse in oral fluid, cell line technology, and the maskless lithography technology.

[5] For example, in one case, the leading firm found a substitute firm for taking over the development and commercialisation of the product as well as its collaborative arrangements. In another case, the firm was less successful in finding a substitute, and the licensing agreement was suspended. In a third case, the firm decided to stop the collaborative and licensing agreement with the joint-venture spin-off (between former university and industrial researchers), after having tried to buy and integrate the spin-off, but internal disputes about the ownership of spin-off prevented it.

[6] In one case, the leader industrial research retired before the end of the project and the substitute was an operational-oriented person not interested on the project. The other case, despite the department existing contact, the involved university researcher had not previous experience with the firm.

interaction. Market dynamics influence negatively the adoption and use of applied innovation developed by university and industry, especially when the innovation was successfully developed with relatively few (i.e. normal level) technical problems. Barriers to knowledge development and transfer caused by their different organisational incentives and objectives frameworks seem associated with the fact that there was no previous common collaborative experience. Moreover, they are more often when the industrial partner is a large multinational following strict secrecy rules and being located far from the university (sometimes in other countries). These barriers may also derive from the relatively little experience of university researchers in managing industrial collaboration, and in realising the particular research needs and objectives of the firm, or from the little absorptive capabilities of the participating firm combined with operational rather than strategic priorities.

5.2. Institutional Facilitators

R&D financing

Sixteen projects benefited from public *research sponsoring*, but in thirteen of them industrial funds also financed the project. Most university-industry projects that benefit from public R&D sponsoring, might have not been undertaken without it. Firms are less likely to participate actively in the design and performance of R&D, and university-industry interaction tends to be less frequent than in non-sponsored projects. Knowledge transfer is usually done through reports and prototypes, and it often leads to plans for the technological development and commercialisation of new products using complementary to existing technologies. These publicly sponsored projects usually allow for university researchers to produce many publications. University researchers engage in these projects to maintain collaborative contacts and, to a lesser extent when part-time professors are the initiators of the project, to get insights on the applicability of their previous research results.

Dutch research sponsors provide an organisational and interaction framework for the university-industry collaborative projects. In particular, this framework for the projects sponsored by *STW* includes the requirement that each project sets up a user committee, used to report results and get technical feedback and direction for research projects. Other firms are likely to join the project, after the project beginning.[7] Moreover, a minimum frequency for interaction and for reporting results within this committee tends to be defined. Additionally, STW and the Dutch research council have specific procedures to analyse

[7] It is noteworthy to refer to one case in which an industrial researcher, involved in the user committee of another project financed by the Dutch Polymer Institute (DPI), was informed about this project's results and joined it as provider of feedback and research direction. Soon, his firm decided to participate in the research, patent the results and work for adoption of the innovation. DPI projects are financed for ca. 50% by the Ministry of Economic Affairs, ca. 25% by the DPI industrial partners and for ca. 25% by the knowledge institute itself.

patentability of the research results, as well as to attribute and negotiate property rights of the knowledge generated within the project. The most common rule is that the ownership of generated patentable results belongs to the research councils and the faculties involved in the project.

Part-time professorships

In seven cases, part-time university researchers are involved in setting up the collaborative project and in the process of knowledge development and transfer. Projects involving part-time professors are more like to benefit from public research sponsoring, in particular from STW, and being implemented through PhD theses. They are mainly set to support *product development* or *technological problems* faced by firms. Firms involved in these projects are national rather than multinationals, often without an R&D lab. Rather than only 'proof-of-concept', these projects are likely to lead to the development of new methods, knowledge, and software, which are mainly transferred to firms through prototypes and labour mobility. The different incentive frameworks at the university and the firm are less likely to be work as a barrier to knowledge transfer. Consequently, the knowledge developed is more likely to be absorbed and commercialised than in projects without part-time professors' involvement. With outputs matching the early goals of the project, the involvement of part-time professors seems to affect positively the overall successful evaluation of the project.

University Technological Transfer Offices

In seven cases, university TTOs or licensing offices intervened in the project. In particular, TTOs were involved when university researchers were confronted with the need to set up a spin-off, or to apply to management and training subsidies (this might not be true among the oldest projects, as university TTOs are relative young). Additionally, university TTOs were involved when university researchers needed help in assessing the patentability of some specific scientific result or in setting up a licensing agreement. In particular, the involvement of university TTOs seems more likely in projects that developed innovations that potentially benefit firms in other industries than those of the participating firms or when innovations are still embryonic and industrial partners are not easily identified by the university researchers. Thus, the main role of these offices is to advise and coach university researchers about management of their knowledge assets after development of a scientific result or before their involvement with industry.

University-patented knowledge as input of university-industry collaboration

In five cases, projects are designed and built on patents based on university-developed knowledge (two owned by firms). University researchers are likely to evaluate these projects as risky mainly due to the high commercial and profitability expectation, and to the fact that their university departments seldom have previous experience with that firm. University and firm come together for collaboration mainly through indirect contacts to develop *substitute* to existing technologies. The firm is more likely to perform R&D independently from the university, and to enforce rules for delaying university publications. Knowledge transfer is mainly done through technological development at the firm, as well as through university advice and feedback on its developments. Projects that build on previous patents based on university knowledge are more likely to suffer severe technical problems, as well as problems related to withdrawn of partners, finance and management, and in some cases personal conflicts. The different organisational incentives and objectives framework of university and industry may create difficulties, and consequently, often both parts are not willing to engage in future collaboration. Projects outcomes are also likely to be patented by firms. Non-participating firms are less likely to absorb or use knowledge developed in these projects.

One of the most caricaturical project is the one in which the firm, located in Germany, came across the university's research work at a conference. Interested in exploring some industrial applications of those new concepts and in tapping on the promising knowledge advances, the firm proposed a two plus two years development 'collaborative project' paid by the firm and a research institute, and the firm patented immediately these early university results. From the beginning of the project, the university was providing constant feedback on research results, and it also trained for a week some of firms' researchers. The firm instead avoided giving feedback of the testing and applications done at home, especially after the first year. Before the second year, other patents were published, but the firm cancelled the collaborative contract. The senior university researcher learned later that the firm had created a new R&D lab that allowed it to reproduce the university's scientific research work and proof of concepts as well as to proceed with the development of a new product. University researchers felt that they have been abused, they kept providing information and knowledge, training firm's researchers, giving their knowledge to be patented, and the firm just did not retribute in any way. Internal conflicts at the university emerged and the project was about to be cancelled, but it continued thanks to the efforts of the researchers involved and to alternative funding sources. Publications and the research work done during this 4-years project brought prestige and many new potential collaborative projects for the researchers involved.

In sum, both public research sponsoring and part-time professorships, in general, lead to less problematical projects, backing up technological development under existing technological frameworks, and often to the use of established collaborative contacts. In particular, collaborative research sponsoring shows a low degree of additionality. Moreover, it is beneficial to university researchers that usually engage on relevant and good quality research and publications, as well as for firms that often can plan the development and commercialisation of a product based on the proof of concepts or prototypes developed in the project. Part-time professorships facilitate the transfer and commercialisation of university knowledge customised to firms' product development or R&D plans.

University-patented knowledge instead often leads to the beginning of new collaborative contacts, as well as to development of substitutive to existing technologies. It usually succeeds in developing advanced prototypes and to plans for product commercialisation. They tend also to attract technical difficulties, and barriers created by the different university and industry incentives frameworks, often leading to withdrawn of partners or personal conflicts. Projects aimed at exploring practical applications of previous university patented knowledge would benefit greatly from the participation of part-time professor, who could make the bridge between industrial and university research organisations. Finally, university TTOs support the use of formal mechanisms of knowledge transfer, and provide counselling to university researchers on patentability and business setting. University researchers tend to consider their role important, but limited to the formal aspects of interaction with industry.

6. Motivational axes and Institutional context

6.1. Axes of university-industry alignment

For better identifying the axes of alignment of university-industry motivations as well as their institutional and organisational context, a principal component analysis is run. Besides variables related to the motivations of university and industry researchers to engage into the collaborative project, we include variables related to the facilitators and barriers to knowledge transfer of that project, the forms of project's implementation, the characteristics of innovation developed in the project, and the characteristics of university-industry interaction during the project. We selected five factors, with eigenvalues greater than 2 and explaining around 70% of the observed variance. The reported factor loadings are rotated by the oblique method. We focus on factor loadings whose absolute value is >0.4 (Hair et al., 2005).

[Table 5 about here]

The first factor recognizes two opposite axes of alignment of motivations: exploring applicability of university research (by universities, with a strongly positive loading) on the one hand, and accessing public research sponsoring and product development (both for industry) and maintaining collaborative contacts (by universities) on the other hand (both with strongly negative loadings). The opposite signs of the loadings of these variables imply a trade-off between these sets of objectives. For this reason, we call this the **academic goals vs. product development trade off axis**. This label brings out the finding that the motivations of industry and university are opposite along this axis. Technical problems are a common barrier along this axis *(academic goal*), and substitute innovations are often the result, and spin-offs occur relatively frequently. Part-time researchers, research sponsoring and STW are often absent as institutional facilitators.

Factor 2 again maps along two opposite motivational axes, i.e., it also represents a trade off of goals and incentives. In this case, the primary trade off is between motivations in the business domain, i.e., between research opportunities recognized by firms, and funding opportunities by universities on the one hand (strongly positive loading), and on the other hand (negative loadings) product development and solving technological problems (motivations experienced in industry) and maintaining collaborative contacts (in universities). Thus, within the set of industry motivations, this factor seems to point to a trade off between long-run motivations (exploring research opportunities) and shorter-run objectives (developing products and solving concrete technical problems. This is why we label this factor the **long-run vs. short-run industry trade off axis**. Along this axis (*long-run*), we find a rather formal mode of knowledge transfer (strongly negative loading on *informal*). Projects often take the form of PhD (but not MSc) projects, and again lead to spin-offs.

The third factor is most aptly characterised by previously existing IPRs on university research as an institutional facilitator, as well as licensing and/or consultancy contracts. We call this the **IPR axis**. The main motivational factor associated with this axis is for universities to explore future research opportunities. Thus, it emerges that universities use IPR to ensure that they keep access to a research field also in the future. Cultural differences are also important in this factor.

Factor 4 identifies itself as not very prolific along industry or university motivations (there are no particularly positive or negative loadings in these blocks). Instead, this factor is characterised by the involvement of STW as an institutional facilitator, strong results in terms of actual commercialisation, and PhD thesis and spin-offs. This factor also loads high and positive on previously existing IPRs and licensing/consultancy, which is in line with the strong focus by STW on IPRs. We label this as the **close to market/STW axis**, which brings out the notion that projects supported by STW are strongly aimed at commercialisation and user involvement.

The last factor is the only one that aligns an industry and university motivation in the same direction (i.e., both with positive loadings). The two motivations are research opportunities (in industry) and applicability (in university). It thus seems that these are highly applied R&D projects, which, in addition, are characterised by absence of market-related barriers. We label this factor the **applied research axis**.

Overall, the results show that industry and university motivations are aligned in particular combinations. Usually, these combinations involve a trade-off, i.e., they describe how motivations of one kind (in university/industry) do not go well with motivations of another kind (in industry/university). The most dominant of these trade-offs, i.e., our first principal component, is that the university motivation of searching for applications of basic research does not go well with a product development motivation in industry, the desire in industry to look for R&D funding, and the desire in university to maintain collaborative networks. The other main trade-off that we find is internal to industry and concerns projects with a short-run horizon vs. long-run horizon. This particular trade-off also involves universities looking for funds, which is well matched with a long-run industry perspective.

There is one particularly strong case where motivations in industry and university align in a positive sense, and this is the applied R&D factor (which is the least important of our five factors in terms of explaining variance). Finally, we find that IPRs play an important role in two of the factors. In one factor, they relate mostly to the university motivation to access future research opportunities (elaborations of patented basic knowledge), while in the other they seem to be associated with a strong emphasis of the research council STW on IPRs.

6.2 A Typology of university-industry projects

These principal components are like ingredients into a menu of actual knowledge transfer projects. None of the thirty cases in our sample is described adequately by only a single of the five factors. Thus, the factors are analytical tools that are useful in interpreting which separate processes are going on, but they do not help in terms of drawing up a typology of cases. To visualise and understand how differences in objectives, motivations and design of university-industry projects characterise the cases, we now set out to construct such a typology.

K-means cluster analysis is our main analytical tool. This was run using data of all 24 variables that were also used in the factor analysis. The results suggest that the best typology of university-industry projects should be based on four clusters.[8] A summary of the results is shown in Table 6. Figures 1a – 1d present

[8] Four clusters maximize the number of variables that are significantly different across clusters.

the summary profile of the clusters in terms of the five principal components that were extracted above. In order to construct these figures, the average factor scores in a cluster were calculated and plotted in a radar plot. Factor scores were calculated using the Bartlett method, and were standardised. Therefore, a positive (negative) value indicates a higher (lower) than average score, relative to the sample of thirty cases.

[Table 6 about here]

[Figures 1a-1d about here]

We refer to the first cluster, which contains the largest number of cases, 11, as *Sponsored Projects*. In fact, all cases in this cluster have research funding by third parties. This cluster also contains 6 of the 8 cases in which the funding agency STW was involved. In terms of the motivational space as represented in the principal component analysis, this cluster is clearly *business-driven (product development)*, as well as *close to market/STW*. The average factor score in these dimensions are positive, while it is strongly negative for the university driven R&D dimension. The main motivation for university researchers to participate in projects in this cluster is to maintain collaborative contacts (8 out 11 cases) and/or to find funding (10 out of 11 cases). Interestingly, of the total 11 cases where university researchers were motivated to participate in the project for access to funding, 10 are found in this cluster. Thus, the cluster seems to capture almost exclusively those cases where funding motivates university researchers.

The projects in the second largest cluster (3), with 9 cases, are all characterised by university researchers being motivated by searching for applications of their basic research. None of the firm motivations are strong in this cluster, but results of these projects tend to be commercialised. In terms of the principal component axes, this cluster has a broad support in *university driven R&D*, *applied R&D* and *close to market/STW*. We label it as the *university-driven* cluster. This cluster is otherwise characterised by a high frequency of technological problems as a barrier to success (7 of the 9 cases).

The other two clusters are much smaller (the two largest clusters contain 20 out of the total 30 cases), although – because our sample of cases did not aim to be representative – cluster size is not an indication of importance. Cluster 2 has six cases, and harbours a relatively large variety of motivations in both industry and university. It has a base in the *short-term business-driven, university-driven (product development)* and *applied R&D* principal components. These projects are usually implemented through Master theses and focus on researching and developing substitute to existing technologies, in an environment of intense formal and informal university-industry interaction. We label as *Industrial* *projects* as the main objective is to support technological problems of industrial product development projects.

Cluster 4 (four cases) is the only one that has a strong basis in the *IPR principal component*, but also in the *long-term business driven* and *university driven* axes. Given the importance of previous patented university-knowledge and university motivations to assure funds to undertake their research and to increase their network of research and industrial partners, we label this cluster as *Contracted.* This cluster is characterised by a high frequency of technological and cultural problems as barriers to success.

7. Conclusions

This paper has aimed at exploring how university and industry motivations come together into collaborative projects with specific organisational and institutional characteristics. We addressed these issues by analysing thirty case studies of successful knowledge transfer between university and industry, in the Netherlands.

This analysis confirmed that university and industry have quite different motivations to participate in collaborative projects. Moreover, it appears that particular combinations of motivational factors are more frequent than others, and that there are trade-offs in motivational space. The most dominant trade-off that we found is between university researchers being interested in finding applications for their basic research results, and industry being motivated by product development. Although these two motivations do not seem to be contradictory *prima facie*, our principal component analysis shows that in the 30 cases that we explore, they do tend not to occur together. Instead, where firms are motivated by product development, university researchers seem much more willing to join a project in order to maintain a collaborative network. We find one instance where firm and university motivations are well aligned, and this is in the field of applied R&D, when university researchers are motivated by applicability, and firms by research opportunities in newly discovered technologies (without an immediate market target).

Specifically with regard to IPRs, we find that projects that are facilitated by the pre-existence of IPR on university inventions, are usually characterised by university researchers motivated to open up (long-run) future research opportunities. Thus, from the point of view of the university researcher, the pecuniary aspects of IPRs seem to be less important than their impact to explore future research agendas.

In our typology of knowledge transfer projects, we find two main clusters or archetypes of projects. One is a group of projects that is strongly influence by external funding opportunities, i.e., by policy measures (like in the current Dutch case, the research funding agency STW). This group of project appears are strongly business driven (exploring research opportunities or close to market research), rather than by the research agenda of university researchers. University researchers participate in these projects mainly to maintain a collaborative network, and to access funding opportunities.

The second type of projects that we find has a much broader motivational based in industry and university, and combines university driven and business driven motivations. These projects are also sometimes sponsored by policy initiatives (STW), but their dependence on external funding is less strong than in the first group. It is interesting to note that IPRs do not play a major role in these two large groups, whereas they do play a role in a smaller cluster in our analysis. It thus seems that IPRs are often not of primary importance in the university-industry knowledge transfer process, except in a number of special cases.

This paper also provides some policy implications.

Our evidence suggests that the type of projects that depend most on external funding are characterised by a peculiar motivational pattern that is strongly biased to the industry side. It is hard to establish how this influences the outcome of these projects, and therefore one can only speculate about the impact of the specific motivational pattern on the effectiveness of the policy. The result does tell us that it may be good for policy-makers to pay more attention to the specific factors that may motivate university researchers to participate in their projects, as this is the group that in our analysis comes out with the weakest "intrinsic" motivation in the sponsored projects group.

The analysis also yields insights into the effectiveness of IPRs in knowledge transfer, which is an important topic in policy discussions. It was found that projects that focus on developing university-patented knowledge are likely to face several managerial and confrontational problems, on which university researchers need to lose much of their time in other issues than on research or education. Moreover, it appears as unlikely that the firm could have started without the university the development of a project that depends strongly on IPRs, as they need to learn how to master it before being able to use (and commercialise) it. Thus, in the Netherlands, efforts to increase university patenting may affect the financing of universities, but not significantly the intensity of university-industry interaction.

More specifically concerning public research sponsoring, our evidence suggests that there is a low degree of additionality, especially when part-time professors are involved. Dutch Research foundations need to be aware of this and try to target (and control) a share of projects with a high (i.e. developing further knowledge in potential industrial interesting areas, and exploring industrial applicability of university results) and those with a relative lower degree of additionality (i.e. development of new complex products).

Part-time professorships seem good bridges of university and industry environments and perspectives; consequently, they facilitate university-industry knowledge transfer. Still, as they enhance alignment towards projects on complementary to existing technologies and resolution of industrial problems, top scientific university might want to have some but not many of these part-time professors. Finally, our results suggest that collaborative Master thesis is potentially a stronger instrument in promoting university-industry interaction than policy-makers tend believe. Master theses facilitate the motivational alignment for developing pre-feasibility studies of industrial applicability, as well as for supporting product development or for solving industrial technological problems.

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Table 1. Some information on the cases of collaborative projects chosen

		N. Cases
Disciplinary	Biomechanics	2
	Biology/ Medicine	4
	Chemical/ Materials	3
	Applied Physics	8
	Electrical engineering	7
	Mechanical engineering	7
Origin of project attributed to	University	13
	Firm	11
	Previous / On-going collaboration	11
	Involving part-time professors	7
	Involving former ind. Researchers	6
	Based on previous patents	13
	of which univ. patented knowledge	5 (3 university owned)
Finance of R&D collaborative project		
	Research sponsoring (STW)	16 (8)
	of which without other sources	3
	Firm	9
	University	2
Outputs	Patents output	16
	Spin offs	7

Table 2. Industrial and University Motivations to collaborate

		Applicability	Future research opportunities	Financing research topic	Maintain collab. contacts	Product development	Technological problem	Access to public sponsoring	Research opportunity
Univ. Motivations	Applicability	1							
	Future research opportunities	-0,07	1						
	Financing research topic	0,03	0,32	1					
	Maintain collab. contacts	**-0,59***	-0,45	**-0,53***	1				
Ind. Motivations	Product development	-0,21	-0,23	-0,11	**0,50***	1			
	Technological problem	0,05	0,26	-0,34	**0,78***	0,36	1		
	Access public sponsoring	**-0,76***	-0,41	-0,01	**0,53***	**0,53***	-0,08	1	
	Research opportunity	0,24	0,00	**0,52***	-0,30	**-0,60***	**-0,99***	-0,41	1
Total		16	10	11	15	15	9	11	6

Note: *Significant at least at 10%

Table 3. Explanation of variables used in the analysis

Variable	**Description**
Variable group *University motivations*	
Applicability	The university researcher is interested in developing industrial applications of previously developed (basic) knowledge
Future research opportunities	The university researcher is interested in obtaining knowledge that will open up new research avenues
Financing research topics	The university researcher is interested accessing additional funding for undertaking research
Maintain collaborative contacts	The university researcher is interested in building and maintaining a network of industrial contacts that will enhance her reputation and performance as a researcher
Variable group *Industrial motivations*	
Product development	Industry is interested in developing specific new products or services
Technological problem	Industry wants to solve a specific technological problem encountered in commercial practice
Access to public sponsoring	Industry is interested in obtaining additional funding to achieve its R&D agenda.
Research opportunity	Industry is interested in exploring technologies that are judged to have future commercial potential
Variable group *Institutional facilitators*	
Part-time researchers	The project was facilitated by the participation of researchers with a part-time appointment in industry and part-time appointment in university
Univ. TTO	The university TTO was significantly involved in initiating and/or managing the project
Previous univ. patented knowledge	The project involved the application of university knowledge that was previously patented by the university (researchers)
Research Sponsoring	The project received funds from a third party
STW	The project was carried out as part of a programme of the Technology Foundation STW , and was funded by STW
Variable group *Barriers*	
Market dynamics	Developments in the market in which the industrial participant operated affected the project in a negative way (e.g., lack of customers or strong competition)
Technical problems	The project encountered severe technical problems in implementing technological principles
Cultural differences	The project suffered from a misalignment of the cultures in university and industry
Variable group *Type of innovation*	
Substitute innovation	The innovation resulting from the project substitutes for an existing technology (used by the firm or by others in its markets)
Commercialized or in process	The project led to a technology that has actually been commercialized or is in the process of being commercialized
Variable group *Interaction during the project*	
Frequency	Interactions occurred often versus occasionally
Informal	Interactions often had an only a formal nature(0) some informality (1), high informality (2)
Variable group *Project implementation*	
PhD thesis	An important part of the project led to a PhD thesis

Master	An important part of the project led to an MSc thesis
Licensing/consultancy	The project involved a licensing and/or consultancy contract
Spin off	The project involved or led to the creation of a spin-off company that employs university researchers

Table 4. Barriers and Facilitators of University-Industry Collaboration

		Market dynamics	Technical problems	Cultural differences	Part-time researchers	Research Sponsoring	STW	Univ. TTO	Previous univ. patented knowledge
Barriers	Market dynamics	1							
	Technical problems	-0,25	1						
	Cultural differences	0,11	0,19	1					
Institutional Facilitators	Part-time researchers	0,04	*-0,53*	0,00	1				
	Research Sponsoring	-0,05	**-0,67***	-0,35	**0,62***	1			
	STW	0	**-0,99***	-0,23	**0,60***	0	1		
	Univ. TTO	0,04	0,33	-0,16	-0,24	-0,46	-0,31	1	
	Previous univ. patented knowledge	0,20	**0,64***	**0,71***	0,00	-0,22	0	-0,07	1
Total		4	12	6	7	16	8	7	5

Note: *Significant at least at 10%

Table 5. Factor loadings of university and industrial motivations with institutional facilitator and barriers to university-industry collaboration

		1	2	3	4	5
Industrial Motivations	Product development	**-0.48**	**-0.51**	0.29	-0.17	-0.39
	Technological problem	-0.20	**-0.83**	0.25	0.26	-0.15
	Access to public sponsoring	**-0.85**	-0.02	-0.07	-0.13	-0.26
	Research opportunity	-0.07	**0.60**	0.17	0.16	**0.91**
University Motivations	Applicability	**0.59**	-0.21	0.17	0.24	**0.51**
	Future research opportunities	0.11	-0.08	**0.63**	0.01	0.01
	Financing research topic	0.07	**0.48**	0.35	0.11	-0.08
	Maintain collab. contacts	**-0.89**	**-0.80**	0.34	-0.02	-0.03
Institutional Facilitators	Part-time researchers	**-0.57**	-0.32	0.15	0.33	-0.01
	Univ. TTO	0.37	-0.08	-0.18	-0.19	0.01
	Previous univ. patented knowledge	0.00	-0.15	**0.91**	**0.44**	0.20
	Research Sponsoring	**-0.53**	**0.46**	-0.21	0.12	0.05
	STW	**-0.60**	-0.05	0.13	**0.50**	0.20
Barriers	Market dynamics	-0.16	-0.16	0.05	-0.32	**-0.88**
	Technical problems	**0.87**	0.27	0.03	0.10	0.04
	Cultural differences	0.18	0.30	**0.44**	-0.07	-0.20
Type of innovation	Substitute innov.	**0.89**	0.07	-0.25	0.21	-0.05
	Commercialized or in process	0.14	0.02	0.19	**0.89**	0.26
Interaction during the project	Frequency	0.38	-0.37	0.24	-0.20	-0.15
	Informal	0.36	**-0.56**	-0.06	0.10	0.23
Project' implementation	PhD thesis	0.07	**0.66**	-0.16	**0.59**	-0.14
	Master	0.34	**-0.61**	-0.07	0.06	-0.11
	Licensing/consultancy	0.00	-0.15	**0.91**	**0.44**	0.20
	Spin off	**0.71**	**0.51**	-0.19	**0.82**	-0.03
	Cronbach' Alpha	**0.83**	**0.73**	**0.82**	**0.47**	**0.49**
	% var	24%	19%	11%	9%	7%
	Cum	24%	43%	54%	63%	70%
	Eigenvalues	7,17	5,65	3,39	2,69	2,05

Note 1: 30 Observations

Note 2: Extraction Method- Principal Component Analysis; Rotation Method – Oblique

Note 3: factor loadings with absolute value >= 0.5 in bold

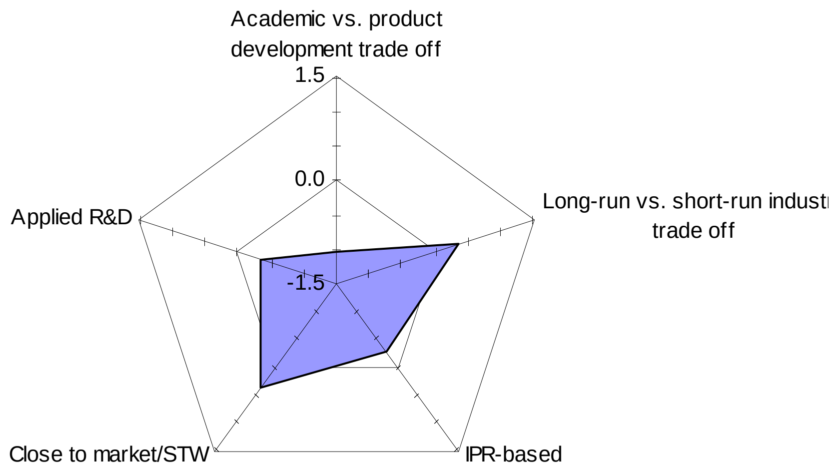
Table 6. Results of Cluster Analysis

		Sponsored	Industrial	Explorative	Contracted
Industrial Motivations	Product development	**1**	**1**	0	**1**
	Technological problem	0	**1**	0	0
	Access to public sponsoring	**1**	0	0	0
	Research opportunity	0	0	0	**1**
University Motivations	Applicability	0	**1**	**1**	**1**
	Future research opportunities	0	**1**	0	**1**
	Financing research topic	0	0	0	**1**
	Maintain collab. contacts	**1**	**1**	0	0
Institutional Facilitators	Part-time researchers	0	0	0	0
	Univ. TTO	0	0	0	0
	Previous univ. patented knowledge	0	0	0	**1**
	Research Sponsoring	**1**	0	0	0
	STW	**1**	0	0	0
Barriers	Market dynamics	0	0	0	0
	Technical problems	0	0	**1**	**1**
	Cultural differences	0	0	0	**1**
Type of innovation	Substitute innov.	0	**1**	**1**	**1**
	Commercialized or in process	**1**	0	**1**	**1**
Interaction during the project	Frequency	0	**1**	**1**	**1**
	Informal	0	**1**	**1**	0
Project' implementation	PhD thesis	**1**	0	**1**	**1**
	Master	0	**1**	0	0
	Licensing/consultancy	0	0	0	**1**
	Spin off	0	0	0	0
	Number of cases	**11**	**6**	**9**	**4**
	Applicability rather than access sponsors	**-.987**	.377	**.593**	**.711**
	Developing new industrial relevant knowledge	**.379**	**-.93**	-.169	**.914**
	Valorising into prod development	.143	**.383**	**-.929**	**.937**
	Support industrial technological problems	-.106	.142	.06	-.075
	Applicability	-.317	**.445**	.253	**-.351**

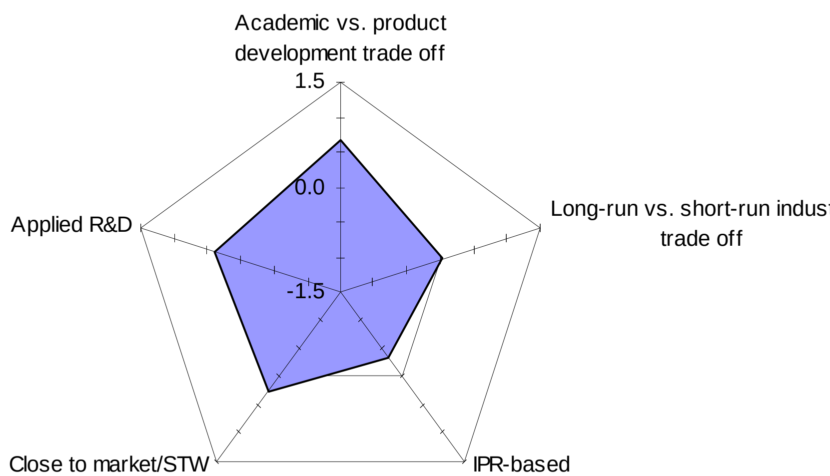
Note: 30 cases. The five variables *part-time professor*, *market-related problems*, *TTOs*, *spin-offs*, and *product commercialised or in process of being commercialised* do not differ significantly across the 4 groups of projects

Graph 1. Motivational Space of Sponsored, Industrial, Explorative and Contracted projects.

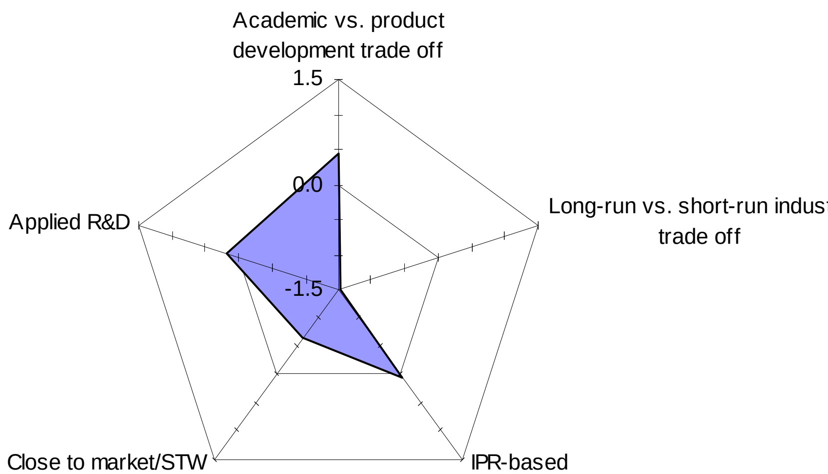
(a) Cluster 1 (11 cases) - Sponsored projects



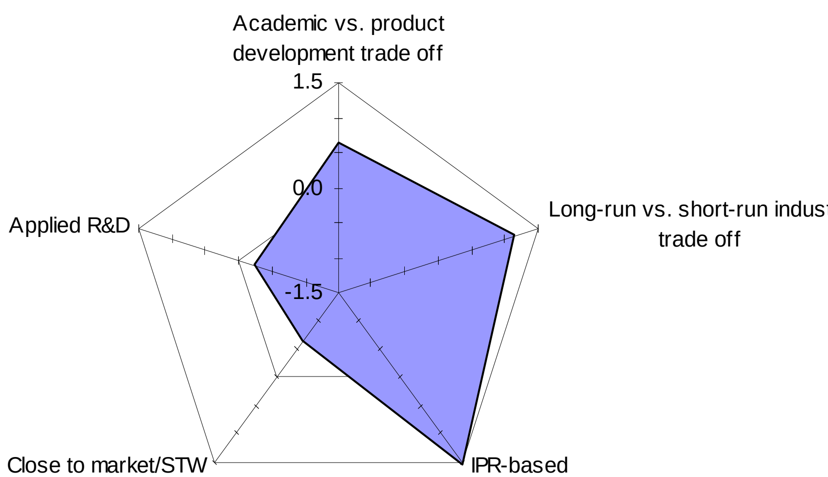
(c) Cluster 3 (9 cases) - University driven projects



(b) Cluster 2 (6 cases) - Industrial projects



(d) Cluster 4 (4 cases) - IPR based projects



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