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Abstract

This study explores the factors determining the propensity of Swiss science institutions at the level of a single institute or department to interact with private enterprises in Switzerland (universities and other research institution), i.e. to get involved in knowledge and technology transfer (KTT) activities 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 interaction, not only through joint research projects but also through training, mobility of academic personnel, jointly supervised master theses and PhDs, consulting and so on. Moreover, we also study the determinants of commercialization of university research output that takes the form of patenting, licensing or spin-offs. 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, cantonalal universities and regional universities of applied sciences) using a questionnaire.

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.[1] 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 which are their main tasks, especially when commercialization revenues are substituted for public funds.[2]

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.

This study explores the factors determining the propensity of Swiss science institutions at the level of a single institute or department to interact with private enterprises in Switzerland (universities and other research institution), i.e. to get involved in knowledge and technology transfer (KTT) activities in order to provide firms with scientific knowledge in research fields

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[1] *Economics*: see e.g. 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"; vol. 34, issue 3 of *Research Policy* of April 2005 (edited by A.N. Link, and D.S. Siegel) devoted to "University-based Technology Initiatives"; vol. 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 (2003), OECD (2002) and OECD (1999); see also Goldfarb and Henrekson (2003) for a comparison of different policies towards the commercialization of university intellectual property.

[2] 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.

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 interaction, 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. 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, cantonalal universities and regional universities of applied sciences) using a questionnaire.

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 general informational and 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. Second, the explicit consideration of a series of relevant motives and obstacles as determinants of KTT which contribute significantly to the econometric explanation of firms' propensity to overall KTT activities as well as to several specific forms of KTT activities. Third, the parallel investigation of the three important channels of KTT patenting, licensing and formation of spin-offs. This is to our knowledge the first Swiss institute-level study on this matter.[3]

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 types of commercialization of university research output (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 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

[3] 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.

member the agent. The analysis in Beath (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 to address 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-o*ff may be an alternative way that guarantees efficiency, because in a spin-off the scientist always internalizes all benefits from search. A last discussion point refers to the lack of an analysis of the dynamic implications of the commercialization of research output. There is empirical evidence that patenting of scientific discoveries may have a negative impact on further scientific progress.

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. As a consequence, an empirical investigation would at least contain measures for anticipated costs and benefits of commercialization activities, measures of the allocation of working time in basic and applied research as well as teaching, and measures of research output.

3. Review of Selected Empirical Literature

In this section we review some selected empirical studies which use a similar approach to ours (firm-level data, econometric investigation of the determinants of some form of KTT activities) and try to detect some regularities. Most studies refer to forms of commercialization of university research output such as patenting, licensing and the formation of new firms. A major topic in part of this literature is the relationship between commercialization and research.

A first group of studies refers to the interaction forms between universities and firms. In 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).

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 Ph.D.s/Masters 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.

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 licences, 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) deals with 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.

Searle Renault (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 form 1993 to 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 licences that are executes at later stages of development.

In an 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.

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.[4] The survey was based on sample of all institutes and

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

departments of the two federal technical universities (with the exception of the departments of humanities), the four federal research organization, the institutes and departments of engineering, natural sciences, mathematics and physics, medicine and economics and business administration of the ten cantonal universities as well as the seven regional universities of applied science, 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 and departments responded to our survey. 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 196 observations could be used in the econometric analysis.

5. Descriptive Analysis: Main Facts

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 or/and before 2002, 71.4% of respondents reported also KTT activities with foreign firms. This is a very high incidence of KTT activities also in international comparisons, but it has to considered with some caution because of the rather low total response rate of 38.3%.[5] KTT activities with foreign firms are also widespread, 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 institutions (federal institutes of technology, federal research institutions, cantonal universities and regional universities of applied sciences) with respect to propensity to KTT activities.

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

[5] We suppose that there exist some positive bias towards KTT-active institutes in our sample.

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 sector" (46.5%) and "thesis projects in collaboration with firms" (42.1%). However, there are some remarkable differences among the various institutions: for the institutions of the ETH-domain and the universities of applied sciences. For the institutions of the ETH-domain and the universities of applied science have research activities a higher priority than informal informational activities. For universities are educational activities 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.

6. Model Specification and Construction of Variables

Dependent Variables

We specified two different 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 and/or in the period before 2002. 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 types of commercialization of university research output. 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. 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 those institutes reporting 1, 2 or 3 for all three original variables; INFR: similar construction as INFO based on the variables for 2 single forms of KTT referring to technical infrastructure facilities; EDUC: based on 10 single variables referring to education and training activities; REAS: based on 3 single variables referring to research activities; CONS: 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.

Independent Variables

Most of the independent variables to be discussed below were included in both models; if a certain variable is used only in one of the models is especially mentioned below. The expected signs for independent variables are referring to both models. 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 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. They include impediments due to deficiencies of potential industry partners or due to deficiencies of the science institutions, due to lack of information on the R&D activities of private enterprises, problems in teaching and basic research resulting from a re-orientation of institute activities towards KTT, costs, risks and uncertainty, institutional and organizational obstacles. 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). The factor values of a six-factor solution of a principal component factor analysis of the original 26 variables were inserted as independent variables in the estimation equations of all four dependent variables (variables OBSTACLE1 to OBSTACLE6). We expect a negative effect for each of these obstacles, although we do not have a priori expectations with respect to the relative importance of each of them.

For the variables for the specific forms of KTT activities as well as variables for patenting, licensing and founding of spin-offs (model B), we also included four variables measuring several aspects of the motivation of institutes for undertaking KTT activities with private enterprises. Institutes with KTT activities reported their assessment for 24 single goals of and/or motives for KTT activities covering a wide spectrum of knowledge-oriented motives (access to “tacit” and or ”codified” knowledge respectively), financial motives (e.g. cost-saving or time-saving in research projects, additional resource for extending research facilities) and institutional and organizational motives (e.g. securing good job prospects for staff and/or students, extending the university’s mission). We consider these motives to reflect to a large extent the *expected benefits* of KTT activities from an institute’s point of view. Therefore we expect a positive effect for each of these motives, although we do not have a priori expectations with respect to their relative importance. 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). The factor values of a four-factor solution of a 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).

An important issue in the discussion over university-industry interplay is whether KTT activities, particularly those associated with financial incentives compromise the research mission of the university by diverting university researchers from basic research. To test this hypothesis, we also included a variable measuring the research output of the institutes, namely the number of PhDs in the period 2002-2004 (PHD). Alternatively, we used the number of scientific publications (PUBL) as a measure of research output in model A. We expect a non-negative effect, i.e. either a positive influence on the propensity of KTT activities including commercialization activities or no effect at all.

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 business administration 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 to be stronger involved in KTT activities than other institutions.

Finally, a structural measure was also included: four dummies for institute size (measured by the number of employees in full-time equivalents). We also used an alternative specification for institute size by inserting a linear term and a quadratic term with respect to the number of employees in the estimation equation. In accordance to empirical literature we expect institute size to be positively correlated to the propensity to KTT activities with private enterprises. Institute size is considered as an important determinant representing factors which favour KTT activities but are not specified in our model. We postulate 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.

7. Empirical Results

7.1 Propensity to KTT Activities

Overall KTT activities (model A)

Table 3 contains the results of the probit estimates for the variable for overall KTT activities (KTT; model A). One model version contains PHD, a second one PUBL as a measure of research output. The overall fit of the model (Pseudo R^2 of 0.37 and 0.41 respectively) is rather satisfactory for a cross-section investigation.

For the coefficients of the variables APPL, TEACH and FINANCE we obtain the expected signs (column 1 in table 3). 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 industry co-operations as reflected by a high share of third-party funds in an institute's budget. We could not find a size effect. This is also confirmed by the results (not presented here) with regard to the alternative specification based on a linear and a quadratic term for the number of employees: the coefficients of both the linear term and the quadratic term are not statistically significant at the usual test level. 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, ranking as presented above, are stronger involved in KTT activities than institutes of mathematics and physics.

Only the coefficients for the obstacle variables that were statistically significant at the 10% level are shown in table 3. 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 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 (legitimate) fears of academics of neglecting their main task or reduce the quality of their work in case they get involved in KTT activities.

Research output is positively correlated with the propensity to KTT activities if measured by the number of PhDs or not at all correlated if measured by the number of scientific publications. This an important first hint that KTT activities do not compromise university research, as critics often assert.

The usual caveats can be made: since the results are only cross-section estimates, it is not possible to test directly the existence of causal relations between the independent variables and the dependent variable. Nevertheless, some robust regularities come out, which if interpreted in view of our hypotheses could possibly indicate the direction of causal links.

Specific forms of KTT activities (model B)

Table 4 contains the results of the probit estimates for the variables for specific KTT activities (INFO; INFR; EDUC; REAS; CONC; model B). In a preliminary step, we investigated the possibility of the existence of a selectivity bias due to the fact that the data for the motive variables were measured only for firms that report KTT activities. Therefore, we estimated a Heckman selection model for all five dependent variable in model B, 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), therefore the existence of a selectivity bias can be excluded. As a consequence, we present here only the probit estimates.

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 focus on educational, research or consulting activities, are stronger oriented towards basic research than KKT-active institutes without such a focus (see columns 3, 4 and 5 in table 4). 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 KKT-active institutes. The level of teaching obligations does not seem to have any effect on the focus of KTT activities (variable TEACH).

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 4. We obtain positive and significant coefficients for the variables MOTIVE1, MOTIVE2 and MOTIV4. MOTIV1 is a combination of the following seven single motives for 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” (see also table A.4 in the appendix). This motive is relevant for the two most important categories of activities, namely educational and research activities. MOTIVE2 is a combination of ten single motives referring to a series of institutional goals such as securing good job prospects for students and staff, promoting regional development and the image of science, extending university's mission, commercial success, promoting the diffusion of key R&D findings amongst the business public, reference for more public funding and so on (see also table A.4 in the appendix). This motive is important for institutes focussing on educational activities or the utilization of business sector technical facilities. Finally, MOTIVE4 is a combination of three single financial motives ("additional resources for basic research", "additional resources for research facilities" and "business funding more flexible than public funding") (see also table A.5 in the appendix). Except for EDUC, MOTIVE4 is positively correlated with all other types of KTT activities. Thus, financial motives in the sense of searching for additional funding are the most important incentives for most types 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 activities did not seem to be impeded by any kind of obstacles.

The number of PHD is negatively correlated with INFO and positively with EDUC; there is no significant effect with respect to the other three types of KTT activities. Institutes focusing on informal contacts with the business sector seem to be less research-intensive than institutes without such a focus. With the exception of this result, for which we could not find an plausible explanation, we obtain a positive or no correlation between the types of KTT activities and research output, as expected.

Firm size showed no effect on the propensity to focus on any type of KTT activities with the exception of INFO. In this case institutes with more than 40 employees seem to be more involved in informal contacts with firms than small institutes.

Institutes of the ETH-domain (ETH) and cantonal universities (UNIV) have a weaker tendency to focus on any type of KTT activities than the universities of applied research or the federal research institutions, which are stronger specialized either in some research fields (e.g. EAWAG), a certain type of technical facilities (e.g. PSI) or consulting (e.g. most of the universities of applied sciences) than the first two groups of institutes.

Finally, institutes of engineering are stronger inclined to informal contacts and educational activities than institutes from other scientific fields. Institutes of natural sciences are significantly more interested in getting involved in activities related to the utilization of technical facilities, but less so with respect to consulting. Otherwise there are no discernible differences among the institutes form different scientific fields with respect to the five categories of KTT activities.

In a last step, we take into consideration the possibility of interdependence among the various specific forms of KTT activities, given that firms are pursuing more than one of them at a time, as already discussed in section 4. We consider here the interdependence of the three most important forms of activities: informal contacts with general informational content (variable INFO), educational activities (variable EDUC) and research co-operation (variable REAS). In order to take account of this interdependency we estimated a trivariate probit model, i.e. a simultaneous system of three equations (for INFO, EDUC and REAS 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 5 contains the estimates for the trivariate probit model.

There is no significant correlation between the equation for INFO and the equations for REAS as well as between the equations for EDUC and REAS. A significant correlation could be found only between the equations for INFO and EDUC (ρ=0.827). Thus, there is also empirical justification for estimating a trivariate probit model. But a comparison with the results for the separate probit estimates in table 4 shows that the results are on the whole similar. The interdependence between EDUC and REAS has only a small influence on the magnitude of the estimated parameters. But there are also some differences. The coefficient of MOTIV4 referring to financial motives for KTT activities is still positive but no more statistical significant in the estimates for INFO and REAS. The same holds also for the coefficient of PHD in the estimate for EDUC.

7.2 Commercialization of Research Output: Patenting, Licensing, Founding of Spin-offs

For patenting as well as for university spin-offs (columns 1 and 3 respectively in table 6) is the research orientation of the institutes practically irrelevant; the variable APPL is in both cases statistically insignificant even at the 10% test level. Rather unexpectedly, the variable TEACH is significantly positive in the estimates for spin-offs. A glance at the data shows that this effect is not a statistical artefact. Universities of applied science where the teaching obligations are high show also a high propensity to spin-offs. In case of licensing we found negative coefficients for both variables. The logical consequence of this finding 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. Further, all three estimates show no significant correlation between PHD as a measure of research output and the three typed of commercialization activities.

MOTIVE1 related to the access of industrial knowledge as well as practical experience and possibilities of application is relevant only for patenting. All three types of activities were hampered by the same category of obstacles, namely 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.

There is a weak positive size effect for spin-offs but no discernible effect for the other two types of commercialization activities. The alternative specification with linear and quadratic term yielded only in the case of spin-offs a positive and statistically significant coefficient of the linear term.

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). The federal research institutions (FRI) are more intensively involved in licensing than any of the other three groups of institutions.

We could not find any differences between engineering and natural sciences vis-à-vis mathematics and physics with respect to all three types of commercialization activities. Economics and management are significantly weaker represented than other disciplines in patenting and licensing, medicine in licensing. Finally, there were no significant differences among the scientific fields with regard to spin-offs.

In a last step, we take also in this case into consideration the possibility of interdependence among the various types of commercialization activities. There are some good reasons why there should exist some correlations between these activities: 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 contains the estimates for the trivariate probit model.

There is no significant correlation between the equation for PATENTING and LICENSING. A significant correlation could be found on the one hand between the equations for PATENTING and SPIN-OFFS (ρ=0.497), on the other hand between the equation of PATENTING and that for SPIN-OFFS (ρ=0.516).[6] Thus, there is also empirical justification

[6] It would be interesting to investigate possible time lags between patenting, licensing and spin-offs, but this is not possible with our data, which refer only to one period (2002-2004).

for estimating a trivariate probit model. But a comparison with the results for the separate probit estimates in table 6 shows that the results are on the whole quite similar. The interdependence between PATENTING and SPIN-OFFS and LICENSING and SPIN-OFFS has only a small influence on the magnitude of the estimated parameters. There are some slight differences with respect to the coefficients of the dummies for the groups of science institutions (the federal research institutions are stronger involved in spin-offs than other institutions) and the dummies for the scientific fields (medicine is not weaker than other disciplines with respect to licensing).

8. Conclusions and Summary

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 which 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 size effect. We could not find any discernible differences among the three groups of science institutions. In accordance to expectations, institutes of economics and business administration, natural sciences, engineering and medicine, ranking as presented, 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 (legitimate) fears of academics of neglecting their main task or reduce the quality of their work when they get involved in KTT activities.

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. KTT-active institutes, which reported a focus on educational, research or consulting activities, are stronger oriented towards basic research than KTT-active institutes without such a focus. The level of teaching obligations does not seem to have any effect on the focus of KTT activities. Financial motives in the sense of searching for additional funding are the most important incentives for most types of KTT activities. There is a positive effect of research output with respect to educational activities and a negative one with respect to informal contacts.

The results with respect to patenting, licensing and the formation of new knowledge-based firms showed considerable differences with respect to the relative importance of the determinants used 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 could diminish the chances for licensing but not for spin-offs. A further important finding was that all three types of activities 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. Research output is not significantly correlated to any of the three types of commercialization. This finding supports the hypothesis that basic research is not compromised by commercialization activities. There is a weak positive effect of institute size with respect to spin-offs.

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Table 1: Incidence of KTT activities of Swiss science institutions (percentage of institutes or departments)

Institutions	N	KTT (*)	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 (**)	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
Northwestern 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

(*): KTT: knowledge and technology transfer in the period 2002-2004 and/or before 2002;
(**): PSI, EAWAG, EMPA, WSL.

Table 2: Forms of KTT activities of Swiss science institutions by type of of science institutions (percentage of institutes with values 4 or 5 for any of the single forms or a category of forms; N=202)

Forms of KTT activities	
Informal contacts, personal network of contacts (variable INFO)	*78.7*
Informal contacts (phone, email)	67.3
Conferences, exhibitions, workshops	35.6
Academic publications of business sector	26.2
Technical facilities (variable INFR)	*17.4*
Joint laboratories	9.0
Technical facilities or research centres at business sector R&D department	12.4
Training, further education, staff mobility (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 (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

(*): PSI, EAWAG, EMPA, WSL.

Table 3: Determinants of KTT activities of institutes of science institutions with enterprises

Explanatory variables	KTT(1) (probit)	KTT(1) (probit)
APPL(2)	0.052**	0.160**
	(0.025)	(0.076)
TEACH(3)	-0.027***	-0.015
	(0.009)	(0.010)
FINANCE(4)	0.010*	0.005
	(0.005)	(0.006)
OBSTACLE4(5)	-0.431***	-0.436**
	(0.152)	(0.197)
PHD(6)	0.052**	//
	(0.025)	
PUBL(7)	//	0.002
		(0.002)
Institute size:		
10 to 19 employees	-0.230	-0.799
	(0.468)	(0.528)
20 to 39 employees	-0.100	-0.303
	(0.516)	(0.573)
40 to 99 employees	0.536	0.631
	(0.530)	(0.609)
100 employees and more	0.689	0.860
	(0.582)	(0.673)
ETH(8)	0.112	1.469*
	(0.634)	(0.777)
UNIV(9)	-0.351	1.127
	(0.671)	(0.922)
FRI(10)	-1.563	-0.068
	(1.030)	(1.233)
ENGINEERING(11)	1.600***	2.257***
	(0.554)	(0.731)
NATURAL SCIENCES(11)	1.887***	1.918***
	(0.529)	(0.514)
ECONOMICS, MANAGEMENT(11)	2.265***	2.536***
	(0.638)	(0.620)
MEDICINE(11)	1.106**	0.960*
	(0.558)	(0.554)
Const.	-0.288	-1.472
	(0.924)	(1.068)
N	196	179
Pseudo R^2	0.373	0.407
Wald χ^2	50***	47***

Note: (1): KTT: knowledge and technology transfer activities in the period 2002-2004 and/or in the period before 2002; (2): APPL: ratio of percentage of an institutes total working time of academic staff devoted to *applied research* to that devoted to *basic research*; (3): TEACH: percentage of an institutes total working time of academic staff devoted to *teaching*; there is also a fourth category of activities, namely 'other tasks'; (4):

FINANCE: share of third-party funds from business sector in an institute's budget; (5): 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); (6): PHD: number of PhDs in the period 2002-2004; (7): PUBL: number of publications in scientific journals in the period 2002-2004; (8): ETH: dummy variable for affiliation to one of the two Federal Institutes of Technology in Zurich and Lausanne respectively; (9): UNIV: dummy variable for affiliation to a University ; (10): FRI: dummy variable for affiliation to a Federal Research Institution (e.g. PSI, EAWAG, etc.); reference group: Universities of Applied Sciences; (11): 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).

Table 4: Determinants of specific forms of KTT activities of institutes of science institutions with enterprises (INFO; INFR; DUC; REAS; CONS); probit estimates

Explanatory variables	INFO(1) (probit)	INFR(2) (probit)	EDUC(3) (probit)	REAS(4) (probit)	CONS(5) (probit)
APPL(6)	-0.009	0.001	-0.016**	-0.015**	-0.011*
	(0.006)	(0.006)	(0.008)	(0.007)	(0.006)
TEACH(7)	0.009	-0.004	0.015	-0.008	0.010
	(0.009)	(0.008)	(0.010)	(0.007)	(0.006)
MOTIVE1(8)	//	//	0.803***	0.398***	//
			(0.167)	(0.120)	
MOTIVE2(9)	//	0.322**	0.713***	//	//
		(0.144)	(0.198)		
MOTIVE4(10)	0.320**	0.529***	//	0.262*	0.264**
	(0.159)	(0.154)		(0.138)	(0.123)
OBSTACLE3(11)	-0.293***	//	//	//	//
	(0.140)				
PHD(12)	-0.009***	-0.005	0.025*	0.009	0.004
	(0.003)	(0.005)	(0.014)	(0.009)	(0.005)
Institute size:					
Up to 9 employees	-0.669*	-0.578	-0.384	0.460	-0.257
	(0.401)	(0.428)	(0.456)	(0.375)	(0.331)
10 to 19 employees	-0.749**	-0.346	-0.127	0.080	0.328
	(0.332)	(0.303)	(0.374)	(0.289)	(0.264)
20 to 39 employees	-0.398	-0.148	-0.865**	0.321	-0.120
	(0.397)	(0.350)	(0.420)	(0.350)	(0.287)
ETH(13)	-1.358***	-0.575	-1.871***	-0.965**	-0.873**
	(0.428)	(0.462)	(0.572)	(0.471)	(0.364)
UNIV(14)	-0.751*	0.340	-0.649	-1.194**	-0.664*
	(0.387)	(0.537)	(0.499)	(0.511)	(0.374)
ENGINEERING(15)	0.777**	0.727	1.409***	-0.047	-0.049
	(0.332)	(0.469)	(0.421)	(0.314)	(0.285)
NATURAL SCIENCES(15)	0.046	0.921***	-0.610	-0.007	-0.697**
	(0.372)	(0.352)	(0.393)	(0.416)	(0.324)
Const.	1.790***	-1.296*	1.847***	1.865***	0.454
	(0.498)	(0.661)	(0.600)	(0.585)	(0.456)
N	170	180	180	180	180
Pseudo R^2	0.177	0.208	0.420	0.148	0.090
Wald χ^2	23**	29***	46***	26***	22**

Note: (1): 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; (2): INFR: similar construction as INFO based on the variables for two single forms of KTT referring to technical facilities; (3): EDUC: based on 9 single variables referring to education and training activities; (4): REAS: based on 3 single variables referring to research activities; (5): CONS: based on 2 single variables referring to consulting activities; see table 2 for details; (6): APPL: ratio of percentage of an institutes total working time of academic staff devoted to *applied research* to that devoted to *basic research*; (7): TEACH: percentage of an institutes total working time of academic staff devoted to *teaching*; there is also a fourth category of activities, namely 'other tasks'; (8): 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); (9): 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); (10): MOTIVE2: combination of ten single motives referring to institutional and/or organizational motives (see table A.4 in the appendix for details); (11): MOTIVE4: combination of three single motives referring to pursuing more research efficiency (see table A.4 in the appendix for details); (12): PHD: number of PhDs in the period 2002-2004; (13): ETH: dummy variable for affiliation to one of the two Federal Institutes of Technology in Zurich and Lausanne respectively; (14): UNIV: dummy variable for affiliation to a University ; reference group: Universities of Applied Sciences and Federal Research Institution (e.g. PSI, EAWAG, etc.); (15): ENGINEERING; NATURAL SCIENCES: dummies for an institute's scientific field; reference group: mathematics/ physics; economics/management; medicine; ***, **, * denote statistical significance at the 1%, 5% and 10% test level, respectively; heteroscedasticity- robust standard errors (White procedure).

Table 5: Determinants of specific forms of KTT Activities of institutes of science institutions with enterprises (INFO; EDUC; REAS); trivariate probit estimates

Explanatory variables	INFO[1] (1)	EDUC[2] (2)	REAS[3] (3)
APPL[4]	-0.010*	-0.025***	-0.014*
	(0.006)	(0.007)	(0.008)
TEACH[5]	0.009	0.015	-0.010
	(0.015)	(0.011)	(0.009)
MOTIV1[6]	//	0.886***	0.332**
		(0.202)	(0.136)
MOTIV2[7]	//	1.156***	//
		(0.259)	
MOTIV4[8]	0.314	//	0.242
	(0.261)		(0.162)
OBSTACLE3[9]	-0.331*	//	//
	(0.191)		
PHD[10]	-0.009***	0.037	0.007
	(0.004)	(0.024)	(0.008)
Institute size:			
Up to 9 employees	-0.837	-0.427	0.482
	(0.676)	(0.477)	(0.390)
10 to 19 employees	-0.789*	-0.420	-0.044
	(0.480)	(0.396)	(0.310)
20 to 39 employees	-0.449	-1.237**	0.344
	(0.501)	(0.497)	(0.372)
ETH[11]	-1.382***	-1.832***	-0.836*
	(0.532)	(0.713)	(0.509)
UNIV[12]	-0.698*	-0.673	-1.249**
	(0.410)	(0.572)	(0.561)
ENGINEERING[13]	0.782**	1.685***	-0.068
	(0.347)	(0.452)	(0.325)
NATURAL SCIENCES[13]	-0.022	-0.751*	0.167
	(0.490)	(0.459)	(0.492)
Const.	1.872***	2.281***	1.848***
	(0.616)	(0.698)	(0.627)
N	172		
Wald χ^2	121***		
ρ (eq. 1, eq. 2)	0.827**		
ρ (eq. 1, eq. 3)	0.180		
ρ (eq. 2, eq. 3)	-0.065		

Note: (1): 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; (2): EDUC: based on 9 single variables referring to education and training activities; (3): REAS: based on 3 single variables referring to research activities; (4): APPL: ratio of percentage of an institutes total working time of academic staff devoted to *applied research* to that devoted to *basic research*; (5): TEACH: percentage of an institutes total working time of academic staff devoted to *teaching*; there is also a fourth category of activities, namely ‘other tasks’; (6): 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); (7): 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); (8): MOTIVE2: combination of ten single motives referring to institutional and/or organizational motives (see table A.4 in the appendix for details); (9): MOTIVE4: combination of three single motives referring to pursuing more research efficiency (see table A.4 in the appendix for details); (10): PHD: number of PhDs in the period 2002-2004; (11): ETH: dummy variable for affiliation to one of the two Federal Institutes of Technology in Zurich and Lausanne respectively; (12): UNIV: dummy variable for affiliation to a University ; reference group: Universities of Applied Sciences and Federal Research Institution (e.g. PSI, EAWAG, etc.); (13): ENGINEERING; NATURAL SCIENCES: dummies for an institute’s scientific field; reference group: mathematics/physics; economics/management; medicine; ***, **, * denote statistical significance at the 1%, 5% and 10% test level, respectively; heteroscedasticity- robust standard errors (White procedure).

Table 6: Determinants of patenting; licensing; founding spin-offs; probit estimates

Explanatory variables	PATENTING(1) (probit)	LICENSING(2) (probit)	SPIN-OFFS(3) (probit)
APPL(4)	-0.007	-0.016**	0.001
	(0.006)	(0.007)	(0.007)
TEACH(5)	-0.005	-0.014***	0.016**
	(0.007)	(0.006)	(0.007)
OBSTACLE3(6)	-0.294**	-0.331*	-0.356**
	(0.144)	(0.178)	(0.154)
MOTIV1(7)	0.242*	//	//
	(0.126)		
PHD(8)	-0.001	0.001	-0.002
	(0.005)	(0.006)	(0.005)
Institute size:			
10 to 19 employees	-0.283	-0.169	0.068
	(0.380)	(0.374)	(0.402)
20 to 39 employees	0.347	-0.817*	0.407
	(0.426)	(0.467)	(0.482)
40 to 99 employees	0.414	0.004	0.998***
	(0.423)	(0.353)	(0.450)
100 employees and more	1.008***	//	1.799***
	(0.486)		(0.515)
ETH(9)	0.134	0.091	0.349
	(0.414)	(0.454)	(0.428)
UNIV(10)	0.211	0.328	-0.272
	(0.489)	(0.527)	(0.454)
FRI(11)	-0.487	1.769***	1.146
	(0.600)	(0.755)	(0.792)
ENGINEERING(12)	0.765	-0.425	0.116
	(0.549)	(0.537)	(0.527)
NATURAL SCIENCES(12)	0.461	-0.859	-0.353
	(0.564)	(0.578)	(0.552)
ECONOMICS, MANAGEMENT(12)	-1.746***	-1.421**	0.372
	(0.664)	(0.567)	(0.537)
MEDICINE(12)	-0.170	-1.206**	-0.435
	(0.574)	(0.539)	(0.543)
Const.	-0.519	0.059	-1.870**
	(0.724)	(0.706)	(0.776)
N	170	170	170
Pseudo R^2	0.294	0.218	0.215
Wald χ^2	56***	37***	42***

Note: (1): application of patents yes/no 2002-2004; (2): licenses yes/no 2002-2004; (3): spin-offs/start-ups yes/no 2002-2004; (4): APPL: ratio of percentage of an institutes total working time of academic staff devoted to *applied research* to that devoted to *basic research*; (5): TEACH: percentage of an institutes total working time of academic staff devoted to *teaching*; there is also a fourth category of activities, namely 'other tasks'; (6): 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); (7): 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); (8): PHD: number of PhDs in the period 2002-2004; (9): ETH: dummy variable for affiliation to one of the two Federal Institutes of Technology in Zurich and Lausanne respectively; (10): UNIV: dummy variable for affiliation to a University ; (11): FRI: dummy variable for affiliation to a Federal Research Institution (e.g. PSI, EAWAG, etc.); reference group: Universities of Applied Sciences; (12): 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).

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

Explanatory variables	PATENTING(1) (1)	LICENSING(2) (2)	SPIN-OFFS(3) (3)
APPL(4)	-0.005	-0.018***	0.005
	(0.007)	(0.006)	(0.007)
TEACH(5)	-0.005	-0.017***	0.018**
	(0.007)	(0.006)	(0.008)
OBSTACLE3(6)	-0.307**	-0.333*	-0.364**
	(0.147)	(0.188)	(0.159)
MOTIV1(7)	0.304**	//	//
	(0.149)		
PHD(8)	-0.002	0.003	-0.004
	(0.007)	(0.006)	(0.006)
Institute size:			
10 to 19 employees	-0.362	-0.079	-0.150
	(0.368)	(0.341)	(0.399)
20 to 39 employees	0.170	-0.643	0.345
	(0.459)	(0.504)	(0.470)
40 to 99 employees	0.275	0.105	0.988***
	(0.451)	(0.368)	(0.445)
100 employees and more	0.756	//	1.609***
	(0.615)		(0.510)
ETH(9)	0.285	-0.130	0.582
	(0.489)	(0.385)	(0.458)
UNIV(10)	0.293	-0.038	-0.029
	(0.543)	(0.439)	(0.452)
FRI(11)	-0.541	1.163***	2.109***
	(0.665)	(0.585)	(0.809)
ENGINEERING(12)	0.333	-0.214	0.754
	(1.555)	(0.642)	(1.046)
NATURAL SCIENCES(12)	0.046	-0.476	-0.033
	(1.297)	(0.611)	(0.987)
ECONOMICS, MANAGEMENT(12)	-2.135*	-1.108*	0.872
	(1.280)	(0.641)	(0.905)
MEDICINE(12)	-0.505	-0.757	0.063
	(1.066)	(0.577)	(0.781)
Const.	-0.101	0.021	-2.568**
	(1.505)	(0.733)	(0.973)
N	170		
Wald χ^2	172***		
ρ (eq. 1, eq. 2)	0.497*		
ρ (eq. 1, eq. 3)	0.516		
ρ (eq. 2, eq. 3)	0.557***		

Note: (1): application of patents yes/no 2002-2004; (2): licenses yes/no 2002-2004; (3): spin-offs/start-ups yes/no 2002-2004; (4): APPL: ratio of percentage of an institutes total working time of academic staff devoted to *applied research* to that devoted to *basic research*; (5): TEACH: percentage of an institutes total working time of academic staff devoted to *teaching*; there is also a fourth category of activities, namely 'other tasks'; (6): 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); (7): 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); (8): PHD: number of PhDs in the period 2002-2004; (9): ETH: dummy variable for affiliation to one of the two Federal Institutes of Technology in Zurich and Lausanne respectively; (10): UNIV: dummy variable for affiliation to a University ; (11): FRI: dummy variable for affiliation to a Federal Research Institution (e.g. PSI, EAWAG, etc.); reference group: Universities of Applied Sciences; (12): 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).

APPENDIX:

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

Institutions	*Net Sample* Number of Institutes or Departments	*Response* Number of Institutes or Departments	*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 (*)	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

(*): PSI, EAWAG, EMPA, WSL.

Table A.2: Institute size

Number of employees (*)	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

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

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 commercialisation 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”.