Research Policy 37 (2008) 1865–1883

Contents lists available at ScienceDirect

Research Policy

journal homepage: www.elsevier.com/locate/respol

University-industry knowledge and technology transfer in Switzerland: What university scientists think about co-operation with private enterprises

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ARTICLE INFO

Article history:
Received 7 September 2006
Received in revised form 3 June 2008
Accepted 1 July 2008
Available online 30 August 2008

JEL classification:
030

Keywords:
Knowledge and technology transfer
Patenting
Licensing
Spin-offs

ABSTRACT

This study explores empirically the factors determining the propensity of Swiss science institutions at the level of a single institute or department to get involved in a wide spectrum of knowledge and technology transfer (KTT) activities with private corporations. A main finding is that scientific institutes with a stronger orientation to applied research and/or lower teaching obligations are also stronger inclined to get involved in overall KTT activities. The same is valid for institutes which have already had experience with industry co-operations as reflected by a high share of external funds in an institute's budget. Further, there is no systematic size effect with respect to KTT activities. Institutes of engineering, natural sciences and economics/management are strongly represented among KTT-active institutes. Universities of applied sciences have an above-average propensity to KTT activities.

1. Introduction

The interaction of business sector and science institutions through the exchange of knowledge and technology has become a central concern not only for applied economics but also for economic policy in the last years.[3] In a knowledge economy, science is exerting an increasingly large influence on innovation, especially in fast-growing knowledge-intensive industries. Thus, the extent and intensity of industry–science relationships is considered to be a major factor contributing to high innovation performance, either at the firm-level, industry-level or country-level (see OECD, 2002). Still, fears are also expressed in the literature that the tendency to commercialization of university research may cause universities to neglect basic research and teaching that are their main

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[3] *Economics*: see e.g. volume 48, issue 1 of *Management Science* of January 2002 (edited by D.C. Mowery and S. Shane) dealing with "University Entrepreneurship and Technology Transfer"; volume 321, issue 9 of the *International Journal of Industrial Organization* of November 2003 (edited by A.N. Link, J.T. Scott and D.S. Siegel) dedicated to the "Economics of Intellectual Property of Universities"; volume 34, issue 3 of *Research Policy* of April 2005 (edited by A.N. Link, and D.S. Siegel) devoted to "University-based Technology Initiatives"; volume 34, issue 7 of *Research Policy* of September 2005 (edited by A. Lockett. D. Spiegel, M. Wright and M.D. Ensley) dealing with the "Creation of Spin-offs at Public Research Institutions: Managerial and Policy Implications". *Policy*: see e.g. OECD (2003a, 2002, 1999); see also Goldfarb and Henrekson (2003) for a comparison of different policies towards the commercialization of university intellectual property.

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doi:10.1016/j.respol.2008.07.005

tasks, especially when commercialization revenues are substituted for public funds.[4]

Experiences of the USA suggest that research of often publicly financed science institutions and commercialization of research results by private enterprises are compatible goals which reinforce each other, if both sides adopt a long-term perspective (as e.g. in aerospace, computers and telecommunication). However, there is accumulating evidence that many OECD countries are lagging behind in this aspect. The interface between business firms and science institutions, especially universities has to be improved and as a consequence knowledge and technology transfer activities have to be intensified. Also in Switzerland it is asserted by many observers that the industry–science interface is far from being satisfactory (see e.g. Zinkl and Huber, 2003). However, so far there does not exist a comprehensive study on extent, intensity, channels, content, goals, and impediments of KTT activities either on part of the science institutions or the private enterprises in Switzerland.

In accordance to Dosi (1982) we define knowledge and technology transfer (KTT) broadly as follows: knowledge and technology transfer between academic institutions and the business sector is understood as any activities aimed at transferring knowledge or technology that may help either the company or the academic institute – depending on the direction of transfer – to further pursue its activities. This study explores the factors determining the propensity of Swiss science institutions at the level of a single institute or department to get involved in knowledge and technology transfer activities with private corporations in order to provide firms with scientific knowledge in research fields which are relevant for their own innovation activities, collect practical experience for students and university staff as well as test the applicability of new research results. We are especially interested in the different forms of this transfer, not only through joint research projects but also through training, mobility of academic personnel, jointly supervised master theses and PhDs, consulting and so on. We hope that our analysis will cast some light on the industry–science interface problem addressed to above. Moreover, we also study the determinants of three important channels of technology transfer activities—patenting, licensing and the founding of spin-offs. As it is meanwhile widely recognized, these are not the most important interaction forms between universities and enterprises but they have been intensively investigated in many studies of universities in the USA (see Agrawal and Henderson, 2002).

The data used in this study were collected in the course of a survey among institutes of all three types of science institutions in Switzerland (federal institutions, cantonal universities and regional universities of applied sciences) using a questionnaire.

A main finding is that scientific institutes with a stronger orientation to applied research and/or lower teaching obligations are also stronger inclined to get involved in overall KTT activities. The same is valid for institutes which have already had experience with industry co-operations as reflected by a high share of external funds in an institute's budget. Further, there is no systematic size effect with respect to KTT activities. Institutes of engineering, natural sciences and economics/management are strongly represented among KTT-active institutes. Universities of applied sciences have an above-average propensity to KTT activities.

The new elements that this paper adds to empirical literature are, first, the analysis at the level of institute or department of a wide spectrum of KTT activities covering not only research co-operation agreements between firms and science institutions but also informal informational contacts, various educational activities, joint use of technical infrastructure and consulting. Although such additional activities seem to be an important part of KTT activities, they have been neglected in most studies mostly due to lack of data. A second element is the explicit consideration of a series of relevant motives and obstacles as determinants of KTT which contribute significantly to the econometric explanation of a scientific institute's propensity to overall KTT activities as well as to several specific forms of KTT activities. A third element is the parallel investigation of the three important channels of KTT, namely patenting, licensing and formation of spin-offs. This is to our knowledge the first Swiss institute-level study on this matter.[5]

The structure of the paper is as follows: in Section 2 we discuss briefly the theoretical background of the study. Section 3 reviews the empirical literature. In Section 4 we present our data and in Section 5 some interesting descriptive results. In Section 6 we specify our econometric model of the determining factors (a) of overall KTT activities as well as five specific forms of KTT activities, (b) of three channels of KTT (patenting, licensing, founding of spin-offs) and describe the construction of the variables. Section 7 is dealing with the empirical results. Finally, Section 8 contains some conclusions and a summary.

2. Theoretical background

To our knowledge there is little theoretical research on the financial incentives facing faculty and the allocation of effort across types of research (see the discussion in

[4] For example, Rosenberg and Nelson (1994) argue for the maintenance of the "traditional" division of labour between university and industry also under the conditions of closer collaboration and more intensive exchange of knowledge taking place in many countries in the last years; Stephan (2001) discusses possible negative implications of university-industry technology transfer; in NATURE, 2001 was the opinion expressed that industry's trend towards "closed science", and closer ties to universities may endanger the intellectual independence of university basic research. Tijssen (2004) concludes in a study based on bibliometric data for the period 1996–2001 that companies "may well have redirected the goals of basic research and narrowed the focus towards strategic and applied research with shorter time-horizons. . .", a development which might also have influence their relationship to university.

[5] In a recent study Vock et al. (2004) presented and discussed the results of a survey on codified forms of KTT (number of R&D projects in co-operation with firms, patents, licences); this survey was addressed to technology transfer offices at universities. Thierstein et al. (2002) investigated the spin-offs/start-ups of graduates of the universities of Eastern Switzerland, Berwert et al. (2002) the spin-offs/start-ups of Swiss technical universities.

Thursby et al., 2005). Beath et al. (2003) and Jensen and Thursby (2004) study faculty research incentives in the framework of a principal agent model where the university is the principal and the faculty member is the agent. The analysis in Beath et al. (2003) is static and investigates the potential for the university to ease its budget constraints by allowing academic scientists to conduct applied research on a consulting basis. They argue that by allowing academics to supplement their income, universities may be able to hold down academic salaries. Furthermore, universities can effectively "tax" the income that academics raise through applied research or consultancy, for example through the imposition of "overhead charges". This model offers some insights with respect to the financial incentives for conducting applied research in co-operation with the industry.

By contrast, the model of Jensen and Thursby (2004) is dynamic and analyzes the effect of patent *licensing* on research and the quality of education. The latter effect is a function itself of research outcomes and hence future stocks of knowledge as well as the share of patentable knowledge that can be used in education. In this model an academic scientist derives utility from just doing research as well as the prestige associated with successful research. They show that with these two effects in a scientist's utility function the opportunity to earn license income may well *not* change an academic scientist's agenda. This result provides according to their assessment one explanation for the fact that little change can be observed in the pattern of basic relative applied research publications of academic scientists.

Thursby et al. (2005) discuss in the framework of a life cycle model of an academic scientist's career the implications of licensing on research. In this context, the utility function of academic scientists contains on the one hand a motive for generating new knowledge, on the other hand a financial motive for additional income. An important issue in the debates over university licensing is whether the associated financial incentives compromise the research mission of the university by diverting academic scientists form basic research. In the various versions of the model the authors consider, the academic scientist faces a fixed teaching load and chooses the amount of time to devote to research (basic or applied) and the amount of time to take as leisure.

Hellman (2005) develops an interesting formal theory of the search and matching process between scientists and firms. At the core of the model is the problem that scientists rarely know what industrial applications may exist for their scientific discoveries. At the same time firms are often unaware what scientific discoveries might help them with their needs. The author calls this the "science to market gap". The model allows addressing the role of *patents* in bridging the science to market gap. The gap can be bridged when scientists and firms engage in a process of search and communication. Since patenting affects the distribution of rents, it has an effect on the relative search intensities of firms and scientists. Patenting scientific discoveries helps scientists to "push" their discoveries out to business sector. However, it may also dampen firms' incentives to "pull" discoveries out of scientists. Thus, the net effect of patenting depends on the relative ease of bridging the science to market gap through "push" or "pull".

The model also examines the importance of universities' technology transfer offices. In principle such offices allow for task specialization. Scientists benefit from delegating search activities, which may free them up to pursue further research. However, the model explains that such delegation typically requires *patenting*. In introducing the role of transfer offices is assumed that they are more efficient at search of industrial partners than scientists. This may be reasonable in many cases but not in all. If this is not the case, the formation of a *spin*-off may be an alternative way that guarantees efficiency, because in a spin-off the scientist always internalizes all benefits from research. A last discussion point refers to the lack of an analysis of the dynamic implications of the commercialization of research output.

On the whole, the existing theoretical literature delivers a number of factors, mainly of motivational character ("push" and "pull" factors as they are named in Hellman, 2005), which determine the propensity of academic scientists to engage themselves in commercialization activities that provide additional income. There exists some kind of trade-off between financial motives in favour of commercialization and hence the perspective of additional income and the inherent motives of a scientist who primarily pursues research goals and the reputation associated with research achievements. In addition, some basic characteristics of institutes or departments, such as the type of scientific field (e.g. engineering vs. social sciences), the size, or the existence of a strategic orientation towards research seem to exert a significant influence on the KTT propensity of academics. As a consequence, an empirical investigation would at least contain measures for anticipated costs and benefits of various channels of KTT between universities and the business sector, and measures of the allocation of working time in basic and applied research as well as teaching.

3. Review of selected empirical literature

In this section we review some selected empirical studies which use a similar approach to ours (university-level or (department-) institute-level data, econometric investigation of the determinants of some form of KTT activities) and try to detect some regularities. Most studies refer to various channels of KTT such as patenting, licensing and the founding of new firms.

3.1. Motives and obstacles of KTT activities

A first group of (rather few) studies refers to the existing forms of KTT between universities and firms and investigates several motives and/or obstacles of KTT activities.

An important study in this direction is the paper of Lee (1996) the dependent variable was the strategy orientation at faculty level, specified as "user-oriented research" or "commercialization of research". Based on the data of 986 faculties of USA universities he found that the strategy orientation towards applications and/or commercialization of research results depended on the type of a faculty's scientific field (applied or basic sciences), the university overall policy of encouraging or not encouraging application-oriented research, and the perceived positive or negative impact on traditional university mission. In a more recent study the same author elaborated further on the motivations and the expected benefits of research co-operation of universities with corporations (Lee, 2000). In order to define the most relevant motives and obstacles of KTT activities, some more studies of primarily descriptive character were taken into consideration Geisler and Rubinstein (1989), Onida and Malerba (1989), Geissler (1997), Mayer (2000), Santoro and Chakrabarti (2002), and Schmoch (2003).

Schartinger et al. (2001) in a study based on data for 309 Austrian university departments investigated the determinants of various forms of interaction between universities and firms (joint research, contract research, joint supervision of PhDs/Master theses, researchers mobility) as well as the sum of interactions. They found that the department size (for all dependent variables with the exception of contract research), research characteristics such as the number of international scientific publications per researcher (for joint research), and the type of scientific field (technical sciences in all cases) are significant determinants of industry-university knowledge and technology transfer.

3.2. Determinants of university patenting, university licensing and university spin-offs

A second group of mostly American studies focuses on the "codified" forms of knowledge and technology transfer through patenting, licensing and the formation of new knowledge-based firms.

Carlsson and Fridh (2002) investigated technology transfer in the USA based on the data for 170 universities, hospitals and research institutes for the period 1991–1996. As dependent variables were used various performance measures such as the number of patent applications, the number of patents issued, the number of licenses, license income as well as the number of start-ups. One of the most important findings was that institution size and level of research expenditure are significantly positively correlated the total number of patents and the number of start-ups respectively.

The study of Owen-Smith and Powell (2001) investigates the motivation of university patenting. Drawing on qualitative data from interviews with 68 faculties and licensing professionals of two USA campuses, the authors found that faculty members decide to patent because of their beliefs about positive personal and professional outcomes of intellectual property protection.

Friedman and Silberman (2003) argued that invention disclosures, not patents, are the primary input into the technology transfer process. Thus, they investigated the determinants of the number of invention disclosures of 83 USA universities. Relevant factors were the university size, measured by the number of faculties per university, the faculty quality, and the extent of external funds (federal and industry research grants).

Azoulay et al. (2005) investigated the determinants of faculty patenting behaviour in a panel dataset spanning the careers of 3884 academic scientists. They found that patenting events are preceded by a flow of publications, i.e. publications are a precondition for patenting. Moreover, the magnitude of this effect is influenced by context such as the presence of co-authors who patent and the patent stock of the scientist's university. Also previous experience with patenting is of relevance.

Renault Searle (2006) studied the entrepreneurial behaviour by professors as measured by the propensity to collaboration with industry, patenting and behaviour and spin-off behaviour. Interviews with 98 professors at 12 U.S. universities showed that the most significant influence on these aspects of entrepreneurial behaviour is the beliefs of academic scientists that the dissemination of knowledge in the economy is an important mission for the university. Patenting correlated positively with the number of publications but not the propensity to collaboration with industry or spin-off behaviour.

In a very recent study Azagra-Caro et al. (2006) investigated the determinants of patent production at the laboratory level for a French university. They used a sample of 83 laboratories for the period 1993–2000. They found that university-owned patents were more responsive to specific public funding, while non-university-owned patents are more responsive to industrial funding. They also highlighted the importance of controlling for institutional differences as well as differences among scientific fields.

Thursby et al. (2001) specified five categories of outcomes of KTT activities, namely the number of licenses, the number patents applications, the amount of license income (royalties), the amount of sponsored research tied to a license and the frequency that sponsored research is included in a license agreement. They investigated several determinants of these five categories for 62 major research universities in the USA. They found, among other things, that more licenses are executed at universities with large technology transfer offices and medical schools. Royalties generated are typically larger the higher the quality of the faculty and the higher the fraction of licenses that are executes at later stages of development. Moreover, in a further study Thursby and Thursby (2002) investigated the growth of university licensing in the USA over time. Using data form a survey of university technology transfer offices they found that that licensing growth has resulted largely from an increased willingness of faculty members to engage in licensing.

Shane and Stuart (2002) examined why some university start-ups are more successful than others. Focusing on 134 new companies founded to exploit MIT-assigned inventions during the period 1980–1006, they found that firms whose founders were related to venture capitalists were less likely to fail. In a further investigation dealing with university start-ups Di Gregorio and Shane (2003) found based on a sample of 457 university departments that the number of start-ups in a given year depended primarily on a department's intellectual eminence, the amount of externally sponsored funds and the type of university licensing policies.

3.3. Summing up: factors explaining KTT activities

Putting together the information we found in the reviewed theoretical and empirical literature, we could identify a series of factors that explain the propensity to KTT (in general or via specific channels) of university faculties. These are:

- A series of *motives* that could be grouped in four main categories (access to industrial knowledge; access to additional resources; institutional or organizational motives; pursuing higher research efficiency – cost and time savings; access to specialized technology). Motives influence positively the propensity to KTT activities;
- A series of *obstacles* that could be grouped in six categories (deficiencies of the firms; different interests and attitudes to research; lack of confidence to business world and risk of damaging scientific reputation; endangering scientific independence and neglect of basic research; lack of human resources for KTT). Obstacles influence negatively the propensity to KTT activities;
- Allocation of university funds (research, teaching); most theoretical studies come to the conclusion that there is no close relationship between the propensity to KTT activities and the orientation (basic vs. applied) of institute research activities.
- Size of faculty or university, having mostly a positive influence;
- Type of scientific field, engineering and natural sciences showing a stronger inclination to KTT activities than other disciplines;
- Existence of Technology Transfer Offices, having mostly a positive influence;
- Extent of external funds, exerting also a positive influence.
- Based on this list of factors we are going to specify our econometric models in Section 6.

4. Data

The data used in this study were collected in the course of a survey among Swiss research institutes using a questionnaire which included questions on the incidence of KTT activities among institutes or departments of Swiss science institutions (federal institutes of technology, federal research organizations, cantonal Universities and universities of applied sciences), forms, channels, motives and impediments of the KTT activities of Swiss science institutions as well on some basic institute or department characteristics such as the number of staff, categories of staff with regard to formal qualification (Diploma, PhD) and function (technical, administrative), academic output (publications, academic degrees), technology output (patent applications, licenses, spin-offs), distribution of human resources over several academic tasks (basic and applied research, teaching, other tasks), and funds from outside the university.[6] The questionnaires were filled in by the directors of the institutes and/or departments to whom they were also addressed.

The survey was based on a sample of institutes and/or departments of the existing Swiss public science institutions. In Switzerland there are three types of institutions of higher education: federal universities that are financed by the federal government, cantonal universities that are financed (mainly) by the cantonal governments and regional universities of applied sciences that are finance partly by the federal government and partly by the cantons constituting the respective region. The two federal technical universities in Zurich and Lausanne are not pure engineering schools; they have the whole spectrum of natural sciences, mathematics and physics and are strongly research-oriented. The ten cantonal universities in Basle, Berne, Lucerne (only social sciences and theology), Geneva, Lausanne, Lugano (only social sciences and architecture), Fribourg, Neuchâtel, St. Gallen (only economics, law and management) and Zurich offer a broad palette of disciplines; five of them have a full medicine school. The university of Zurich is the largest university and has about 24,000 students. The seven regional universities of applied sciences (Central Switzerland, Eastern Switzerland; Western Switzerland, North-western Switzerland, Italian Switzerland, Berne and Zurich) have been for a long time almost exclusively teaching-oriented, but since the middle of the nineties they have been re-orienting their activities towards applied research. They cover not only engineering and management but also social work, pedagogic, health professions and fine arts. Besides the three types of universities, research activities take place also in four large highly specialized federal research organizations that are located mainly in the eastern part of Switzerland: the Swiss Federal Institute of Aquatic Science and Technology (EAWAG), the Research Institute for Material Sciences and Technology (EMPA), the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL) and the Paul Scherer Institute (PSI) where research in done on energy technologies and elementary particles physics. Meanwhile almost all of these institutions have their own Technology Transfer Offices for the promotion knowledge and technology transfer to the business sector, the third mission of public science institutions besides research and teaching. The two federal technical universities and some of the stronger research-oriented universities of applied sciences show a considerably higher intensity of technology transfer activities, also using the more codified forms of transfer such as patents and licensing (see OECD, 2003b); in the nineties these institutions began to promote also the formation of new science-based enterprises (university spin-offs).

Our survey was addressed to all these institutions (with the exception of the university of Lucerne) but only to the institutes and departments of engineering, natural sciences, mathematics and physics, medicine and economics and business administration, on the whole 630 single institutes and departments covering all scientific fields related to technology and science (see Table A.1 in the appendix for the composition of the sample). This sample has been constructed according to internet information on the structure of each institution especially for this study. We received 241 completed questionnaires, i.e. 38.3% of the institutes

[6] Versions of the questionnaire in German, French and English are available in www.kof.ethz.ch.

Table 1
Incidence of KTT activities of Swiss science institutions (institutes or departments having KTT activities as a percentage of all responding institutes or departments of a certain science institution)

Institutions	N	KTT ([a])	Foreign KTT
ETH-domain			
Swiss Federal Institute of Technology Zurich	45	88.9	77.8
Swiss Federal Institute of Technology Lausanne	12	58.3	58.3
Federal Research Institutions ([b])	11	72.7	63.6
University of			
Basle	11	81.8	81.8
Berne	33	84.8	78.8
Fribourg	5	80.0	60.0
Geneva	15	73.3	46.7
Italian Switzerland	2	50.0	100.0
Lausanne	12	66.7	58.3
Neuchâtel	6	83.3	100.0
St. Gallen	8	87.5	75.0
Zurich	22	81.8	77.3
University of Applied Sciences of			
Berne	9	88.9	55.6
Central Switzerland	5	100.0	20.0
Eastern Switzerland	14	92.9	64.3
Italian Switzerland	2	100.0	50.0
North-western Switzerland	17	100.0	70.6
Western Switzerland	4	100.0	100.0
Zurich	8	100.0	75.0
Total	241	84.2	71.4

[a] KTT: knowledge and technology transfer activities in the period 2002–2004.
[b] PSI, EAWAG, EMPA, WSL.

and departments responded to our survey.[7] However, the response rates vary significantly among the single universities (see column 3 in Table A.1 in the appendix). Thus, there is a tendency of the universities of applied sciences and the federal institutions to be over-represented, of the cantonal universities to be under-represented in our data set. Institutions from the French-speaking or Italian-speaking part of the country have responded less frequently than those of the German-speaking part. Due to missing values only 200 observations in maximum could be used in the econometric analysis. Tables A.2 and A.3 in the appendix contain some additional information on the composition of the sample by institute size and scientific field respectively.

5. Descriptive analysis: main facts

5.1. Incidence of KTT activities

According to the results in Table 1 84.2% of the responding institutes or departments were involved in KTT activities with private enterprises in the period 2002–2004, 71.4% of respondents reported also KTT activities with foreign firms. 94.1% of KTT-active institutes co-operate with European firms, 48.2% with American and 18.2% with Japanese firms. There are not significant differences among the various types of institutions (federal institutes of technology, federal research institutions, cantonal universities and regional universities of applied sciences) with respect to propensity to KTT activities.

5.2. Forms of KTT activities

Institutes reported their assessment of the importance of 19 single forms of KTT activities on a five-point Likert scale (1: "not important"; 5: "very important") which were grouped together in the following five categories: informal informational activities, activities related to technical infrastructure, educational activities, research activities and consulting. By calculating the share of institutes that reported the values 4 or 5 for any single form or category of forms of KTT activities we could determine a ranking of the importance of various forms of KTT activities (see Table 2). Educational activities were given the first priority (80.2% of all KTT-active institutes), followed closely by informal informational activities (78.7%) and research activities (75.2%). Much less important were consulting (49.0%) and activities related to the utilization of technical facilities (17.4%); the latter is quite understandable in view of the high endowment of Swiss science institutions with respect to technical equipment. The two most important single educational activities were "contacts with former staff employed in the business sec-

Table 2
Forms of KTT activities of Swiss science institutions (percentage of KTT-active institutes with values 4 or 5 for a single form; percentage of KTT-active institutes with values 4 or 5 for at least one single form of those belonging to a certain category of forms respectively; $N = 202$)

Forms of KTT activities	
Informal informational contacts (variable INFO)	78.7
Informal contacts (phone, email)	67.3
Conferences, exhibitions, workshops	35.6
Academic publications of business sector	26.2
Activities related to the use of technical facilities (variable INFR)	17.4
Joint laboratories	9.0
Technical facilities or research centres at business sector R&D department	12.4
Educational activities (variable EDUC)	80.2
Contacts with graduates employed in the business sector	52.0
Contacts with former staff employed in the business sector	46.5
Student participation in corporate R&D projects	29.7
Thesis projects in collaboration with firms	42.1
Doctoral projects in collaboration with firms	24.3
Business sector scientists in own R&D projects	29.2
Joint teaching courses or programmes	20.3
Teaching assignments for business sector staff	25.2
Courses or programmes of institute by business sector scientists	33.2
Research activities (variable REAS)	75.2
Research projects in collaboration	66.8
Longer term research contracts	42.6
Research consortiums	34.2
Consulting (variable CONS)	49.0
Expertises/reports for the business sector	32.7
Consulting for the business sector	43.1

[7] This relatively high non-response rate could have an influence on the estimated parameters and/or standard errors. The natural way to test this would be to estimate a Heckman selectivity model for the KTT equation with a selection equation based on data for the institutes/departments that did not respond. Unfortunately, this could not be done due to lack of data for the non-respondents.

Table 3
Commercialization of university research output (percentage of all institutes; $N = 202$)

Patents ([a])	34.4
Licenses ([a])	12.2
Spin-offs ([a])	22.2

[a] At least one patent, one license or one spin-off respectively in the period 2002–2004.

tor" (46.5%) and "thesis projects in collaboration with firms" (42.1%). However, there are some remarkable differences among the various types of institutions. For the institutions of the ETH-domain (federal institutes of technology and federal research institutions) and the universities of applied science research activities have a higher priority than informal informational activities. For universities educational activities are less important than informal informational activities. The access to joint technical infrastructure is relatively more important for the universities (being confronted with more severe financial restrictions) than the other two categories of institutions. Finally, among educational activities is the single activity "doctoral projects in collaboration with firms" quite important for the ETH-domain (41.8%) and "thesis projects in collaboration with firms" (77.2%) for the universities of applied sciences.

Table 3 gives an overview on university patenting, university licensing and university spin-offs. 34.4% of all institutes in our sample reported patent applications in the period 2002–2004, i.e. 40.9% of the KTT-active institutes. Only 12.2% of all institutes reported licenses in the same period (14.5% of the KTT-active institutes), 21.7% (25.8% of the KTT-active institutes) helped spin-offs to start operations.

6. Model specification and construction of variables

6.1. Dependent variables

We specified two different econometric models. First, we specified model A for the determinants of overall KTT activities. The dependent variable (KTT) was a binary variable which was defined as follows: knowledge and technology transfer activities in the period 2002–2004 yes/no. Model A refers to all institutes in the sample. Second, we specified model B for the determinants of (a) five specific forms of KTT activities and (b) three channels KTT. For model B only KTT-active institutes were taken into consideration.

The five different dependent variables for specific forms of KTT (model B) were also binary variables and were constructed as follows:

Variable INFO: 3 variables for single forms of KTT referring to informal contacts, attendance of conferences or workshops of the business sector, etc. (see Table 2) measured on a five-point Likert scale (1: "not important"; 5: "very important") were combined to one dummy variable: value 1 was attached to institutes which reported a value 4 or 5 for any of the three original variables, value 0 to the institutes that do not fulfil this condition;
INFR: similar construction as INFO based on the variables for 2 single forms of KTT referring to technical infrastructure facilities;
EDUC: similar construction as INFO based on 9 single variables referring to education and training activities;
REAS: similar construction as INFO based on 3 single variables referring to research activities;
CONS: similar construction as INFO based on 2 single variables referring to consulting activities (see Table 2 for a description of the single forms of KTT activities).

Finally, we also constructed three further binary variables, which are referring to patent applications (yes/no), licenses (yes/no) and spin-offs (yes/no) in the period 2002–2004.

6.2. Independent variables

6.2.1. Overall KTT activities (model A)

A first group of independent variables contains measures of various institute or department characteristics which could influence the propensity to undertake KTT activities with private enterprises. The allocation of human resources in teaching, applied and basic research and other tasks could implicate a stronger or weaker disposition for interaction with the business sector and is measured by two variables: ratio of percentage of an institutes total working time of academic staff devoted to *applied research* to that devoted *to basic research* (APPL); percentage of an institutes total working time of academic staff devoted to *teaching* (TEACH) (there is also a fourth category of activities, namely 'other tasks'). We expect a *negative* effect for the variable of TEACH and a *positive* effect for the variable APPL. Institutes which are a) stronger oriented to applied research[8] and/or b) have rather low teaching obligations would be stronger inclined to get involved in KTT activities. Further, the share of third-party funds from business sector in an institute's total budget would reflect already existing co-operations with firms (FINANCE); thus, we expect a *positive* impact for this variable as well (only model A).

A second group of variables is related with possible obstacles of the KTT activities. Both institutes with KTT and without KTT activities reported their assessment for 26 single possible obstacles of KTT activities with private enterprises. These obstacles would reflect *costs* of realizing KTT activities from an institute's point of view. With the help of a principal component factor analysis we compressed these 26 single motives, which were measured on a five-point Likert scale (1: "not important"; 5: "very important"), to six main groups (see Table A.5 in the appendix).[9] The factor values of the six-factor solution of the principal component factor analysis of the original 26 variables were

[8] It is clear that this hypothesis is contrary, e.g. to that in Jensen and Thursby (2004). We postulated it after discussions with ETH researchers we contacted in the phase of data collection.

[9] The six-factor solution was chosen according to statistical criteria that are implemented in the software we used (SAS). In addition, we took a look whether these results made a sense in economic terms.

inserted as independent variables in the estimation equations of all four dependent variables (variables OBSTACLE1 to OBSTACLE6).

A first category of obstacles are impediments due to deficiencies of potential industry partners (OBSTACLE1) such as lack of qualified staff, technical facilities or financial resources of potential industry partners, but also due to lack of interest in scientific projects in the business sector. A second category (OBSTACLE3) includes such problems as lack of discernible commercialization opportunities of research findings or difficulties to find an appropriate partner, i.e. a partner that shares research interests and is ready to finance joint research. Further, also administrative and institutional obstacles (OBSTACLE2) such as property rights problems, resource-intensive administrative and approval procedures and legal restrictions from the side of the university could be severe hindrances of KTT activities. This kind of obstacles reflects deficiencies from the side of the university. A fourth category of obstacles (OBSTACLE6) refers to the lack of human resources for KTT activities due to high teaching obligations and/or lack of academic specialists for KTT activities. The last two groups of impediments (OBSTACLE4, OBSTACLE5) are related to fears of academics that KTT activities could endanger their reputation, and lead to neglecting basic research and academic publication activities.

We expect a *negative* effect for each of these (groups of) obstacles, although we do not have a priori expectations with respect to the relative importance of each of them.

The possible influence of the scientific field in which an institute is engaged was taken into account through four dummies for engineering, natural sciences, economics and management and medicine (basic research disciplines mathematics and physics serving as a reference group). With the exception of medicine institutes or departments we expect that institutes from all other three disciplines are stronger oriented to KTT activities than institutes of mathematics and physics.

The affiliation to one of the four main groups of institutions (federal institutes of technology, federal research institutions, cantonal universities and regional universities of applied science) would reflect the policy orientation of the groups of institutions with respect to KTT and was also taken into consideration by inserting three dummies for each of the main groups of institutions, the universities of applied sciences serving as a reference group. We expect universities of applied sciences, for which KTT activities are explicitly an important part of their mission, to be stronger involved in KTT activities than other institutions.

Further, we use a dummy variable for the relevance of Technology Transfer Offices as intermediaries of KTT activities. Due to the fact that almost all universities and federal research organizations have now such offices, we expect a positive effect of this variable. This is at the same time a test of the usefulness of such offices.

Finally, a structural measure was also included: four dummies for institute size (measured by the number of employees in full-time equivalents). In accordance to empirical literature we expect institute size to be positively correlated to the propensity to KTT activities with private enterprises. We assume that, given their scientific field and research orientation, larger institutes or departments anticipate more and better possibilities for KTT activities than small ones, due e.g. to the existence of personnel specialized in KTT. A summary of all expected effects is presented in Table 4.

6.2.2. Various forms of KTT activities (model B)

Model B contains the same variables as model A with the exception of variable FINANCE, which we consider to be relevant for an institute's decision to get involved in KTT activities and not for choosing a specific KTT form. In addition, Model B includes also four variables measuring several aspects of the motivation of institutes for undertaking KTT activities with private enterprises. The questions on the motives were answered only by KTT-active institutes. This is the reason why we could use this information only for model B but not for model A where all institutes, i.e. also institutes without KTT activities, were included.

We expect a positive effect for variable APPL and a negative effect for variable TEACH particularly for the KTT forms INFR and REAS. The inclination to engage in a research cooperation with the business sector or to utilize industrial technical facilities would be stronger for institutes with low teaching obligations and applied research interests that dispose of the resources and capabilities needed for such activities than for institutes that get involved in any of the other three types of KTT activities.

Further, we expect that OBSTACLE1, OBSTACLE2, and OBSTACLE3 would be relevant impediments particularly for research (REAS) and infrastructure-related activities (INFR) (see also the discussion in Section 6.2.1 above).

Institutes with KTT activities reported their assessment for 24 single goals of and/or motives for KTT activities. We consider these motives to reflect to a large extent the *expected benefits* of KTT activities from an institute's point of view. With the help of a principal component factor analysis we compressed these 24 single motives, which were measured on a five-point Likert scale (1: "not important"; 5: "very important"), to four main groups (see Table A.4 in the appendix).[10] The factor values of a four-factor solution of the principal component factor analysis of the original 24 variables were inserted as independent variables in the estimation equations of model B (variables MOTIVE1 to MOTIVE4).

A first group of motives (MOTIVE1) is related to the possibility of either acquiring specific knowledge from the business sector or receiving feedbacks from there with respect to university research findings, practical experience and application opportunities. Thus, MOTIVE1 relates to immediate, short-term objectives.

A second category of motives (MOTIVE2) refers to a series of institutional as well as strategic longer term goals such as extending university's mission, improving the image of science, promoting regional development, promoting the diffusion of research findings, etc. However, getting engaged in KTT can also be forced upon by

[10] The four-factor solution was chosen according to statistical criteria that are implemented in the software we used (SAS). In addition, we took a look whether these results made a sense in economic terms.

Table 4
Summary of hypotheses

Variable	Definition	Expected effect
APPL	Ratio of the percentage of the total working time of academic staff of an institute devoted to *applied research* to the working time percentage devoted to *basic research*	Positive
TEACH	Percentage of the total working time of academic staff devoted to *teaching*; there is also a fourth category of activities, namely 'other tasks'	Negative; especially for the KTT forms INFR and REAS
FINANCE	Share of third-party funds from business sector of an institute's budget	Positive
OBSTALE1 to OBSTACLE5	See Table A.5 in the appendix	Negative; OBSTACLE1, OBSTACLE2 and OBSTACLE3 especially for the KTT forms REAS and INFR; also for PATENTING, LICENSING, SPIN-OFFS
MOTIVE1 to MOTIVE4	See Table A.4 in the appendix	Positive; MOTIVE1, MOTIVE3 and MOTIVE4 especially for INFR and REAS; also for PATENTING, LICENSING, SPIN-OFFS; MOTIVE4 especially for CONS
ETH	Dummy variable for affiliation to one of the two Federal Institutes of Technology in Zurich and Lausanne respectively	Negative (reference group of institutions: universities of applied sciences)
UNIV	Dummy variable for affiliation to a University	Negative (reference group of institutions: universities of applied sciences)
FRI	Dummy variable for affiliation to a Federal Research Institution (e.g. PSI, EAWAG, etc.)	Negative (reference group of institutions: universities of applied sciences)
TTO	Importance of the Technology Transfer Offices (TTO) of the various institutions as intermediaries of KTT activities in the period 2002–2004 (1: 'important'; 0: 'not important');	Positive
ENGINEERING; NATURAL SCIENCES; ECONOMICS, MANAGEMENT; MEDICINE	Dummies for an institute's scientific field	Positive (reference group: mathematics/physics); engineering or natural sciences especially for REAS and INFR; also for PATENTING, LICENSING and SPIN-OFFS; engineering or economics and management especially for CONS
Institute size	Number of employees	Positive

institutional conditions such as the presence of business representatives in a university's consultant bodies or the procedures for receiving more public funding.

A third and fourth category of motives (MOTIVE3 and MOTIVE4 respectively) have to do either directly (additional resources for basic research or research facilities) or indirectly (pursuing cost and time savings or access to (expensive) specialized technological equipment) with financial motives.

We expect a *positive* effect for each of these (groups) of motives, although we do not have a priori expectations with respect to their relative importance. We also expect MOTIVE1 and the two categories of financial motives (MOTIVE3, MOTIVE4) to be especially important for research and infrastructure-related activities, MOTIVE4 also for CONS.

The existence of Technology Transfer Offices should be especially useful for the intermediation of research projects or co-operation projects related to the utilization of technical facilities.

As already mentioned, we expect universities of applied sciences to be in general stronger involved in KTT activities than other institutions.

With respect to the scientific disciplines, we expect that research activities (variable REAS) and infrastructure-related activities (variable INFR) would be more frequent for institutes with an engineering or natural sciences background, consulting activities more frequent for institutes of engineering or economics and management.

Finally, we expect larger institutes to be stronger inclined to research activities than smaller ones. A summary of the expected effects is given in Table 4.

6.2.3. *Various channels of KTT (model B)*

We use for the estimates of the three channels of KTT (patenting, licensing, spin-offs) the same specification as in Section 6.2.2 (Model B). We have the same sign expectations for the variables APPL and TEACH as in Section 6.2.1. Low teaching obligations and a focus on applied research should enhance also the use of resource-consuming activities such as patenting, licensing or the foundation of new science-based firms.

In accordance with the discussion in Sections 6.2.1 and 6.2.2, we would expect the obstacle categories OBSTACLE1, OBSTACLE2, and OBSTACLE3 to be particularly relevant for these three types of activities that are closely related with research co-operation between institutes and firms. Analogously, we expect MOTIVE1, MOTIVE3, and MOTIVE4 to be important for the propensity to patenting and licensing as well the promotion of new high-tech firms.

Technology Transfer Offices are founded with the aim of supporting such commercialization activities.

Thus, we expect a positive effect for all three channels of KTT.

The universities of applied sciences are expected to have a higher patenting and licensing propensity as well as a higher rate of formation of spin-offs than the other three types of institutions in our sample. This is also in accordance with the expectation that they are stronger involved in research co-operations with firms.

In accordance to empirical literature we assume that larger institutes are presumably better equipped than smaller ones for resource- and time-consuming activities such patenting, licensing or promotion of spin-offs.

All three channels of KTT should be utilized more often in engineering and the natural sciences, which are the scientific fields with a stronger inclination to research activities. Also in this case a summary of expected effects is given in Table 4.

7. Empirical results

7.1. Propensity to KTT activities

7.1.1. Overall KTT activities (model A)

Table 5 contains the results of the probit estimates for the variable for overall KTT activities (KTT; model A). For the coefficients of the variables APPL, TEACH and FINANCE we obtain the expected signs (column 1 in Table 5). Institutes with a stronger orientation to applied research and/or lower teaching obligations are also stronger inclined to get involved in KTT activities. The same is valid for institutes which have already had experience with business sector co-operations as reflected by a high share of third-party funds in an institute's budget.

We could not find any regularity across size classes. The two significant coefficients for the dummies (49–99 employees) and (100 employees and more) do not differ significantly from each other. There is a threshold of 40 employees above which the propensity of KTT activities correlates positively with institute size.

Rather unexpectedly, institutes belonging to the federal institutes of technology (ETH) or to the cantonal universities (UNIV) or to the federal research institutions (FRI) are not less inclined to KTT activities than the universities of applied sciences for which KTT activities are explicitly an important part of their mission.

In accordance to expectations, institutes of economics and business administration, natural sciences, engineering and medicine are stronger involved in KTT activities than institutes of mathematics and physics. The effect for engineering, natural sciences and economics/management is significantly stronger than that for medicine but the differences between the dummies for the three afore-mentioned scientific fields are not statistically significant (two-tailed *t*-test).

Only the coefficients for the obstacle variables that were statistically significant at the 10% level are shown in Table 5. As the significantly negative coefficient of the variable OBSTACLE4 indicates, institutes not involved in KTT activities were seriously impeded from undertaking such activities by a combination of the following four single obstacles: "scientific independence impaired"; "hindrance

Table 5
Determinants of KTT activities of institutes of science institutions with enterprises

Explanatory variables	KTT[a] (probit)
APPL[b]	0.048* (0.025)
TEACH[c]	−0.026*** (0.009)
FINANCE[d]	0.010* (0.005)
OBSTACLE4[e] (Endanger scientific independence, neglect basic research)	−0.416*** (0.153)
Institute size:	
10–19 employees	−0.204 (0.465)
20–39 employees	−0.057 (0.501)
40–99 employees	1.008* (0.518
100 employees and more	1.234** (0.522)
ETH[f]	0.464 (0.612)
UNIV[g]	−0.008 (0.633)
FRI[h]	−1.111 (0.913)
ENGINEERING[i]	1.517*** (0.529)
NATURAL SCIENCES[i]	1.825*** (0.477)
ECONOMICS, MANAGEMENT[i]	2.089*** (0.574)
MEDICINE[i]	0.853* (0.493)
Const.	−0.262 (0.905)
N	200
Pseudo R^2	0.353
Wald χ^2	44***

[a] KTT: knowledge and technology transfer activities in the period 2002–2004.

[b] APPL: ratio of the percentage of the total working time of academic staff of an institute devoted to *applied research* to the working time percentage devoted to *basic research*.

[c] TEACH: percentage of the total working time of academic staff devoted to *teaching*; there is also a fourth category of activities, namely 'other tasks'.

[d] FINANCE: share of third-party funds from business sector of an institute's budget.

[e] OBSTACLE4: combination of the following four single obstacles: "scientific independence impaired"; "hindrance to academic publication activities"; "neglecting of basic research"; "difficulties to get informed about R&D activities in industry" (see also Table A.4 in the appendix).

[f] ETH: dummy variable for affiliation to one of the two Federal Institutes of Technology in Zurich and Lausanne respectively.

[g] UNIV: dummy variable for affiliation to a University.

[h] FRI: dummy variable for affiliation to a Federal Research Institution (e.g. PSI, EAWAG, etc.); reference group: Universities of Applied Sciences.

[i] ENGINEERING; NATURAL SCIENCES; ECONOMICS, MANAGEMENT; MEDICINE: dummies for an institute's scientific field; reference group: mathematics/physics; ***, **, * denote statistical significance at the 1%, 5% and 10% test level, respectively; heteroscedasticity-robust standard errors (White procedure).

to academic publication activities"; neglecting of basic research"; "difficulties to get informed about R&D activities in industry" (see also Table A.5 in the appendix). Besides the informational problem of not knowing exactly what the research topics in industry R&D are, the three other single obstacles reflect fears of academics of neglecting their main task or reduce the quality of their work in case they get involved in KTT activities.

7.1.2. Specific forms of KTT activities (model B)

In a preliminary step, we investigated the possibility of the existence of a selectivity bias due to the fact that for estimating Model B only the KTT-active institutes were taken into consideration. Therefore, we estimated a Heckman selection model for all five dependent variable in model B (INFO, INFR EDUC, REAS, CONC), using the KTT equation of model A as a first step equation (selection equation). In all five cases the two equations were not significantly correlated (10% test level), so that the existence of a selectivity bias can be excluded.

In a second step, we took into consideration the possibility of interdependence among the various specific forms of KTT activities, given that institutes are pursuing more than one of them at a time, as already discussed in Section 5. To this end, we estimated a multivariate probit model, i.e. a simultaneous system of five equations (for INFO, INFR, EDUC, REAS and CONS respectively), instead of five separate probits. We applied the respective procedure implemented in STATA, which is based on the so-called GHK-simulator for multivariate distributions.[11] Table 6 contains the estimates for the multivariate probit model.

Significant correlations could be found between the equation for REAS and the equation for INFR (rho42 = 0.460 in Table 6) and between INFO and EDUC (rho31 = 0.616 in Table 6). Thus, there is considerable empirical justification for estimating a multivariate probit model.

Contrary to our expectations, the variable APPL has a significantly negative coefficient in the estimates for EDUC, REAS and CONS. This means that KTT-active institutes, which reported a stronger engagement in educational, research or consulting activities, are stronger oriented towards basic research than KTT-active institutes without such an engagement (see columns 3, 4 and 5 in Table 6). Thus, a stronger orientation towards applied research is relevant only for distinguishing between institutes involved in KTT activities and those not involved in such activities but not for explaining the activity focus of KTT-active institutes.

The level of teaching obligations (variable TEACH) does not seem to have any effect on four out of five forms of KTT. The expected negative effect could be found only for research activities (REAS). In the light of these results we have to differentiate somewhat our hypothesis on teaching in order to take into account a specific effect with respect to educational activities. For institutes with a focus in educational activities one could think even of a positive effect of the variable TEACH for this specific form of KTT activities.

Informal contacts (INFO) were hampered by OBSTACLE3, which is a combination of the following four single obstacles of KTT activities: "institute's research focus not interesting enough for industry"; "insufficient interesting research questions in industry for institute"; "no possibility of commercialization of research results"; "difficulties to find an appropriate industry partner" (see also Table A.5 in the appendix). This bundle of obstacles reflects the perception of academics of an industry research profile which does not correspond well to their own needs and interests. All other types of activities did not seem to be impeded by any kind of obstacles.

Motives as expressions of expected benefits are relevant for every category of KTT activities. Only the coefficients for the motive variables that were statistically significant at the 10% level are shown in Table 6. We obtain positive and significant coefficients for the variables MOTIVE1, MOTIVE2 and MOTIV4.

In accordance to our expectation, MOTIVE1 (access to business sector knowledge as an immediate, short-term objective) and MOTIVE4 (access to additional resources) are relevant for research activities (REAS). MOTIVE4 is important also for consulting (CONS), MOTIVE1 also for informal activities (INFO) and educational activities (EDUC). Finally, the variable MOTIVE2 reflecting institutional longer term goals with respect to KTT such as extending university's mission, promoting regional development, improving the image of science, etc. is positively correlated with infrastructure-related (INFR) and educational activities (EDUC).

Institute size showed no systematic effects on the propensity to engage in any type of KTT activities. For EDUC and CONC we found that larger institutes with more than 100 employees seem to be more involved in such activities than smaller institutes. In case of INFO only institutes with 40–99 employees seem to be particularly interested in such activities.

Obviously, the activities of Technology Transfer Offices are stronger oriented towards educational activities (EDUC) and informal contacts (INFO) and less involved in research (REAS), consulting (CONC) and infrastructure-related activities (INFR) than we expected.

As expected, all three types of institutions (ETH, UNIV, FRI) show a weaker tendency to engage in research cooperation with the business sector (variable REAS) than the reference group of the universities of applied sciences, for which KTT activities build explicitly an important part of their mission (column 4 in Table 6). Also the propensity to consulting activities is lower for the federal and cantonal universities than for the reference group (column 5). With respect to infrastructure-related activities (INFR) we could not find a significantly higher propensity for the universities of applied science (column 2). Only the ETH universities showed a weaker tendency than the reference group both with respect to informal contacts (INFO) and educational activities (EDUC) (column 1 and 3). For the federal research organizations we found an effect with respect to EDUC that was stronger than for the reference group. On the whole, the institutes of the two federal technical universities (ETH)

[11] The STATA procedure mprobit estimates *M*-equation probit models by the method of simulated maximum likelihood. The Geweke-Hajivassiliou-Keane (GHK)-simulator is applied to evaluate the *M*-dimensional Normal integrals in the likelihood function (for a description of the GHK-simulator see Greene, 2003).

Table 6
Determinants of specific forms of KTT activities of institutes and/or departments with enterprises (INFO; INFR; EDUC; REAS; CONS); multivariate probit estimates

Explanatory variables	INFO[a]	INFR[b]	EDUC[c]	REAS[d]	CONS[e]
APPL[f]	−0.010 (0.007)	−0.005 (0.007)	−0.023*** (0.009)	−0.025*** (0.006)	−0.015** (0.006)
TEACH[g]	0.005 (0.008)	−0.003 (0.010)	0.007 (0.011)	−0.018** (0.008)	−0.001 (0.007)
MOTIVE1[h] (Access to industrial knowledge)	0.205* (0.120)		0.896*** (0.214)	0.298*** (0.116)	
MOTIVE2[i] (Institutional/organizational motives)		0.523*** (0.168)	1.042*** (0.223)		
MOTIVE4[j] (Access to additional resources)				0.257* (0.146)	0.318** (0.123)
OBSTACLE3[k] (Differing interests or attitude to research	−0.406*** (0.136)				
Institute size:					
10–19 employees	0.140 (0.377)	0.367 (0.511)	0.165 (0.458)	−0.158 (0.361)	0.404 (0.332)
20–39 employees	0.158 (0.460)	0.653 (0.558)	−0.456 (0.564)	−0.040 (0.431)	0.360 (0.403)
40–99 employees	0.853* (0.496)	0.441 (0.578)	0.740 (0.503)	−0.184 (0.412)	0.485 (0.373)
100 employees and more	0.199 (0.450)	0.461 (0.561)	1.168** (0.549)	0.062 (0.493)	0.912** (0.410)
TTO[l]	0.921** (0.443)	0.517 (0.381)	3.904*** (0.772)	0.561 (0.481)	0.130 (0.390)
ETH[m]	−0.891* (0.471)	−0.162 (0.560)	−1.063* (0.630)	−1.515*** (0.485)	−1.051** (0.437)
UNIV[n]	−0.148 (0.472)	0.303 (0.661)	0.107 (0.638)	−1.722*** (0.465)	−0.833* (0.456)
FRI[o]	−0.164 (0.724)	−0.679 (0.799)	1.672* (0.868)	−2.524*** (0.592)	−0.766 (0.667)
ENGINEERING[p]	1.446*** (0.522)	−0.371 (0.613)	1.829*** (0.711)	0.290 (0.538)	1.369** (0.620)
NATURAL SCIENCES[p]	0.575 (0.586)	0.351 (0.576)	−0.629 (0.786)	0.831 (0.604)	0.697 (0.624)
ECONOMICS, MANAGEMENT[p]	0.496 (0.582)	−5.143*** (0.591)	0.626 (0.762)	0.241 (0.565)	2.008*** (0.638)
MEDICINE[p]	0.873 (0.585)	−0.249 (0.599)	−0.237 (0.784)	−0.188 (0.556)	0.710 (0.613)
Const.	−0.020 (0.815)	−1.123 (0.841)	1.125** (0.549)	2.659*** (0.821)	−0.870 (0.797)
N			172		
Wald χ^2			1267***		
Rho21			0.232		
Rho31			0.616***		
Rho41			0.193		
Rho51			0.163		
Rho32			0.010		
Rho42			0.460***		
Rho52			0.078		
Rho43			0.133		
Rho53			0.138		

Table 6 (*Continued*)

Explanatory variables	INFO[a]	INFR[b]	EDUC[c]	REAS[d]	CONS[e]
Rho54			0.141		
LR test of rho21 = . . .·... = rho54 = 0			21**		

[a] INFO: 3 variables for single forms of KTT referring to informal contacts, attendance of conferences, workshops of private enterprises, etc. measured on a five-point Likert scale (1: not important"; 5: "very important") were combined to one dummy variable: value 1 is attached to institutes that reported a value 4 or 5 for any of the three original variables, value 0 to those institutes reporting 1, 2 or 3 for any of the three original variables.

[b] INFR: similar construction as INFO based on the variables for two single forms of KTT referring to technical facilities.

[c] EDUC: based on 9 single variables referring to education and training activities.

[d] REAS: based on 3 single variables referring to research activities.

[e] CONS: based on 2 single variables referring to consulting activities; see Table 2 for details.

[f] APPL: ratio of the percentage of the total working time of academic staff of an institute devoted to *applied research* to the working time percentage devoted to *basic research*.

[g] TEACH: percentage of the total working time of academic staff devoted to *teaching*; there is also a fourth category of activities, namely 'other tasks'.

[h] OBSTACLE3: combination of the following four single obstacles of KTT activities: "institute's research focus not interesting enough for industry"; "insufficient interesting research questions in industry for institute"; "no possibility of commercialization of research results"; "difficulties to find an appropriate industry partner" (one factor out of total six factors of a principal component factor analysis of 26 single obstacles measured on five-point Likert scale (1: 'not important'; 5: 'extremely important') (see also Table A.5 in the appendix).

[i] MOTIVE1: combination of the seven single motives of KTT activities referring to access to industrial knowledge as well as practical experience and application of university knowledge (one factor out of total four factors of a principal component factor analysis of 24 single motives measured on five-point Likert scale (1: 'not important'; 5: 'extremely important') (see also Table A.4 in the appendix).

[j] MOTIVE2: combination of ten single motives referring to institutional and/or organizational motives (see Table A.4 in the appendix for details).

[k] MOTIVE4: combination of three single motives referring to pursuing more research efficiency (see Table A.4 in the appendix for details).

[l] TTO: importance of the Technology Transfer Offices of the various institutions as intermediaries in the period 2002–2004.

[m] ETH: dummy variable for affiliation to one of the two Federal Institutes of Technology in Zurich and Lausanne respectively.

[n] UNIV: dummy variable for affiliation to a University.

[o] FRI: Federal Research Institution (e.g. PSI, EAWAG, etc.); reference group: Universities of Applied Sciences.

[p] ENGINEERING; NATURAL SCIENCES; ECONOMICS, MANAGEMENT; MEDICINE: dummies for an institute's scientific field; reference group: mathematics/physics; ***, **, * denote statistical significance at the 1%, 5% and 10% test level, respectively; heteroscedasticity-robust standard errors (White procedure).

show a weaker tendency to engage in any type of KTT activities than the universities of applied research (with the exception of INFR). A possible explanation is that these two universities are primarily basic research oriented.

Finally, institutes of engineering are stronger inclined to informal contacts, educational activities and consulting than institutes from other scientific fields. It is not astonishing that institutes of economics/management are stronger involved in consulting (e.g. University of St. Gallen) and less in infrastructure-related activities than institutes in the other disciplines. Otherwise there are no discernible differences among the institutes from different scientific fields with respect to the five categories of KTT activities.

7.2. Channels of KTT: patenting, licensing, spin-offs (model B)

Also in this case we take into consideration the possibility of interdependence among the various types of channels of KTT. There are some good reasons why some correlations between these activities should exist: patenting is a precondition for licensing; patenting and/or licensing are often the main motivation for grounding a new firm to exploit these assets. In order to take account of this interdependency we estimated a trivariate probit model, i.e. a simultaneous system of three equations (for PATENTING, LICENSING and SPIN-OFFS respectively), instead of three separate probits. To this end, we applied the respective procedure implemented in STATA, which is based on the so-called GHK-simulator for multivariate distributions. Table 7 shows the estimates for the trivariate probit model.

There is no significant correlation between the equations for patenting and licensing and between the equations for patenting and spin-offs. A significant correlation could be found only between the equations for licensing and spin-offs (rho23 = 0.538 in Table 7). Thus, there is empirical justification for estimating a trivariate probit model.

For patenting as well as for university spin-offs (columns 1 and 3 respectively in Table 7) the research orientation of the institutes is practically irrelevant; the variable APPL is in both cases statistically insignificant even at the 10% test level. Rather unexpectedly, the effect of APPL is negative in the LICENSING equation, as it was the case also for EDUC, REAS and CONS in Table 6. For patenting the coefficient of the variable TEACH is also insignificant, for licensing and spin-offs shows this variable the expected negative sign. Rather unexpected is the significantly positive coefficient of the variable TEACH in the estimates for spin-offs. A glance at the data shows where this effect is coming from. Universities of applied science, where the teaching obligations are on average higher than in the other types of science institutions, show also an above-average propensity to spin-offs.

The logical consequence of the findings for licensing (column 2 in Table 7) is that primarily institutions with much basic research and low teaching obligations would be engaged in licensing. A glance at the data shows that particularly the Swiss Federal Institute of Technology in Lausanne (EPFL) and the four federal research institutions, all institutions with a strong profile in basic research *and* low teaching obligations, are heavily engaged in licensing.

Table 7
Determinants of patenting; licensing; founding spin-offs; trivariate probit estimates

Explanatory variables	Patenting[a] (1)	Licensing[b] (2)	Spin-offs[c] (3)
APPL[d]	−0.009 (0.007)	−0.022*** (0.011)	0.001 (0.006)
TEACH[e]	−0.007 (0.006)	−0.021*** (0.012)	0.018*** (0.006)
OBSTACLE3[f] (Differing interests, attitudes to research)		−0.378** (0.181)	−0.459*** (0.140)
MOTIVE1[g] (Access to industrial knowledge)	0.216* (0.121)		
Institute size:			
10–19 employees	−0.201 (0.350)	−0.051 (0.334)	0.066 (0.374)
20–39 employees	0.459 (0.376)	−0.983* (0.517)	0.109 (0.464)
40–99 employees	0.604 (0.402)	0.312 (0.360)	1.128** (0.459)
100 employees and more	0.942** (0.408)	//	1.357*** (0.449)
TTO[h]	0.705**** (0.287)	0.657* (0.364)	1.274*** (0.406)
ETH[i]	−0.068 (0.443)	−0.245 (0.466)	0.340 (0.406)
UNIV[j]	−0.154 (0.481)	−0.090 (0.468)	0.066 (0.455)
FRI[k]	−0.991 (0.664)	1.004 (0.667)	1.765** (0.842)
ENGINEERING[l]	1.732*** (0.324)	−0.225 (0.539)	0.977 (0.660)
NATURAL SCIENCES[l]	1.359*** (0.440)	−0.096 (0.562)	0.174 (0.699)
ECONOMICS, MANAGEMENT[l]	//	−0.894 (0.595)	0.832 (0.686)
MEDICINE[l]	0.908** (0.450)	−0.797 (0.595)	0.120 (0.659)
Const.	−1.404** (0.550	−0.001 (0.712)	−2.794*** (0.845)
N		169	
Wald χ^2		202***	
Rho12		0.090	
Rho13		0.212	
Rho23		0.538***	

[a] Application of patents yes/no 2002–2004.
[b] Licenses yes/no 2002–2004.
[c] Spin-offs/start-ups yes/no 2002–2004.
[d] APPL: ratio of the percentage of the total working time of academic staff of an institute devoted to *applied research* to the working time percentage devoted to *basic research*.
[e] TEACH: percentage of the total working time of academic staff devoted to *teaching*; there is also a fourth category of activities, namely 'other tasks'.
[f] OBSTACLE3: combination of the following four single obstacles of KTT activities: "institute's research focus not interesting enough for industry"; "insufficient interesting research questions in industry for institute"; "no possibility of commercialization of research results"; "difficulties to find an appropriate industry partner" (one factor out of total six factors of a principal component factor analysis of 26 single obstacles measured on five-point Likert scale (1: 'not important'; 5: 'extremely important') (see also Table A.5 in the appendix).
[g] MOTIVE1: combination of the following seven single motives for of KTT activities: "access to specific capabilities complementary to institute's expertise"; "new research impetus"; "exchange of ideas and experience with industry researchers"; "practical experience for staff/students"; "gaining additional research insights"; "opportunity to test research findings in practice"; promoting the diffusion of a particular technology" (one factor out of total four factors of a principal component factor analysis of 24 single motives measured on five-point Likert scale (1: 'not important'; 5: 'extremely important') (see also Table A.4 in the appendix).
[h] TTO: importance of the Technology Transfer Offices (TTO) of the various institutions as intermediaries of KTT activities in the period 2002–2004 (1: 'important'; 0: not important').
[i] ETH: dummy variable for affiliation to one of the two Federal Institutes of Technology in Zurich and Lausanne respectively.
[j] UNIV: dummy variable for affiliation to a University.
[k] FRI: dummy variable for affiliation to a Federal Research Institution (e.g. PSI, EAWAG, etc.); reference group: Universities of Applied Sciences.
[l] ENGINEERING; NATURAL SCIENCES; ECONOMICS, MANAGEMENT; MEDICINE: dummies for an institute's scientific field; reference group: mathematics/physics; ***, **, * denote statistical significance at the 1%, 5% and 10% test level, respectively; heteroscedasticity-robust standard errors (White procedure).

MOTIVE1 related to the access of industrial knowledge as well as practical experience and possibilities of application is relevant only for patenting. Licensing and spin-offs were hampered by the same category of obstacles, namely OBSTACLE3, which reflects the perception of academics of an industry research profile that does not correspond well to their own needs and interests.

There is a weak positive size effect for spin-offs but no discernible effect for the other two types of KTT channels.

As expected, Technology Transfer Offices are relevant for all three channels of KTT.

There were no discernible differences with respect to patenting and the foundation of spin-offs among the various groups of federal, cantonal and regional institutions (variables ETH, UNIV, FRI vs. the reference group of universities of applied sciences), with the exception of the federal research institutions (FRI) showing a higher propensity to spin-offs than the reference group (column 3 in Table 7).

We could not find any differences for the scientific fields with respect to licensing and spin-offs. Engineering and natural sciences are significantly stronger represented than other disciplines in patenting.

8. Summary and conclusions

A new element that this paper adds to empirical literature is the analysis at the level of institute or department of a wide spectrum of KTTT activities covering besides research co-operation also informal informational contacts, educational activities, consulting and joint use of technical infrastructure. Thus, it is understandable that no other comparable empirical study could be found for this part of the study with the exception of the paper of Schartinger et al. (2001) in this journal.

A first important finding of the study refers to the *overall propensity* to KTT activities with private enterprises. Institutes with a stronger orientation to applied research and/or lower teaching obligations are also stronger inclined to get involved in KTT activities. The same is valid for institutes that have already had experience with industry co-operations as reflected by a high share of external funds in an institute's budget. There is no systematic size effect. We could not find any discernible differences among the three groups of science institutions with respect to overall KTT activities. In accordance to expectations, institutes of economics and business administration, natural sciences, engineering and medicine are stronger involved in KTT activities than institutes of mathematics and physics. Institutes not involved in KTT activities were seriously impeded from undertaking such activities by a series of single obstacles which primarily reflect the fears of academics of neglecting their main task or reduce the quality of their work when they involved in KTT activities. Institutes of engineering, natural sciences and economics/management are strongly represented among KTT-active institutes. For this part of the study no comparable evidence from other studies was available.

A stronger orientation towards applied research is relevant only for distinguishing between institutes involved in KTT activities and those not involved in such activities but not for explaining the *specific activities* of KTT-active institutes. KTT-active institutes, which reported a strong engagement in educational, research or consulting activities, are stronger oriented towards basic research than KTT-active institutes without such an engagement. The level of teaching obligations has the expected negative effect only in the case of research activities. Access to business sector knowledge, financial motives in the sense of searching for additional funding and organization or institutional motives such as extending university's mission, promoting regional development, improving the image of science, etc. are the most important incentives for most types of KTT activities. Technology Transfer Offices are particularly relevant for informal contacts and educational activities. Engineering sciences are strongly represented among the institutes with a strong engagement in educational and consulting activities as well as informal contacts. With respect to research activities the engagement of various scientific fields is quite evenly distributed. Schartinger et al. (2001) found that departments of engineering sciences in Austrian universities are more strongly inclined to research activities than other departments of other scientific fields. Also for the specific activities we could not find a size effect, contrary to the results of Schartinger et al. (2001) who found that the department size was positively correlated to various KTT activities with the exception of contract research.

The second part of the study refers to patenting, licensing and formation of spin-offs at institute-level or department-level. The results with respect to the three important channels of KTT, patenting, licensing and the formation of new knowledge-based firms showed considerable differences with respect to the relative importance of the determinants examined in this study. An institute's research focus (basics vs. applied research) does not influence the propensity for patenting and spin-offs; a focus on basics research seems to be quite compatible with licensing activities. High teaching obligations seem to negatively influence KTT activities such as licensing and spin-offs. A further important finding was that licensing and spin-offs were hampered by the same category of reported obstacles reflecting the perception of academics of an industry research profile which does not correspond well to their own needs and interests. There are small differences among the four types of science institutions and the various scientific fields with respect to the propensity of licensing and spin-offs. Engineering and natural sciences are strongly represented among institutes with an inclination to patenting. Finally, there is a weak positive effect of institute size with respect to spin-offs. Looking for comparable evidence, we mention here the results of the study of Carlsson and Fridh (2002) at university level who found that university size is positively correlated to all three activities discussed in this paragraph: patenting, licensing, promotion of spin-offs. A positive effect of university size was also found by Friedman and Silberman (2003) with respect to invention disclosures. A further comparable effect refers to the positive influence of Technology Transfer Offices found by Thursby et al. (2001). Otherwise, large differences with respect to model specification, level of analysis, etc. do not allow a comparison of our results with those of other studies.

Finally, there are two pieces of information in our results that could be policy-relevant. The first point is related to the role of Technology Transfer Offices. They seem to fulfil well their function as 'specialized consultants' with respect to patenting, licensing and the promotion of new firms. But they seem to perform less well as 'KTT intermediaries'. They are important for mediating informal contacts and educational activities but not for negotiating research and consulting contracts or infrastructure-related activities. Thus, there is some scope for university policy here trying to drive TTO stronger to a 'research-oriented' path. A second and more important point refers to the obstacles of KTT. Differing interests and attitudes, fears to lose scientific independence or neglect basic research and scientific publication activities seem to be the most relevant impediments for scientific institutes to get engaged in KTT activities. These are primarily 'culture differences' between university and business that can be partly traced back to the different goals pursued by the university and the corporation but also to a lack of knowledge of the problems and interests of each other. This is could build the starting point for a policy intervention aiming at bringing universities and business closer together.

Acknowledgements

This study was financially supported by the ETH-Board. The authors acknowledge gratefully the fruitful comments and suggestions of two anonymous referees.

Appendix A

See Tables A.1–A.5.

Table A.1
Composition of net sample, response sample and response rates

Institutions	*Net sample*[a]	*Response*[a]	*Response rate* (%)
ETH-domain			
Swiss Federal Institute of Zurich	87	45	51.7
Swiss Federal Institute of Technology Lausanne	31	12	38.7
Federal Research Institutions ([b])	11	11	100.0
University of			
Basle	32	11	34.4
Berne	84	33	39.3
Fribourg	17	5	29.4
Geneva	46	15	32.6
Italian Switzerland	9	2	22.2
Lausanne	69	12	17.4
Neuchâtel	22	6	27.3
St. Gallen	21	8	38.1
Zurich	74	22	29.7
University of Applied Sciences of			
Berne	13	9	69.2
Central Switzerland	10	5	50.0
Eastern Switzerland	36	14	38.9
Italian Switzerland	7	2	28.6
Northwestern Switzerland	27	17	63.0
Western Switzerland	12	4	33.3
Zurich	22	8	36.4
Total	630	241	38.3

[a] Number of institutes or departments.
[b] Paul Scherer Institute (PSI); Swiss Federal Institute of Aquatic Science and Technology (EAWAG); Research Institute for Material Sciences and Technology (EMPA); Swiss Federal Institute for Forest, Snow and Landscape Research (WSL).

Table A.2
Institute size

Number of employees ([a])	*N*	Percentage share of institutes
Up to 9 employees	36	14.9
10–19 employees	63	26.2
20–39 employees	47	19.5
40–99 employees	54	22.4
100 and more employees	41	17.0
Total	241	100.0

[a] Institute employees (in full-time equivalents): professors, academic staff with doctorate and 'habilitation', academic staff without doctorate, technical staff with university degree, staff carrying out other supporting and administrative functions.

Table A.3
Institutes by scientific field

Scientific field	*N*	Percentage share of institutes
Economics, Business Administration	47	19.5
Engineering	79	32.8
Mathematics, Physics	21	8.7
Medicine	62	25.7
Natural Sciences	32	13.3
Total	241	100.0

Table A.4
Principal component factor analysis of the motives for KTT Activities

Motives	Rotated Factor Pattern (factor loadings)			
	Factor 1	Factor 2	Factor 3	Factor 4
Access to specific capabilities complementary to own ones	0.61			
Research impetus	0.74			
Exchange of experience with industrial researchers	0.77			
Practical experience for staff/students	0.66			
Additional insights in own research field	0.72			
Test own research findings in practice	0.58			
Promoting the diffusion of a particular technology	0.51			
Securing good job prospects for students/staff		0.60		
Presence of business representatives in university's academic consultant bodies		0.61		
Extending university's mission		0.54		
Promoting the diffusion of key findings		0.56		
Promoting regional development		0.74		
Improving image of science		0.52		
Commercial success		0.63		
Reference for more public funding		0.53		
Applied research possible only in collaboration		0.54		
Gaining knowledge about practical problems for curriculum		0.54		
Cost savings			0.83	
Time savings			0.84	
Access to technological equipment, specialised technology			0.53	
Additional resources for basic research				0.76
Additional resources for research facilities				0.83
Business funding more flexible than public funding				0.67
Statistics				
Number of observations	205			
Kaiser's measure of sampling adequacy (MSA)	0.888			
Root mean square off-diagonal residuals (RMSE)	0.060			
Variance explained by each factor	8.62	2.36	1.43	1.26
Final communality estimate	13.7			
Characterization of the four factors based on the factor pattern				
Factor 1 (MOTIVE1): Access to industrial knowledge as wells as practical experience and possibilities of application				
Factor 2 (MOTIVE2): Institutional or organizational motives				
Factor 3 (MOTIVE3): Financial motives (achieving more research efficiency)				
Factor 4 (MOTIVE4): Financial motives (access to additional resources)				

Note: The table shows only factor loadings of 0.5 and more; one single motive ("access to industrial patents and licenses") is not included in the table because of low factor loadings in every factor.

Table A.5
Principal component factor analysis of the impediments of KTT Activities

Impediments	Rotated Factor Pattern (factor loadings)					
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Lack of qualified staff in industry	0.57					
Lack of technical facilities in industry	0.51					
Lack of interest in scientific projects in industry	0.52					
Uncertainty about R&D results	0.68					
Differing ideas on costs and/or productivity	0.67					
R&D budgets of potential business partners too low	0.77					
Resource-intensive administrative and approval procedures, legal restrictions		0.75				
Lack of project administration support on the part of the academic institution		0.68				
Lack of support for the commercialization of findings on the part of the academic institution		0.69				
Property Rights problems		0.63				
Difficulty to find an appropriate partner in industry			0.52			
Insufficient interesting research questions in industry			0.69			
Insufficient interesting research focus for firms			0.82			
No possibility of commercialising research findings			0.74			
Lack of Information about firms' research activities				0.57		
Scientific independence impaired				0.69		
Hindrance to academic publication activities				0.71		
Neglecting basic research				0.69		
Different views on urgency with regard to scheduling					0.58	
Lack of confidence					0.69	
Reputation at risk					0.75	
Teaching requires too much time						0.76
Lack of academic specialists for KTT activities						0.61
Statistics						
Number of observations	221					
Kaiser's measure of sampling adequacy (MSA)	0.844					
Root mean square off-diagonal residuals (RMSE)	0.059					
Variance explained by each factor	7.37	2.10	1.72	1.65	1.42	1.2
Final communality estimate	15.4					
Characterization of the six factors based on the factor pattern:						
Factor 1 (OBSTACLE1): Deficiencies of the firms						
Factor 2 (OBSTACLE2): Administrative problems						
Factor 3 (OBSTACLE3): Different interests, different attitudes to research						
Factor 4 (OBSTACLE4): Endangering scientific independence, neglect of basic research and publishing						
Factor 5 (OBSTACLE5): Lack of confidence, risk of damaging reputation						
Factor 6 (OBSTACLE6): Lack of human resources						

Note: The table shows only factor loadings of 0.5 and more; the following three single obstacles are not included in the tables because of low loadings in every factor: "interface to the business sector poorly equipped (e.g. lack of capacity of technology transfer offices)"; "approach of institute staff not entrepreneurial enough"; "project management problems on the part of science institutions".

References

Agrawal, A., Henderson, R.M., 2002. Putting patents in context: exploring knowledge transfer from MIT. Management Science 48 (1), 44–60.

Azagra-Caro, J.M., Carayol, N., Llerena, P., 2006. Patent production at a European research university: exploratory evidence at the laboratory level. Journal of Technology Transfer 31, 257–268.

Azoulay, P., Ding, W., Stuart, T., 2005. The Determinants of Faculty Patenting Behaviour: Demographics or Opportunities? NBER Working Paper No. 11348, Cambridge, Mass.

Berwert, A., Rütter, H., Künzle, D. Lüthi, E., Leu, A., 2002. THISS – Technische Hochschulen und Innovationen: start-ups und Spin-offs unter besonderer Berücksichtigung von Aus- und Weiterbildung und Supportstrukturen, in: Horvath. F. (Hrsg.), Forum Bildung und Beschäftigung. Workshop-Dokumentation (NFP 43), Arbeitsbericht 29, Bern, pp. 22–40.

Beath, J., Owen, R.F., Poyago-Theotoky, J., Ulph, D., 2003. Optimal incentives for income-generation in universities: the rule of thumb for the compton tax. International Journal of Industrial Organization 21, 1301–1322.

Carlsson, B., Fridh, A.-C., 2002. Technology transfer in United States Universities. Journal of Evolutionary Economics 12, 199–232.

Di Gregorio, D., Shane, S., 2003. Why do some universities generate more start-ups than others? Research Policy 32, 209–227.

Dosi, G., 1982. Technological paradigms and technological trajectories. Research Policy 11, 147–162.

Friedman, J., Silberman, J., 2003. University technology transfer: do incentives, management, and location matter? Journal of Technology Transfer 28, 17–30.
Geissler, E., 1997. Intersector technology co-operation: hard myths, soft facts. Technovation 17 (6), 309–320.
Geisler, E., Rubinstein, A.H., 1989. University-industry relations: a review of major issues. In: Link, A.N., Tassey, G. (Eds.), Cooperative research and development: the industry-university-government relationship. Kluwer Academic Publishers, London.
Goldfarb, B., Henrekson, M., 2003. Bottom-up vs. top-down policies towards the commercialization of university intellectual property. Research Policy 32, 639–658.
Greene, W.H., 2003. Econometric Analysis. Prentice-Hall, New York.
Hellman, T., 2005. The Role of Patents for Bridging the Science to Market Gap. NBER Working Paper No. 11460, Cambridge, Mass.
Jensen, R., Thursby, M., 2004. The Academic Effects of Patentable Research. NBER Working Paper No. 10758, Cambridge, Mass.
Lee, Y.S., 1996. Technology transfer and the research university: a search for the boundaries of university-industry collaboration. Research Policy 25, 843–863.
Lee, Y.S., 2000. The sustainability of university-industry research collaboration: an empirical assessment. Journal of Technology Transfer 25, 111–133.
Mayer, V., 2000. Regional Innovationspotentiale und Innovative Netzwerke der Industrieunternehmen in der Metropolitanen Region Wien – Ergebnisse einer Unternehmensbefragung, ISR-Forschungsberichte, Hrsg.: Institut für Stadt- und Regionalforschung. Verlag der Österreichischen Akademie der Wissenschaften, Wien.
NATURE, 2001. Is the University-industrial Complex Out of Control? 423, 908.
OECD, 1999. Special Issue on "Public/Private Partnerships in STI Review No. 23.
OECD, 2002. Benchmarking Industry–Science Relationships. OECD, Paris.
OECD, 2003a. Turning Science into Business, Patenting and Licensing at Public Research Organizations. OECD, Paris.
OECD, 2003b. Verwertung wissenschaftlicher Ergebnisse: Patentverwertung und Lizenzvergabe durch öffentliche Forschungseinrichtungen, Kurzfassung. OECD, Paris.
Onida, F., Malerba, F., 1989. R&D Co-operation between Industry, Universities and Research Organizations in Europe, Background Report. Technovation 9, 131–193.
Owen-Smith, J., Powell, W.W., 2001. To patent or not? Faculty decisions and institutional success at technology transfer. Journal of Technology Transfer 26, 99–114.
Renault Searle, C., 2006. Academic capitalism and university incentives for faculty entrepreneurship. Journal of Technology Transfer 31, 227–239.
Rosenberg, N., Nelson, R.R., 1994. American universities and technical advance in industry. Research Policy 23, 323–348.
Santoro, M.D., Chakrabarti, A.K., 2002. Firm size and technology centrality in industry-university interactions. Research Policy 31, 1163–1180.
Schartinger, D., Schibany, A., Gassler, H., 2001. Interactive relations between universities and firms: empirical evidence for Austria. Journal of Technology Transfer 26, 255–268.
Schmoch, U., 2003. Hochschulforschung und Industrieforschung, Perspektiven und Interaktion. Campus Verlag, Frankfurt, New York.
Shane, S., Stuart, T., 2002. Organizational endowments and the performance of university start-ups. Management Science 48 (1), 154–170.
Stephan, P.E., 2001. Educational implications of university-industry technology transfer. Journal of Technology Transfer 26, 199–205.
Thierstein, A., Wilhelm, B.E., Behrendt, H., 2002. Gründerzeit. Unternehmensgründungen von Absolventen der Ostschweizer Hochschulen, Schriftenreihe des Instituts für Öffentliche Dienstleistungen und Tourismus der Universität St. Gallen, Beiträge zur Regionalwirtschaft. Haupt Verlag, Bern.
Thursby, J.G., Jensen, R., Thursby, M.C., 2001. Objectives, characteristics and outcomes of university licensing: a survey of major U.S. universities. Journal of Technology Transfer 26, 59–97.
Thursby, J.G., Thursby, M.C., 2002. Who is selling the ivory tower? Sources of growth in university licensing. Management Science 48 (1), 90–104.
Thursby, M.C., Thursby, J.G., Mukherjee, S., 2005. Are There Effects of Licensing on Academic Research? A Life Cycle View. NBER Working Paper No. 11497, Cambridge, Mass.
Tijssen, R.J.W., 2004. Is the commercialization of scientific research affecting the production of public knowledge? Global trends in the output of corporate research articles. Research Policy 33, 709–733.
Vock, P., Sultanian, E., Hinrichs, U., 2004. Technologietransferaktivitäten 2002 – Umfrage bei Hochschulen und öffentlich finanzierten Forschungsorganisationen, Zentrum für Wissenschafts- und Technologiestudien. CEST 2004/3, Bern.
Zinkl, W., Huber, H., 2003. Strategie für den Wissens- und Technologietransfer an den Hochschulen in der Schweiz. Mandat im Auftrag der Schweizerischen Universitätskonferenz SUK, Hauptbericht: Strategie und Politik im WTT, Basel.