Diversity in technology transfer policies and practices? : empirical evidence from the Netherlands

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Diversity in Technology Transfer Policies and Practices?

Empirical Evidence from the Netherlands

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Diversity in Technology Transfer Policies and Practices?

Empirical Evidence from the Netherlands

Abstract

This paper contributes to the discussion of the effectiveness of current technology transfer policies. More specifically, this paper examines the degree of fit between current technology transfer policies on the one hand and standing practices in technology transfer on the other hand, in the Netherlands. For this purpose, we both discuss the development of Dutch technology transfer policy and provide an in-depth empirical analysis of standing practices of university-industry technology transfer. Our findings indicate that national policy has a better fit with current practices of technology transfer than university policies. Furthermore, our findings are supportive of the idea that policies should be generic rather than (sector) specific.

Key-words: technology transfer policy, university-industry technology transfer

Diversity in Technology Transfer Policies and Practices?

Empirical Evidence from the Netherlands

1. Introduction

During the last two decades, university-industry technology transfer has become a ubiquitous phenomenon. Since the Bayh-Dole Act, in 1980, in the United States, many governments are undertaking actions to improve their research and knowledge infrastructures and stimulate technology transfer activities of universities (e.g. Anderson et al., 2007; Huggins et al., 2008; Link et al., 2007; Mowery and Nelson, 2004; Siegel et al., 2007). As a consequence, university-industry technology transfer has become a key priority for policy-makers worldwide (OECD, 1999; 2002, 2003).[1] Despite this growing policy interest and the large amount of resources that are currently invested to support university-industry technology transfer, there is still little understanding of how policy initiatives are designed at a government level as well as of the extent these policies achieve intended objectives (e.g. Rasmussen, 2008). More specifically, there is little insight in the degree in which policy matches indeed with standing technology transfer practices (e.g.; Goldfarb and Henrekson, 2003; Langford et al., 2006; Rasmussen, 2008).[2] In this respect, technology transfer policies are increasingly being criticized for their 'one-size-fits all' approach, for example in US-based technology transfer policies (e.g. Litan et al., 2007). According to this critique policy ignores the various types of diversity that are present in university - industry technology transfer activities. Following this idea, technology transfer policy should stimulate a wide variety of

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[1] For instance, in Europe, the Lisbon Agenda (2000) has reinforced the pace for an intensified focus of European science and innovation policymakers on the university-industry technology transfer (e.g. European Commission 1995, 2003).

informal and formal technology transfer channels because practitioners actually use a diversity of channels (e.g. Litan et al., 2007). In addition, some advocate the creation of sectoral customized policies given the large sectoral differences in technological knowledge (e.g. Siegel et al., 2007: 495; Wright et al, 2004). This plea may seem reasonable as it echoes the importance attached to diversity in the science, technology and innovation (STI) literature (e.g. Metcalfe, 1995; Nowothy, 2001, Sterling, 2008).

In this paper, we aim to assess the degree to which the criticism that technology transfer policy carries a too generic character is justified. We take two steps here. First, we analyze empirically the standing practices of the transfer of technology between academia and industry and consider to what extent diversity is present. Next, we present a comprehensive overview of the development of Dutch technology transfer policy from the early 1980s to the present and consider in how far it addresses diversity in technology transfer practices in the Netherlands. Based on these two steps, we can assess the degree of fit between policy and standing practices. If policy indeed misses out certain forms of diversity in standing practices, then it seems to be too generic indeed, implying that it should be made more specific to the extent that diversity is better captured. In contrast, if it turns out that policy adequately captures diversity in current technology transfer practices then no major redesign of current Dutch policy is required.

Overall, our study contributes to the discussion of the effectiveness of the current technology transfer policies, focusing on the usefulness of taking diversity of university-industry technology transfer into consideration. Whereas the 'one-size-fits-all' criticism is primarily based on the US, we analyze empirically if this criticism is relevant for other countries as well (e.g. Wonglimpiyarat, 2006), in particular for The Netherlands. A second contribution is that we provide an in-depth empirical inquiry into the policy development process. In this way, we respond to requests made in the literature to come up with such analyses as they are lacking currently, hindering a useful discussion on the effectiveness of these national technology transfer policies (e.g. Goldfarb and Henrekson, 2003; Rasmussen 2006).

The paper is structured as follows. Section 2 describes the data and methodology of the empirical analysis of university-industry technology transfer practices.[3] In section 3, we explore diversity in the standing practice of technology transfer in terms of technology transfer channels used (3.1), disciplinary (3.2) and sectoral (3.3) patterns of technology transfer, as well as university and industrial institutional barriers to university and useful technology transfer policy initiatives (3.4). Section 4 discusses technology transfer policy development in the Netherlands focusing on how policies deal with diversity of technology transfer. Finally, section 5 concludes and provides a policy discussion.

2. Data and methodology

To undertake this study we collected data on both technology transfer policies and instruments as well as on the technology transfer activities of university and industry researchers.

Data on Dutch policies were collected from policy documents in the Netherlands (Green papers, White Papers, Parliamentary hearings, policy reports) for the period 1980 until 2008. In addition, we conducted 30 semi-structured interviews with policy makers from the Ministry of Economic Affairs, the Ministry of Education and the Innovation Platform and policy experts as well as university administrators. These interviews have been conducted in three periods: 1998, 2001, 2006.

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[3] In this paper technology transfer refers to technological knowledge interactions between university and industry.

Dutch policies have changed rapidly, especially in the last five years. Therefore, we have chosen an explorative study to get an overview of how science, technology and innovation policies have developed to the current technology transfer policy vision and policy initiatives.

2.1 Survey Data

The analyses of the standing practice of university industry technology transfer are based on original data collected from May to June 2006. We developed two related questionnaires, one aimed at university researchers and one at industry researchers. The questionnaires were sent to actual academic and industry researchers, rather than their seniors or managers. The questionnaires are available from the internet at http://home.tm.tue.nl/rbekkers/techtrans.

Based on the Pavitt and Marsili industrial taxonomies (Pavitt, 1984; Marsili, 2001), the sample of university researchers was constructed by collecting addresses of all scientific staff at faculties in four selected disciplines: pharmaceutics and biotechnology, chemistry, mechanical engineering, and electrical engineering.In particular, respondents were sought at two technical universities (Technische Universiteit Eindhoven, Technische Universiteit Delft) as well as three regular universities (Rijksuniversiteit Groningen, Universiteit Leiden, Universiteit Utrecht).. A pilot study was conducted, and the final survey was sent out to 2082 staff members. We collected 575 valid responses. Full professors, associate professors and assistant professors are somewhat underrepresented in our sample (by approximately 20%) while Ph.D. students are somewhat overrepresented (by approximately 20%).

Similarly, the sample of industry researchers aimed at four sectors held exemplary in the Marsili and Pavitt taxonomies and recognised in the Netherlands (Marsili and Verspagen, 2002): pharmaceutical or biotechnology sector, chemical sector, machinery, basic and fabricated metal products, and mechanic, and electrical and telecommunications equipment. We selected industry researchers in three ways: Dutch individuals that were listed as inventers in EPO patents that were not owned by universities; Dutch authors of papers published in selected refereed journals for whom a non-university affiliation was given; members of the Royal Institution of Engineers in the Netherlands (KIVI NIRIA). The total sample accounted to 2088 and we received 422 valid responses.[4] Our questionnaire to researchers at the industry produced a quite homogeneous response across the four sectors we aimed at studying, each representing between 18.8% and 22.9% of all responses. An additional category called 'Other manufacturing' represents 9.7% of the sample and a category 'service sector' received 2.4%. Only 3.2% of the respondents indicated they did not work in any of the categories mentioned.

2.2 Methodology

Using the data obtained from the questionnaires to industrial and university researchers, we proceed in three steps to explore diversity in technology transfer channels used as well as the existence of structural disciplinary and sectoral patterns of technology transfer (in terms of technology transfer channels used, experienced barriers to interact an useful policy initiatives).

In order to do so, we started our analysis with four constructs (groups of variables): disciplinary origin of knowledge, the fundamental characteristics of the knowledge, channels of technology transfer, and the individual and organisational characteristics of respondents. A great number of variables are related to those constructs. Therefore, we decide to compute four Factor analyses on these four groups of variables: the scientific disciplinary origin of knowledge, the fundamental characteristics of the knowledge, the channels of technology

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[4] As it could not be guaranteed that all individuals identified in these three ways were actually active in R&D in firms; we included that question at the top of our questionnaire and discarded those that answered negatively. This was the case for 32 respondents.

transfer, and the individual and organisational characteristics of respondents. Table 1A with the factor loadings (see annex). We report and use results from the Varimax rotation method, which provide a much clear view of the main aspects of knowledge than the original un-rotated factors.

Four factors explain 71.8% of variance of the different importance of disciplines. Factor One refers to Engineering disciplinary area, including Mathematics, Electrical engineering, Computer Sciences and Mechanical engineering. Factor Two refers to Biomedical disciplinary area given the large loadings of Medical science and engineering, and Biology. Factor Three refers to Materials- related studies, given the large loadings of Chemical engineering, Chemistry, Material Sciences and Physics. Factor Four refers to Social sciences**,** in particular, Psychology and Cognitive studies, Economics and business and other social sciences.

Two factors explain 65.6% of the total variance of the fundamental characteristics of knowledge. Factor One refers to Embodied rather than to written knowledge. Factor Two refers to knowledge on complex systems as well as to expected breakthroughs in technology transfer.

The channels of technology transfer can be divided into five significant main components, which explain 65.1% of the variance. Factor One refers to contract and collaborative research as well as labour mobility. Factor Two refers to flow of (master, PhD and trainee) students and of university staff to industry. Factor Three refers to formal channels of technology transfer such as patents, licensing, spin offs and technology transfer activities (TTA) organised by universities. Factor Four refers to publications, participation in conferences and informal contacts. Factor Five refers to contacts via alumni and professional organisations and to a less extent TTA organised by university.

Individual and Organisational characteristics can be divided into 3 main components, which explain 61.8% of total variance. Factor One refers to research environments with a basic rather than an applied focus. Factor Two refers to researchers characteristics related to experience and entrepreneurship. Factor Three refers to research environments with a basic rather than an experimental focus in which researchers publish intensively

Based on these factors, first we investigate whether disciplinary knowledge patterns exist. For this purpose, we run an OLS regression models for each of the four disciplinary areas, as these variables are continuous. The dependent variables are the four factors related to disciplines- Engineering, Biomedical, Materials and Social. Independent variables are the factors related to characteristics of knowledge, channels of technology transfer and the industry dummies. We also run the same model with the factors related to the individual and organisational characteristics of respondents.

Second, we explore whether 'receiving' firms in different sectors make exclusive use of a specific disciplinary area. For this purpose, we compute a Multinomial LOGIT model on the dependent variable sector of activity (categorical variable), using all the other factors related to disciplinary origin as independent variables.

Third, we investigate whether or not respondents in different disciplinary areas identify specific institutional barriers or specific policy instruments as good to support university-industry cooperation, using Spearman's correlation coefficients.

3. Diversity in university-industry technology transfer practices

3.1 Diversity in use of technology transfer channels

In this section, we explore whether diversity is found in the use of technology transfer channels by university and industrial researchers. Based on the data, we observe a great diversity of technology transfer channels that are considered important by university and industrial researchers. Table 1 reports the share of use, the average rated importance of its use, and the share of 'high importance' (i.e. 'important' or 'very important') of each of the 23 channels of technology transfer for industrial researchers in different sectors. Figures printed in bold indicate the outliers. Moreover, when analysing the ranking of the importance and use of channels of technology transfer, we find that they are identical for industrial and university researchers.[5] Still, in general, respondents at university rate higher all the channels, followed by respondents from large firms.

[Table 1 about here]

These results suggest that university and industrial researchers use a wide range of channels to communicate and interact, as well as to transfer knowledge. In particular the 9 most used channels are considered important in terms of frequency and importance by more than 60% of respondents. Instead, diversity is not much found in the behaviour of university and industrial researchers.

3.2 Disciplinary technology transfer patterns

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[5] The main difference between the rating of university and industrial researchers refers to the greater rating of 'patents' text' and 'membership of professional organisations 'by industrial researchers and the greater rating of 'staff holding positions in both industry and university', 'financing of PhDs' and 'Temporary exchange of staff' by university researchers.

We examine now whether diversity is found across technology transfer patterns of the four identified disciplinary areas: Engineering, Biomedical, Material, and Social. For this purpose, we compute a linear regression analysis for each disciplinary area on the factors related to characteristics of knowledge, channels of technology transfer and the industrial dummies. Results in table 2 suggest that the importance of each disciplinary area is explained by the sector activity of users, by the form of interaction between university and industry, the characteristics of researchers and to a less extent to type of knowledge.

[Table 2 about here]

The table shows that the importance of *Social* scientific area is not significantly affected by the sector of activity of receiving firms. Moreover, systemic interdependent knowledge as well as expected breakthrough technology transfer seems to be an identified characteristic in all disciplinary areas. In addition, we find that the collaborative, contract and labour mobility, as well as publications and informal contacts are common forms of university-industry interaction in both *Engineering* and *Biomedical* disciplinary areas. Therefore, contrary to expected, there are no major differences between these two main scientific fields of Engineering and Biomedical – which are assumed to have different levels of interaction with industry (Balconi and Laboranti, 2006). Still, university-industry interaction through flow of students and staff is very important in *Engineering*, but not so much in *Biomedical*.

Moreover, as expected results show that researchers that use intensively *Materials* related sciences, which tend to be associated with highly codified research results, find important formal channels of technology transfer such as patents, licensing, Technology transfer offices (TTOs), spin offs, but not flows of students or staff. In addition, *Social* disciplinary area is most important for those respondents that identify contacts via alumni and professional organisations important forms of technology transfer from university to firms.

In addition, we run the same model, but this time including as well the characteristics of researchers and their working environment. Results suggest that these environmental and individual factors explain significantly the importance of disciplinary areas, except for Engineering. In particular, Biomedical disciplinary area is more important, the stronger the basic rather than the experimental research focus of the environment, and the higher the number of publications of researcher. Materials disciplinary area is instead more important, the more the applied, rather than basic research focus of the environment. Finally, the importance of Social disciplinary area is higher in basic and experimental research environment, in particular for experienced and entrepreneurial researchers with low number of published papers.

Furthermore, the industrial activities do not seem to have a unique effect on one disciplinary area. These results suggest, as some literature has put forward, the need of firms to use a wide portfolio of disciplinary knowledge to produce and compete in specific industrial context (Granstrand et al., 1997). We will explore this further in the section 3.3.

Overall, these results suggest the existence of a disciplinary pattern of technology transfer between universities to firms. These results are compatible with those provided by our Hierarchical Cluster Analysis in annex 2 (the annex provides the full analysis of Hierarchical Cluster Analysis). Table 2A in the Annex, provides results from the Hierarchical cluster analysis. Still, results from OLS provide a more complex perspective of the disciplinary knowledge patterns, since *Biomedical* and *Engineering* are revealed more similar in terms of the main forms of knowledge interaction between university and industry than usually believed and found in the literature (Balconi and Laboranti, 2006).

3.3. Sectoral technology transfer patterns

In this section, we focus on analysing diversity of technology transfer across industries. Our results in section 3.1 already suggested that firms use a wide multi-disciplinary portfolio of knowledge to produce and compete in specific industrial context. To test and explore this hypothesis, we run a Multinomial LOGIT model on the dependent variable sector of activity of the receiving firm, using as independent variable the factors related to disciplinary areas.[6] Table 3 shows the summary of the regression estimates.

[Table 3 about here]

Results suggest that researchers in electrical and mechanical activities differ significantly from those in chemical activities on the degree to which they rely on *Engineering*, *Biomedical* and *Materials* knowledge. Moreover, researchers in pharmaceutical activities differs significantly from those in electrical and mechanical activities by making a different use of *Engineering* and *Biomedical* knowledge, and to a less extent of *Social, cognitive and economics* knowledge, which is more used by pharmaceutical firms. Additionally, respondents in electrical and mechanical activities also differ in their use of *Biomedical* and *Materials* scientific knowledge.

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[6] When we include factors related to the channels of technology transfer, characteristics of the individuals and their research environment and policy instruments, results do not change. Characteristics of the individuals and their research environment and policy instruments do not help much in differentiating the industrial context in which the research work of respondents is applied. Still, we find that knowledge is more codified in chemical than in electrical activities, while knowledge is considered more interdependent and more break through tech transfer activities are expected in electrical activities. Pharmaceutical firms attach more importance to publications and informal contacts than firms in mechanical engineering. Finally, interdependent and breakthrough technology transfer activities is more common in electrical than in mechanical engineering.

Hence, firms rely on a multi-disciplinary portfolio of knowledge, but some industrial differences on average portfolios are found. *Engineering* scientific knowledge is most used by firms active in mechanical and electrical industrial activities. *Biomedical* knowledge is of greatest importance to pharmaceutical firms, followed by firms active in chemical and electrical activities. *Materials* knowledge is of great importance for chemical firms, followed by firms operating in pharmaceutical and mechanical industrial activities. Finally, *Social* scientific knowledge is of greatest importance for pharmaceutical, followed by chemical and electrical firms.

To conclude, there is not a well-defined one-to-one relationship between disciplinary areas and sectoral activities of firms. Firms instead use a wide and overlapping multidisciplinary portfolio of scientific knowledge to produce and compete in specific industrial context. Moreover, firms within the same sector of activity may need to use a more multidisciplinary portfolio of scientific knowledge than we would expect. Furthermore, the use of channels of technology transfer does not depend on the sector activity of the receiving firms, but instead, on the disciplinary origin and characteristics of knowledge, as well as on the organisational and individual characteristics of research environment (Bekkers and Bodas Freitas, 2008).

3.4 Diversity in experienced institutional barriers and useful policy instruments

In this section, we analyze whether and how institutional barriers and policy support instruments are correlated with the four disciplinary areas. In the questionnaires to industrial and university researchers, respondents were asked to report their understanding of the two best instruments for governments to support technology transfer. Table 4 shows the average score for each proposed instrument. Results suggest that general policy instruments are rated higher than targeted or specific innovation or than entrepreneurship programmes.

[Table 4 about here]

Given the large number of policy instruments, a Factor analysis of the eight surveyed policy instruments was computed. Table in the annex provides the factor loadings. Preferences for policy instruments can be divided into 4 main factors, which explain 60.5% of total variance. Factor One refers to *general policy incentives*, such as tax exemptions and financial support to the university technology transfer offices, rather than targeted programmes. Factor Two refers *support entrepreneurship* at university and incubating start-ups. Factor Three refers to *European university-industry cooperation* schemes rather than support bridging organisations. Factor Four refers to *Dutch university-industry cooperation* schemes rather than support entrepreneurship.

In addition, we asked respondents to identify the major barriers to technology transfer. The questions posed to industrial and to university researchers were obviously different to address their specific institutional context. Hence, we analyze individually, the barriers identified by university an industrial respondents. Before exploring the relationship between barriers to technology transfer and each disciplinary area, we need to reduce the number of elements of comparison. Consequently, we run a Factor Analysis for the university barriers and other for industrial barriers. Table 4A and Table 5A in the annex provide the factor loadings.

University Barriers to interact and collaborate with industry may be divided into three factors, which explain 52.8% of the total variance. Factor One refers to the understanding that *industry* *is not interested* for reasons not immediately acknowledged. Factor Two refers to the perspective that *it is difficult to find industrial partners* because industry does not want to cooperate in the process of knowledge development but only to absorb university knowledge. Factor Three refers to the understanding that technology transfer *requires considerable time and money from universities*.

Industrial Barriers to interact and collaborate with university can be mainly divided into three factors, which explain 62.3% of the total variance. Factor One refers to the understanding that university *knowledge is too general and, theoretical as well as that industrial and university have different cultures;* consequently, it is expensive to apply university knowledge. Factor Two refers to the perspective that *joint research with university involves risks of information leakage,* consequently expensive and difficult to manage. Factor Three refers to the understanding that *ownership of patents or exclusive licensing of joint research results is fundamental* to firms to use university knowledge. Factor Four refers to the *difficulties in using university knowledge* and the preference to contract an academic researchers as consultant than contract research with the university. Factor Five refers to the *acknowledgement of the importance of university knowledge* for their industrial R&D activities.

Reduced the number of elements referring to institutional barriers and to policy instruments, we proceed to the computation of the Spearman's correlation coefficients between these factors and each identified disciplinary area.

In order to infer on the relationship between disciplinary areas and preferences for policy instruments and institutional barriers, we proceed to the computation of the Spearman's correlation coefficients between these factors and each identified disciplinary area. Table 5 provides a summary of the significant coefficients between barriers and disciplinary areas as well as between policy instruments and disciplinary areas.

[Table 5 about here]

Results suggest a very weak correlation relationship between disciplinary areas and policy instruments as well as between disciplinary areas and institutional barriers. Moreover, most of policy instruments and institutional barriers are not significantly correlated. The existing significant correlations reveal that industrial researchers that recognised more barriers to university-industry interaction value less European or Dutch public programmes sponsoring collaborative projects with university.[7]

The pattern of correlations between the identified barriers by university researchers and the disciplinary areas turns out compatible with barriers identified by industrial researchers.

In particular, university researchers, who find *Engineering* disciplines very important, are lore likely to identify the barrier that industry is not interested in collaboration. Importance of *Biomedical* is positively correlated with the barrier that it is costly and time consuming to cooperate with industry. *Materials* disciplinary area is correlated with the barrier that it is difficult to find industrial partners, who are ‘only interested to absorb university knowledge’ than to collaborate on knowledge development.

Industrial researchers -who find *Biomedical* and *Materials* disciplinary areas more important- tend to identify two main barriers to interact with university: their request of patenting the

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[7] In particular, European projects are valued the least by industrial respondents, who recognise barriers related to knowledge is too general and joint research is risky. These European projects are valued more by respondents who acknowledge the importance of university knowledge. Dutch university-industry sponsoring is less valued by industrial respondents who recognise barriers related to issues of property rights and difficulty in using university knowledge.

joint research results and keeping their ownership. Respondents more involved with *Materials* sciences experience fewer barriers to interact. This may coincide with our previous finding, in section 2.2, that formal channels are more important for them. Finally, the importance of *Social* disciplinary area tends to be associated with the experienced barrier that joint research is expensive and involves risks of information leaking.

Policy instruments are significantly correlated with some disciplinary areas. If the respondent is more involved with the *Biomedical* disciplinary area, then European collaborative programmes and policy support for university entrepreneurship are appreciated more (rather than programmes that support Dutch collaborative projects or organisations bridging institutes). If the s*ocial* disciplinary area is important for respondents, then general tax incentives are appreciated more (rather than entrepreneurial support or targeted programmes).

In summary, we find that some specific barriers to technology transfer are significantly correlated with disciplinary areas, although the correlation is quite weak. We do not find significant correlations between preferred policy incentives for university-industry cooperation and disciplinary areas, except for the higher importance of EU collaborative projects for users of biomedical disciplinary knowledge. In general, researchers seem to prefer general policy incentives to university-industry interaction (such as general tax benefits, and support to TTOs) rather than targeted or specific innovation programmes (especially university entrepreneurship initiatives)

4. Diversity in technology transfer policies in the Netherlands

In this section we discuss the development of technology transfer policy from early 1980s to the present and consider in how far it addresses diversity in technology transfer practices in the

Netherlands. We explore to what extend technology transfer policy stimulates different kinds of technology transfer channels and if disciplinary and sectoral patterns of technology transfer (in terms of channels used and institutional barriers) are considered in policy making.

Traditionally, Dutch technology transfer policy has been part of science policy of the Ministry of Education, Culture and Science and the innovation policy of the Ministry of Economic Affairs. In 2005 these separate policy initiatives were formally integrated in the national technology transfer policy. The last five years the Dutch technology transfer policies have changed rapidly. Therefore, we present in this section an overview of how science, technology and innovation policies have developed to the current technology transfer policy. We first analyze diversity in the national science policy (4.1), second diversity in the technology and innovation policies (4.2) and third in the current national technology transfer policy (4.3). Moreover, we discuss diversity in university technology transfer policy at the institution level (4.4) to present a complete picture of government's steering towards university and industry researchers.

4.1 Science policy development and diversity of technology transfer

We explore here to what extend science policy have stimulated the use of different technology transfer channels by university researchers and if tailored policy initiatives have been installed across academic disciplines.

The last decades, science policy in the Netherlands has not formally emphasized on university technology transfer. Universities traditionally have an autonomous status in the Netherlands and have a free choice whether and how to interact with industry. For instance, in patent law Dutch universities have the right to patent their inventions but they do not have an obligation to patent or disseminate this knowledge in a commercial way (OECD, 2003).

Since the 1990s, the formal science policy of the Ministry of Education, Culture and Science has been focused on stimulating scientific excellence. The Ministry was cautious about formal technology transfer activities of scientists and it was assumed that it did not increase the scientific level of universities. Technology transfer and commercialization of university knowledge was not perceived as a activity or responsibility of universities: university researchers conduct excellent scientific research and firms can chose to use this knowledge to their commercial benefits (See for instance AWT 1999; Ministry of Economic Affairs et al, 1995). The preferred way to transfer this knowledge was via the more 'traditional' academic channels such as scientific publications and student (PhD) flows.

Formally, the science policy vision on university technology transfer changed in 2004. The current policies aim to actively stimulate both scientific excellence as well as the usefulness of scientific knowledge for industry and society (Ministry of Education, 2004a, 2004b). An example is the National Genomics Initiative (NGI).[8]

The current science policy is generic (it does not differentiate across disciplines) and no specific attention f or particular technology transfer channels.

4.2 Technology and Innovation policy development and diversity of technology transfer

The innovation policy of the Ministry of Economic Affairs aims to stimulate technology transfer between firms and universities, as an instrument to support industry in using university knowledge and inventions. Their policy vision and instruments regarding technology transfer changed over time.

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[8] The selection for research grants is conducted by the National Research Council, that selects on the basis of peer recognition and scientific quality of the (professorial) applicant with the selection criteria of excellence of research in combination with a good potential for research commercialization and usefulness for society.

With the Innovation White Paper (1979), the Ministry of Economic Affairs had formally acknowledged the importance of university knowledge as an input factor in innovative processes of firms. Consequently, it was recognized that universities are important partners for firms that aim at developing industrial innovations. The policy vision was then still based on the so-called pipe-line (or linear) view of innovation: universities develop new knowledge, which can be transferred to firms mainly via formal technology transfer channels such as formal pre-competitive research collaboration. After the technology transfer, firms can choose to use and exploit the new knowledge and develop it further into new products or processes. The policy instruments were dominated by financial incentives to formal pre-competitive R&D collaboration programmes. So in the 1980s the technology and innovation policy did not differentiate across sectors and there was a focus on formal technology transfer channels.

During the nineties, the Ministry of Economic Affairs introduced many new policy instruments to stimulate a wide diversity of technology transfer channels (Ministry of Economic Affairs et al, 1994, 1995). The idea was to implement policy instruments that increase the various technology transfer interactions in the Dutch national innovation system'.[9] Consequently, the small panoply of incentives to formal R&D collaboration of the 1980s was complemented with public support for many different technology transfer channels. Moreover, there is (re)newed attention for sector-specific barriers that hinder technology transfer between universities and firms. Examples are the government programmes Stigon and (1996-2001) and Biopartner (2001-2007) aiming to stimulate the establishment of university spin-offs in Life Sciences.

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[9] Via working groups of the OECD (e.g. OECD 1999) and innovation conferences (e.g. Porter 1990), notions such as economic clusters, innovation systems and 'excellence and usefulness of university knowledge' entered the policy jargon of the Ministry of Economic Affairs (see Ministry of Economic Affairs, 1994; Ministry of Economic Affairs et al, 1995).

So, the end of the 1990s was characterized by many technology-specific programs to stimulate different technology transfer channels (AWT, 1999).

This intensification period was reinforced by the Lisbon agenda (2000). The presumed European Knowledge Paradox has legitimated a new array of European and national policy instruments, stimulating formal and informal technology transfer channels (e.g. Ministry of Economic Affairs, 2004).[10] In particular, European networking activities were now stimulated (e.g. Dosi et al., 2006) mainly through the European Technology Platforms. Under the influence of European policies, several national instruments were installed such as the Dutch Casimir programme (2004), which became popular.[11] Consequently from late 1990s to 2004, we saw an increase in the number of policy instruments used by Ministry of economic affairs to support firms' innovative activity through interaction with universities

So, during the period from the 1990s until 2004 the technology and innovation policy is sector specific and has attention for many different technology transfer channels.

4.2 National technology transfer policy and diversity

So, around 2004, there were about 20 technology transfer instruments in use in the Netherlands. Most policy instruments resided at the Ministry of Economic Affairs and aimed at the stimulation of 'third mission activities of universities', such as university spin-offs and the improving the 'entrepreneurial culture' of university. Herewith, the political lines between science and innovation policy instruments became more and more blurred and the political question was raised who was in charge of the technology transfer policy in the Netherlands.

The National Innovation Platform, including among others the prime minister, the Minister of Education and the Minister of Economic Affairs stepped in and took responsibility for

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[10] For similar developments in other countries in Europe see: Beesley (2003) and Vavakova, (2006).

[11] The Casimir programma is a fiscal instrument to stimulate temporary employment of university scientists at firms

developing a national technology transfer policy vision. The Innovation Platform has argued that university-industry technology transfer instruments are so interwoven that effective policies require consistency between science and innovation policies. This resulted in three outcomes.

First, around 2004, the large number of policy instruments was reduced again to a generic policy framework. The streamlining operation did not only reduce the number of policy instruments to those that were positively evaluated but also removed sector-specific ones (Ministry of Economic affairs, 2003).[12] Although the 20 scattered policy programmes have been reduced to 4 generic ones frameworks, which still address a variety of formal and informal knowledge channels, as shown in Table 8 (Ministry of Economic Affairs, 2005: 21).

[table 8 about here]

Second, the national technology transfer instruments now reside in a new interdepartmental directorate at the Ministry of Economic Affairs, half staffed by government officials from the Ministry of Education and the other half by officials of the Ministry of Economic Affairs.

Third, since 2007, The Innovation Platform has developed a formal national strategy and policy vision of Dutch university-industry technology transfer policy, also known as the national "knowledge valorisation policy" (Innovation Platform, 2007).

So, the national technology transfer policy is generic (does not differentiated between sectors or disciplines) and includes an array of policy instruments stimulating different technology transfer channels.

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[12] The White Paper 'Strong basis for top performance; the renewed policy instruments for entrepreneurs (2005: p21) shows that the 20 technology transfer instruments were reduced to only four generic policy technology transfer instruments

4.4 University policy development and diversity of university technology transfer

In this section we discuss university technology transfer and explore if it stimulates diversity of technology transfer channels and if it differentiates across disciplines.

The science policies of the Ministry of Education, Culture and Science (see above section 4.1) influenced the formal engagement of universities in technology transfer. During the 1980s-1990s some universities were already actively pursuing entrepreneurial, commercial technology transfer activities, where many other universities did not (formally) engage in technology transfer activities (Arundel et al, 2003). Some universities already had technology transfer policies in place, for instance the active spin-off policy of the University of Twente since the 1980s, where others did not have formal policies. Moreover, the policies that were in place varied greatly, either focusing on establishing spin-offs or research collaborations with particular multinational firms. TTOs were often still administrative offices and their engagement with technology transfer was merely an administrative or legislative involvement (OECD, 2003).

So, until very recently, technology transfer was a decentralized activity at universities. It was common practice in the Netherlands that individual professors or research units interact directly with firms (both Dutch as well as multinationals), often on a structural basis. If commercially interesting scientific outcomes occurred at the university labs, collaborating firms often assured ownership of this invention, offering (Ph.D.) funding, access to research facilities, or equipment/machinery in return (Bekkers et al, 2006). Anecdotal evidence points out that these structural, but often informally organized exchanges and interactions of research units and firms differed across technological fields (OECD, 2003, Arundel et al, 2003). So, even within a Dutch university, one could find a large variety of technology transfer practices across research units.

Since the science policy shift of the Ministry of Education, Culture and Science in 2004 (see section 4.1), the relevance of the 'third mission' of universities became formally recognized. As a response all Dutch universities have been developing and implementing formal policies to enhance university-industry technology transfer. The so-called 'third mission activities' of universities are focused on a limited number of formal exchange channels such as university spin-offs, university patenting and formal R&D research such as participation in the EU Framework Programmes. The National Innovation Charter (2006), signed by universities, the Dutch multinational firms and representative organisations of universities and firms, is an agreement for a code of conduct for university patenting and licensing. This is an example of the focus on formal technology transfer channels from the perspective of universities.[13]

So, the university technology transfer policies are generic (they do not differentiate across disciplines) and are focused on a limited number of formal channels of technology transfer.

4.4 Summary of the Dutch technology transfer policy development

The main question we raised in this section is to what extend the Dutch technology transfer policy encourages diversity of technology transfer in channels used and whether it is of a generic or specific (sectoral and, or disciplinary) character. We found that the current national technology transfer policy is generic (does not take into account sectoral or disciplinary

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[13] The most recent policy discussion is related to a national initiative of the Committee 'Delta Plan Valorization' installed by the National Innovation Platform, to develop standardized university technology transfer indicators that will be monitored on a national and regular basis by government. (Innovation Platform, December, 2008). The choice of performance indicators (either remains focused on formal channels or also include measurements of informal knowledge channels) will have a strong impact on the pace of technology transfer activities of universities in the future).

patterns and, or barriers to technology transfer) and stimulates a variety of technology transfer channels. The university technology transfer policy at the level of the institution is also generic but focuses on a limited number of technology transfer channels used by university researchers.

One should keep in mind that the respondents of our survey will have based their opinions (at least partly) on policy instruments of the policy framework prior to 2006. Two issues are relevant here. First, the earlier technology transfer policy instruments, as part of the innovation policy of the Ministry of Economic Affairs, were still sector specific. Second, at the level of university policies, most universities had no formal and active technology transfer policy in place yet (i.e. policies focused on a limited number of formal technology transfer channels).

5. Conclusion and policy discussion

Technology transfer policy is increasingly being criticized for its ‘one-size-fits-all’ approach, i.e. for being too general in nature. According to this critique, it misses out on various types of diversity that are present in standing practices of transfer of technology. The validity of this critique is difficult to judge given the limited understanding of the degree in which policy matches with standing technology transfer practices, especially outside the US (Rasmussen, 2008; Goldfarb and Henrekson, 2003). To address this, we have considered in this paper the case of the Netherlands and assessed in how far current Dutch policy captures sufficiently three types of diversity in technology transfer activities.

Based on an in-depth empirical study of standing practices of technology transfer from academia to industry, we analyzed the role of diversity along three dimensions. First, as far as the diversity in types of technology transfer channels is concerned, we found that knowledge between university and firms flows through multiple channels. The most important ones are publications, students flow and staff mobility, informal contacts and collaborative research. In fact, formal mechanisms, such as licensing, TTOs, and spin-off are among the least used technology transfer channels. Second, we found significant disciplinary patterns of university-industry technology transfer. However, given that firms are increasingly multi-technological and their products (highly) multi-disciplinary, no significant sectoral patterns of university-industry technology transfer were found. Thus, despite the fact that industry researchers use multiple channels of technology transfer and that some disciplinary diversity seem to exist in forms of technology transfer, we could not identify any systematic patterns across sectors, excluding a possible rationale for more specific (sectoral or disciplinary-oriented) technology transfer policies.

Third, with regard to the role of different barriers in university-industry interaction, we found that perceived barriers were not that relevant from an academic discipline perspective, and even non-existent from an industry perspective. Moreover, no considerable disciplinary nor sectoral differences were identified when respondents were asked about their preferred policy instruments. University and industry researchers appreciated generic incentives for technology transfer higher (such as support for in-house technological development, or industrial financed university research and generic support for TTO activities), which mainly support effectiveness of formal mechanisms, rather than targeted or specific innovation programmes, especially those aimed at improving university entrepreneurship.

Following these findings, we can conclude that technology transfer activities indeed exhibit diversity in various ways, in line with some earlier claims as made in the literature. However, diversity is not present to the extent that highly systematic patterns can be identified along any of the three dimensions. Although diversity is clearly present, it appears to be more idiosyncratic rather than to be very systematic.

Given this we can conclude that national Dutch policy matches standing technology transfer practices to a large extent. Current policy does not deliberately target specific transfer mechanisms nor does it focus on certain technologies and/or sectors. Instead, it offers a rather comprehensive toolbox of a wide array of policy instruments that, in combination, adequately reflect the broad and diverse nature of technology transfer. Seen in this way, policy is based on a common denominator across different transfer practices but with room for diversity in its various identities.

The paper also addressed university technology transfer policies at the institution level and concluded that, despite being generic across disciplines, these policies focused mainly on formal channels of technology transfer (TTO, spin-offs and university patenting). In this respect, there is a misfit between the actual practice of technology transfer (in terms of multi-channels, differences across disciplines and the importance of the traditional 'scientific' knowledge channels such as publications, graduates) and the current university policies (focused on a few commercial formal knowledge channels such as patenting). The observed discrepancy between the national policies and the limited interpretation of university TT policies is in line with Langford et al. (2006: 1587) criticism that: 'high level' policy may implicitly recognize the non-linear nature of innovation, but the measurements of TT activities at universities is limited to some formal channels.

Policy implications

Our study also informs policy. Our findings are supportive of horizontal and generic technology transfer policies, rather than sector-specific ones, as firms tend to be multi-technological and their products and innovations (highly) multi-disciplinary. By large, this is in line with the current technology transfer framework of the Netherlands. The establishment of the new directorate of technology transfer policy (2007) represents the shared responsibility of the Ministry of Economic Affairs and the Ministry of Education in this policy field. This new organizational structure fits better with the practice of technology transfer as a two-way iterative process involving different technology transfer channels at the same time.

The Ministry of Education is still the sole responsible for science policies, aimed at encouraging excellence of research. In fact, publications are one of the most used mechanisms by firms to access university knowledge. As a consequence, it remains a challenge for science policies to protect the traditional university tasks of excellence in teaching and in scientific research. Although we recognize in line with our respondents that government and universities should have technology transfer institutions in place (such as efficient TTOs to support the effective use of formal channels, rules on property rights of university and collaborative knowledge, as well as general tax incentives to industrial financed R&D), our evidence suggests that it is crucial not to neglect generic policy incentives for students traineeship, master and PhD research in collaboration with industry. Instead, further efforts to increase the entrepreneurship of university researchers do not seem to yield marginal benefits. However, further research should analyse the mutual use of technology transfer channels in relation to the effectiveness of university –industry technology transfer effectiveness.

In sum, any ‘fear’ for the risks and dangers of one-size-fits-all policy seems to be unjustified. Standing Dutch policy seems to strike a careful balance between generality, in view of ensuring broad coverage, and specificity, in view of respecting diversity in specific cases, which is largely consistent with the idiosyncratic role of diversity in technology transfer activities.

A final remaining challenge, for the Netherlands is to overcome the discrepancy between the national policy vision and the more narrow-focus of most university technology transfer policies (focused on a few commercial formal knowledge channels such as patenting and spin-off creation). This issue becomes more urgent in the Netherlands because the gravity of technology transfer policy making will be shifted from the national to the university level in the coming years (Valorisation Intention Declaration, December 2008). More specifically, performance indicators of university TT activities will become more important in the near future. The challenge will be to include a broader set of indicators that cover the actual practice of technology transfer activities. This requires that the national technology transfer (and science) policy allows for diversification of university -scientific and related technology transfer- profiles.

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Tables and figures

Table 1: Share of use, Average importance rating and share of high importance for each channel of technology transfer surveyed, the perspective of industrial and university R&D performers

	Industrial R&D performers			University R&D performers		
Form of Technology transfer from universities to firms	Share of use	Average importance	Share of high use	Share of use	Average importance	Share of high use
Specific technology transfer activities organised by the university's TTO	0.65	1.99	0.15	0.68	2.19	0.26
Contract-based in-business education and training delivered by universities	0.69	2.07	0.14	0.79	2.69	0.36
Temporary staff exchange with universities (e.g. staff mobility programmes)	**0.71**	**2.35**	**0.27**	**0.82**	**2.89**	**0.43**
Personal contacts via alumni organisations	0.72	2.09	0.10	0.79	2.44	0.23
Sharing facilities (e.g. laboratories, equipment, housing) with universities	0.72	2.47	0.33	0.81	2.86	0.44
Licenses of university-held patents and 'know-how' licenses	0.76	2.56	0.32	0.79	2.63	0.33
University spin-offs (as a source of knowledge)	0.77	2.53	0.32	0.81	2.91	0.47
Staff holding positions in both a university and a business	**0.77**	**2.62**	**0.36**	**0.90**	**3.48**	**0.63**
Financing of Ph.D. projects	**0.78**	**2.70**	**0.37**	**0.93**	**3.83**	**0.76**
Contract research by universities or public research labs (excl. Ph.D. projects)	0.80	2.83	0.44	0.89	3.32	0.55
Inflow of new employees from university positions	0.81	2.74	0.35	0.91	3.23	0.47
Joint R&D projects with universities in the context of EU Framework Programmes	0.82	3.01	0.49	0.89	3.54	0.65
Consultancy by university staff members	0.83	2.73	0.35	0.91	3.36	0.55
Personal contacts via membership of professional organisations (e.g. KIVI NIRIA)	**0.85**	**2.80**	**0.32**	**0.88**	**3.02**	**0.41**
Other joint R&D projects with universities	0.87	3.31	0.60	0.95	3.96	0.80
Inflow of university graduates as employees (PhD level)	0.87	3.43	0.62	0.97	4.21	0.89
Students working as trainees	0.90	3.38	0.63	0.93	3.51	0.63
Inflow of university graduates as employees (BSc or MSc level)	0.90	3.57	0.69	0.95	3.84	0.77
Patent texts, as found in the patent office or in patent databases	**0.93**	**3.72**	**0.71**	**0.81**	**2.74**	**0.38**
Participation of university staff in conferences and workshops that you attend	0.93	3.59	0.67	0.98	4.16	0.89
Personal (informal) contacts with university staff	0.94	3.77	0.73	0.99	4.29	0.91
Scientific publications in (refereed) journals or books	0.97	3.93	0.76	1.00	4.45	0.90
Other publications, including professional publications and reports	0.98	3.92	0.82	0.99	4.45	0.81
Total Average	**0.83**	**2.96**	**0.46**	**0.89**	**3.39**	**0.59**

Note 1: Observations 340 industrial researchers, 392 university researchers

Table 2: Summary of significant coefficients explaining the importance of each disciplinary area

		Engineering	**Biomedical**	**Material**	**Social Sciences**
Model	Independent variables				
Base model	K characteristics	+ Interdependent and Expected breatechnology transferhroughs + Embodied [a]	+ Interdependent and Expected breatechnology transferhroughs	+ Interdependent and Expected breatechnology transferhroughs	+ Embodied + Interdependent and Expected breatechnology transferhroughs [a]
	Channels of technology transfer	+ Students and Staff flows + Publications & informal contacts + Collaborative and contract & labour mobility	+ Publications & informal contacts + Collaborative and contract & labour mobility	+ Formal channels (patents, licensing, TTA, spin offs) - Students and Staff flows	+ Contacts via alumni and professional organisations
	R Square	0.09	0.11	0.08	0.09
Base model + sector dummies	Sector [b]	- Chemical - Pharmaceutical	+ Pharmaceutical + Chemical + Electrical	+ Chemical - Electrical - Pharmaceutical	
	R Square	0.34	0.42	0.25	0.1
Based model plus sector dummies + individual and organisational characteristics	Individual and Organisational characteristics		+ number of papers, basic rather than experimental environments	+ applied rather than basic research environment	- applied rather than basic research environment + experienced and entrepreneurial researchers - number of papers, basic rather than experimental environments
	R Square	0.34	0.43	0.26	0.16

([a]) Coefficient is not significant anymore when variables on the individual and organisational characteristics of researchers are introduced.

([b]) Mechanical engineering is the reference category, together with other few populated categories (other manufacturing and services) Observations: 618. When factors related to the individual and organisational characteristics of respondents are included, the number of observations is reduced to 585.

Table 3: Summary of Results from the Multinomial LOGIT model on the variable sector

	Differences			
reference category	Chemical	pharmaceutical	mechanical	Electrical
Chemical		+ Biomedical - Materials	+ Engineering - Biomedical - Materials	+ Engineering - Biomedical - Materials
Pharmaceutical			+ Engineering - Biomedical - Social	+ Engineering - Biomedical - Social*
Mechanical				+ Biomedical - Materials

Note 1: * Significant at 5.7%

Note 2: Observations: 613

Note 3: Pseudo R Square: 0.4567; Wald chi2 (12) = 210.27

Table 4: The best instruments for governments to improve research cooperation. Percentage of respondents that tick each of the following instruments

	Percentage
Financial and other support to Technology Transfer Offices at universities	38.1
Tax instruments (e.g. tax deductions for joint R&D work)	32.5
Support for organisations that bridge science and business R&D (e.g. TNO)	27.3
University programmes for reviewing and rewarding research output	21.4
Support for new technological enterprises in their start-up phase (e.g. housing, tailored support, specific tax schemes)	21.1
Targeted innovation programmes (such as Genomics, Bsik, Technological TopInstitutes)	19.9
Dutch innovation policy schemes related to public-private research cooperation	19.4
European innovation policy schemes related to public-private research cooperation	17
Policy to improve the entrepreneurial climate at universities	15.9

Observations: 818

Table 5: Barriers and Policy Instruments: Significant Spearman's correlation coefficients

		Engineering	Biomedical	Material	Social Scien
Policy instruments	University and Industry	(+ 0.07*) Support entrepreneurship	(+ 0.129**) European collaborative programmes, rather than bridging org. (- 0.103**) Dutch collaborative projects		(+ 0.19**) gener incentives rather targeted progra (- 0.106**) sup entrepreneurs
Barriers to interaction	University	(+ 0.12*) industry is not interested (- 0.117*) it is costly and time consuming	(+ 0.141*) it is costly and time consuming	(+ 0.118*) it is difficult to find industrial partners	
	Industry		(- 0.366**) university knowledge is general, theoretical as well as that different culture (+ 0.168**) request to patent the join research results and keeping their ownership.	(+ 0.121*) request to patent the join research results and keeping their ownership (- 0.118*) difficulty in using the university knowledge	(+ 0.113*) joint res expensive and in risks of informa leaking

* Significance at 95%; **Significance at 99%

Table 6 Technology Transfer Policy framework 2004 present (Innovation Omnibus)

Technology transfer channel	Type of policy instrument	Technology transfer barrier addressed	Name subprogram within Omnibus
(Targeted) Support for new technological enterprises in start up phase	Support for entrepreneurship Tax schemes	Difficult to find industry partners Industry is not (yet) interested Develop university patents Difficult using university knowledge	Technopartner 215 million (2004 2010) NGI Genomics
(Targeted) Seed and venture capital funding for growth of new technological enterprise in start up phase	Tax instrument: tax deductions	Industry is not (yet) interested Research is costly and time consuming	Technopartner see scheme (24 million per year) NGI Genomics see capital fund
Innovation policy scheme for public private research	Tax instrument	Difficult using university knowledge Industry is not interested	Smart mix (100 million per year)

cooperation	Mobility of university and industry researchers	Overcome cultural differences between university and industry	CASIMIR RAAK
Targeted schemes for structural pre competitive public private research cooperation	Tax scheme and pre competitive R&D subsidy for university industry research consortia	Difficult using university knowledge Difficult to find industry partners	Technological Top Institutes
Overcome institutional barriers for university industry research cooperation	Intention Charter of university and industry parties in the Netherlands	Joined R&D is hindered by conflicts between academic researchers who want to publish Overcome institutional and cultural differences between university and industry	Innovation Charter (2006) Deltaplan Valorization (2008)

Annexes

Table 1A: Varimax Factor loadings: disciplines, fundamental characteristics of knowledge, channels of technology transfer from universities to firms, and individual and organisational characteristics

Disciplines	**Engineering**	**Biomedical**	**Materials**	**Social**	
	1	**2**	**3**	**4**	
Biology	-0.283	**0.83**	0.122	0.087	
Medical science	-0.182	**0.913**	-0.039	0.139	
Medical engineering	0.149	**0.858**	0.023	0.076	
Chemistry	-0.355	0.297	**0.77**	0.03	
Chemical engineering	-0.121	0.146	**0.852**	0.143	
Physics	**0.544**	-0.092	**0.604**	-0.126	
Material science	0.305	-0.262	**0.726**	-0.044	
Mathematics	**0.805**	-0.044	0.112	-0.049	
Computer science	**0.679**	0.101	-0.158	0.226	
Electrical engineering	**0.762**	-0.19	-0.144	0.142	
Mechanical engineering	**0.561**	-0.309	0.295	0.178	
Economics and business studies	0.142	-0.14	0.194	**0.764**	
Psychology, cognitive studies	0.083	0.211	-0.073	**0.86**	
(Other) social sciences	0.062	0.207	-0.031	**0.863**	
Fundamental knowledge characteristics	**Embodied**	**Systemic and breatechnology transferhroughs**			
	1	**2**			
knowledge is primarily expressed in written documents	**-0.836**	0.084			

knowledge is predominantly embodied in people	**0.783**	0.208			
major technological breatechnology transferhroughs expected within the next five years	-0.088	0.815			
we often work with systems that have many interdependent parts	0.206	0.738			
Channels of technology transfer from university to firms	**Collaborative and contract research & labour mobility**	**Flow of students and staff**	**Formal channels (patents, licensing, spin offs, TTA)**	**Publications & informal contacts**	**Contacts via professional org.**
	1	**2**	**3**	**4**	**5**
Scientific publications in (refereed) journals or books	0.192	0.071	0.021	**0.802**	-0.053
Other publications, including professional publications and reports	-0.012	0.072	0.139	**0.706**	0.175
Participation of university staff in conferences and workshops	0.387	0.197	-0.008	**0.633**	0.198
Personal (informal) contacts with university staff	0.426	0.295	-0.054	**0.518**	0.141
Personal contacts via membership of professional organisations	0.198	0.102	0.037	0.243	**0.814**
Personal contacts via alumni organisations	0.242	0.138	0.135	0.054	**0.82**
Students working as trainees	0.233	**0.713**	0.152	0.063	0.177
Inflow of university graduates as employees (BSc or MSc level)	0.221	**0.84**	0.112	0.114	0.1
Inflow of university graduates as employees (PhD level)	0.348	**0.771**	0.037	0.229	-0.016
Inflow of new employees from university positions	0.405	**0.45**	0.21	0.189	0.309
Staff holding positions in both a university and a business	**0.566**	0.334	0.108	0.087	0.149
Temporary staff exchange with universities	**0.673**	0.236	0.138	0.129	0.25
Joint R&D projects with universities in the context of EU Framework	**0.592**	0.293	0.081	0.244	0.147
Other joint R&D projects with universities	**0.652**	0.318	0.06	0.349	-0.063
Contract research by universities or public research labs (excl. Ph.D. projects)	**0.712**	0.124	0.183	0.164	0.141
Financing of Ph.D. projects	**0.708**	0.285	0.02	0.267	0.029
Consultancy by university staff members	**0.746**	0.136	0.15	0.195	0.136
Contract-based in-business education and training, delivered by universities	**0.681**	0.138	0.256	0.014	0.338
Patent texts, as found in the patent office or in patent databases	0.039	0.068	**0.893**	0.071	-0.029
Licenses of university-held patents and ‘know-how’ licenses	0.332	0.16	**0.795**	0.091	0.132

University spin-offs (as a source of knowledge)	**0.545**	0.131	**0.524**	0.013	0.207
Specific technology transfer activities organised by the university's Technology Transfer Office	0.472	0.12	**0.534**	-0.032	**0.408**
Sharing facilities (e.g. laboratories, equipment, housing) with universities	**0.597**	0.175	0.308	0.004	0.176

Individual and Organisational Characteristics	**basic rather than applied research environment**	**experienced and entrepreneurial researcher**	**basic rather than experimental research environment, number of publications**		
	1	**2**	**3**		
(Co) authored referred papers	0.236	0.118	**0.7**		
Patent inventor	-0.13	**0.696**	-0.206		
Personally involved in creating a spin-off	-0.07	**0.53**	0.186		
Personally involved in establishing a start-up	0.115	**0.461**	-0.106		
Age	-0.082	**0.755**	-0.011		
Basic research percentage	**0.739**	-0.188	**0.562**		
Applied research percentage	**-0.983**	0.02	0.104		
Experimental research percentage	0.223	0.225	**-0.857**		

Extraction Method: Principal Component Analysis

Rotation Method: Varimax with Kaiser Normalization.

Table 2A: Results from the Hierarchical cluster Analysis

	6 Clusters	5 Clusters	4 Clusters	3 Clusters	2 Clusters
D. Engineering	1	1	1	1	1
K. C Breatechnology transferhrough and interdependent	1	1	1	1	1
Ch. Flow of Students and University Staff	1	1	1	1	1
D. Material	3	3	3	1	1
Ch. Patents, licensing, spin offs and TTA	3	3	3	1	1
D. Biomedical	2	2	2	2	1
Ch. Publications and informal contacts	2	2	2	2	1
Ch. Collaborative and contract research, labour mobility	5	5	2	2	1
D. Social, Cognitive and Economics	4	4	4	3	2
K. C. Embodied	4	4	4	3	2
Ch. Contacts via alumni and professional org	6	4	4	3	2

621 Observations

Table 3A: Varimax Factor loadings: Good Policy Instruments to support university-industry cooperation

	General financial support rather than Targeted programmes	**Support entrepreneur ship**	**EU collaborative rather than bridging org.**	**Dutch collaborative rather than Support university entrepreneur ship**
	1	**2**	**3**	**4**
Tax instruments (e.g. tax deductions for joint R&D work)	**0.62**	-0.001	0.268	0.092
Financial and other support to TTOs at universities	**0.694**	-0.182	-0.05	-0.09
Support for new technological enterprises in their start-up phase (e.g. housing, tailored support, specific tax sch	-0.023	**0.605**	-0.039	0.112
Support for organisations that bridge science and business R&D (e.g. TNO)	0.301	**-0.463**	**-0.648**	-0.169
Targeted innovation programmes (e.g. Genomics, Bsik, Technological TopInstitutes)	**-0.665**	-0.3	0.115	-0.115
Policy to improve the entrepreneurial climate at universities	0.156	**0.637**	-0.059	**-0.472**
Dutch innovation policy schemes related to public-private research cooperation	0.11	0.069	-0.023	**0.884**
European innovation policy schemes related to public-private research cooperation	0.211	-0.267	**0.761**	-0.107

Extraction Method: Principal Component Analysis; R. Method: Varimax with Kaiser Normalization

Table 4A: Varimax Factor loadings: University Barriers to cooperate with industry

University Barriers to cooperate with industry	**Industry is not interested**	**Difficult to find industry partners**	**Time and Money**
Private businesses active in my discipline are making too little use of the knowledge available in universities	**0.798**	0.128	0.046
I see significant barriers stand in transferring my knowledge to the industry	**0.816**	0.057	0.163
The industry is not interested in the knowledge developed at the university	**0.683**	0.237	0.12
Universities are not willing to spend time and money in transferring their knowledge to industry	0.195	-0.066	**0.841**
Cooperation with the industry is hindered by cultural differences between academic and commercial researchers	0.409	0.351	0.202
Transferring knowledge to the industry is too costly for universities (either in terms of money of time)	0.126	0.27	**0.654**
Companies do not want to cooperate on R&D with universities; they just want to absorb our knowledge	0.199	**0.742**	0.036
Conducting contract research only results in more income for our research group. We do not learn anything from conducting such research	0.134	**0.683**	0.037
It is hard to find appropriate industrial partners for joint R&D projects	0.253	0.438	0.384
Joint R&D is hindered by conflicts between academic researcher who want to publish research and commercial researchers who want to patent research	0.152	**0.625**	0.133
I hardly have any incentive to cooperate with the industry since my rewards mostly depend on scientific publications	-0.057	**0.489**	0.417

Extraction Method: Principal Component Analysis

Rotation Method: Varimax with Kaiser Normalization

Table 5A: Varimax Factor loadings: Industrial Barriers to cooperate with university

Industry Barriers to cooperate with university	**university is general, theoretical & different culture**	**risk of information leaking and expensive**	**keeping exclusivity of the joint research results**	**little use of universit knowledg**	**great importance knowledge**
	1	**2**	**3**	**4**	**5**
The most important R&D activities of my research group over the last few years could not have been realized without knowledge generated in universities or PROs	-0.065	-0.051	-0.077	-0.015	**0.945**
The most important R&D activities of my research group over the last few years could not have been realized without the involvement of researchers working in universities or	-0.63	-0.15	0.006	0.219	-0.071
Private businesses active in my sector are making too little use of the knowledge available in universities or PROs	-0.172	-0.221	-0.001	**0.656**	-0.201
Significant barriers stand in the way of our using knowledge developed in universities and PROs	0.151	0.025	0.232	**0.701**	0.187
Knowledge developed in universities and PROs is too theoretic to be useful in our particular case	**0.827**	0.092	0.011	0.062	-0.044
Knowledge developed in universities and PROs is too general to address our specific knowledge needs	**0.823**	0.136	0.189	0	-0.008
Relevant knowledge developed in universities and PROs is difficult to locate (e.g., finding the right publications or people)	**0.512**	0.285	-0.113	**0.428**	-0.15
Researchers working in universities or PROs do not fit in well with our corporate culture	**0.481**	**0.424**	-0.124	0.353	-0.125
Being involved in the application of knowledge developed in universities or PROs is too costly (either in terms of time or money)	**0.448**	0.391	-0.071	0.39	-0.045
Joint research projects with universities or PROs imply a significant risk that our firm's knowledge could leak to competitors	0.131	**0.888**	0.13	-0.038	0.018
The results of joint research projects with universities or PROs imply a significant risk of leaks to competitors	0.118	**0.866**	0.192	-0.046	-0.007
Joint research projects with universities or PROs are difficult to manage and/or involve high overhead costs	0.249	**0.589**	0.027	0.085	-0.062
Our business will insist that the results of joint research projects with universities or PROs are patented	-0.069	-0.011	**0.822**	0.052	-0.008

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Our business will always claim ownership of patents resulting from joint research projects with universities or PROs (as opposed to leaving ownership to the university or PRO)	0.23	0.096	**0.791**	0.033	0.076
We would rather offer a university researcher a personal consultancy contract than enter into a contract with the university or PRO	-0.04	0.217	0.328	**0.478**	0.002
Having an exclusive licence on knowledge developed in a university or PRO is absolutely necessary for our business to use that knowledge in our R&D projects	-0.067	0.203	**0.624**	0.235	-0.234

Extraction Method: Principal Component Analysis

Rotation Method: Varimax with Kaiser Normalization