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Arbeitspapiere/ Working Papers

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Determinants of Knowledge
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Determinants of Knowledge and Technology Transfer Activities between Firms and Science Institutions in Switzerland: An Analysis Based on Firm Data*

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Abstract

This study explores the factors determining the propensity of Swiss firms to interact with public science institutions in Switzerland (universities and other research institution), i.e. to get involved in knowledge and technology transfer (KTT) activities in order to gain new tacit and/or codified scientific knowledge in research fields which are relevant for their own innovation activities. We are especially interested in the different forms of this interaction, not only through joint research projects but also through training, recruitment of qualified R&D personnel, jointly supervised master theses and PhDs, consulting and so on. The data used in this study were collected in the course of a survey among Swiss enterprises.

The new elements that this paper adds to empirical literature are, first, the analysis 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 (transfer of “tacit” knowledge), 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, a further important 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 firms’ propensity to overall KTT activities as well as to several forms of KTT activities. Third, some insights are gained with respect to the differences between manufacturing and service firms in transacting with science institutions. This is the first Swiss firm-level study on this matter.

1. Introduction and Review of Empirical Literature

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).

Experiences of the USA suggest that research excellence of 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 in Switzerland.

This study explores the factors determining the propensity of Swiss firms to interact with public science institutions in Switzerland (universities and other research institution), i.e. to get involved in knowledge and technology transfer (KTT) activities in order to gain new both tacit and codified scientific knowledge in research fields which are relevant for their own innovation activities. We are especially interested in the different forms of this interaction, not only through joint research projects but also through training, recruitment of qualified R&D 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 Swiss enterprises using a questionnaire.

The new elements that this paper adds to empirical literature are, first, the analysis 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 (transfer of “tacit” knowledge), joint use of technical infrastructure and consulting. Although such

¹ *Economics*: see e.g. volume 34, issue 3 of *Research Policy* of April 2005 (edited by A.N. Link and D.S. Siegel) dedicated to “University-based Technology Initiatives”; “Academic Science and Entrepreneurship” (edited by A. Jaff, J. Lerner, S. Stern and M. Thursby), forthcoming in the *Journal of Economic Behaviour and Organization*; volume 28, issue 3-4 of the *Journal of Technology Transfer* of August 2003 devoted to the “Symposium on the State of the Science and Practice of Technology Transfer”. *Policy*: see e.g. OECD (2003), OECD (2002) and OECD (1999).

additional activities seem to be an important part of KTT activities, they have been neglected in most studies. Second, a further important 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 firms' propensity to overall KTT activities as well as to several forms of KTT activities. Third, some insights are gained with respect to the differences between manufacturing and service firms in transacting with science institutions. This is the first Swiss firm-level study on this matter.²

Comprehensive empirical investigations on the determinants of KTT and on different forms of KTT activities are still relatively rare. Especially international comparisons on an econometric level (same model, same method for different countries) are lacking to a great extent. The study of Fritsch (2002) is one such exception. This study compares R&D co-operation behaviour in eleven European regions including co-operations between universities and firms. The most important common feature among these different regions is the positive effect of firm size (number of employees) and R&D intensity (share of R&D employees) on the decision to co-operate in R&D. In the following paragraph 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 – mostly joint R&D projects) and try to detect some regularities.

Schartinger et al. (2001) investigated four forms of KTT in Austria (joint research projects, contract research, joint supervision of PhDs and Master Theses and mobility of university researchers into firms) focusing on innovative firms and university departments. They found based on data for 99 firms that older firms tend to have no KTT activities, while larger firms are more likely to have such activities. This is rather surprising since usually size and age are positively correlated and very often point at the same direction. Further, they considered firms' assessments on two motivations for and two barriers to KTT activities respectively. They reported that direct support in development process but not the utilization of basic research is a relevant motive for KTT activities. Finally, both lack of information on university research and cultural differences between universities and firms are significant obstacles of KTT activities.

Mohnen and Hoareau (2004) used pooled CIS-2 data for France, Germany, Ireland and Spain to investigate the factors that allow firms to benefit from knowledge developed in universities and government labs or that drive them to collaborate with these institutions. They found that the probability to co-operate with research institutions (conditional on innovating and co-operating in R&D with other firms) is positively correlated with firm size, government

² 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. The study of Lenz (1998) dealt mainly with horizontal innovation co-operation between firms.

support for a firm's innovation activities, with having patents applied for (but not with R&D intensity) and the firm being affiliated to science-oriented sectors.

Based on a survey of 2400 manufacturing firms in the United Kingdom Laursen and Salter (2004) investigated what type of firms use universities as a source of innovation. They found in accordance with other empirical studies that R&D intensity, long-term R&D and firm size show a positive impact on KTT activities. In contrast to the Austrian study they did not find an effect of firm age. A further important result of this study was that firms that choose "open" information search strategies are more likely to draw from universities in their innovative activities; "openness" was measured by the intensity of use of several sources of information reported by the firms.

Fontana et al. (2004) investigated the determinants of the propensity to as well as the extent of R&D collaboration between Public Research Organizations and firms in seven European countries in 2000. The econometric estimations produced some evidence that firm size and a firm's openness to the external environment as measured by the use of external channels of information have a significant effect on both the propensity and the extent of university-industry collaboration.

Schmidt (2005) investigated for Germany knowledge flows and emphasised the characteristics of spillovers in order to explain R&D co-operation from a firms' perspective. The study was based on CIS-3 data for about 1000 firms. Firms showed a higher probability to be engaged in any type of R&D co-operation if incoming spillovers measured by firms' evaluation on the importance of external information sources were high. Also outgoing spillovers (or rather their prevention through appropriability mechanisms) were found to correlate positively in case of formal protection methods like patents and negatively in case of strategic protection methods like secrecy respectively. In accordance to other studies the author also finds positive effects with respect to firm size and R&D intensity. Finally, risk obstacles exert a negative influence on a firm's propensity to co-operate with research institutions.

Veugelers and Cassiman (2005) analysed which firm characteristics are decisive for co-operating in R&D with universities. They applied an approach which takes into account several alternative innovations strategies. Based on CIS-1 data for 325 Belgian firms they found that R&D co-operations with universities are complementary to other innovation activities of a firm (e.g. in-house R&D activities, co-operating with other (corporate) partners). Large firms and firms in the chemical sector are more likely to get involved in R&D co-operations with universities. Furthermore, co-operation agreements become relevant when innovation costs are a severe innovation obstacle, but not innovation risks. Appropriability strategies do not seem to be important for R&D co-operation with universities.

In a further study with Belgian CIS-2 data for about 1200 firms Cincera and Capron (2004) found that the propensity to co-operate in R&D with universities depends positively on firm

size, public support of a firm's innovation activities, the propensity to patent innovations (but not the R&D intensity), and firm orientation to certain innovation goals.

The structure of the paper is as follows: Section 2 describes the conceptual framework and postulates a series of determinants of KTT activities. In section 3 we present our data and in section 4 some interesting descriptive results. In section 5 we specify our econometric model and describe the construction of the variables. Section 6 is dealing with the empirical results. Finally, section 7 contains some conclusions and a summary.

2. Conceptual Framework

Economic Theory Background

Our analysis is guided by the “stylized” model from Bozeman (2000). In this model the knowledge and technology transfer (KTT) between transfer agent and transfer recipient covers a wide spectrum of joint activities including research and education and is influenced by environmental conditions and perceived obstacles. For an analysis at firm level we envisage KTT activities as a result of firms' decision a) to get involved in KTT activities with science institutions and b) given this basic decision, to choose a specific form of KTT activities.

What do we know about the factors that determine this kind of firm decisions? Most of the existing *Industrial Organization* literature on this subject focuses on the determinants of R&D co-operation *between firms that are direct competitors*. Further transfer activities, e.g. those related to human capital, are not considered. Theoretical literature deals primarily to the effect of imperfect appropriability of results of innovation activities on the incentives to innovate, when firms co-operate in R&D (see e.g. Spence 1984; D'Aspremont and Jacquemin 1988). There is a twofold incentives problem. On the one hand, the existence of imperfect appropriability (above a critical level of the underlying knowledge spillovers) increases the incentives to co-operate, because of the profits resulting from internalizing the external losses caused by imperfect appropriability (see e.g. De Bondt 1997). On the other hand, imperfect appropriability also increases the incentives to utilize spillovers resulting from the R&D investment of a co-operating partner and encourages free-riding on the R&D efforts of the co-operating firms by outsiders (see e.g. Shapiro and Willig 1990; Greenlee and Cassiman 1999).

However, when firms are not direct competitors (e.g. suppliers of complementary goods), or when one partner is a science institution imperfect appropriability of the benefits of generated knowledge is not an important issue for firm-science institution co-operation. The notion of “absorptive capacity” introduced by Cohen and Levinthal (1989) emphasizes the importance of a firm's own R&D efforts for developing the ability to absorb and utilize external knowledge. High absorptive capacity is thus a precondition for co-operations between firms and science institutions.

Veugelers and Cassiman (2005) mention a series of further factors which possibly influence industry-science co-operation and are related with the specific nature of the know-how being transacted in such co-operations. First, due to the specific characteristics of scientific knowledge a specific profile of firms can be expected to pursue such co-operations. Science institutions offer new technological knowledge which is mainly needed in innovation activities characterized by high technological uncertainty and at the beginning low demand for the innovation outcomes. As a consequence, only firms within specific industries using specific technologies (e.g. biotechnology or nanotechnology) will have a strong interest in co-operations with science institutions. This is a strong but too narrow-focussed hypothesis which cannot cover the wide spectrum of effective KTT activities. Second, “R&D co-operation between universities and industry is characterized by high uncertainty, high information asymmetries between partners, high transaction costs for knowledge exchanges requiring the presence of absorptive capacity, and high spillovers to other market actors” (Veugelers and Cassiman 2005, p. 359).

Based on the above notions from IO literature and the experiences of previous empirical studies we postulate in the next paragraphs a series of possible determinants of KTT activities which will be taken into consideration in the model specification presented in section 5.

Determinants of KTT Activities

A first group of determinants are related to the resource endowment of the enterprises with human capital, physical capital and knowledge capital. It is expected that particularly firms with high human capital and knowledge capital intensity leading to a high knowledge absorptive capacity would possess the profile needed for KTT activities with science institutions. Physical capital intensity would be a complementary measure for absorptive capacity especially for manufacturing firms. Such firms would be most frequently found in high-tech manufacturing (e.g. pharmaceutical industry, electronics) and in knowledge-based service industries (e.g. software industry). Thus, a firm’s industry affiliation would be important for the propensity to KTT activities. Further, in case of regional focussed industrial clusters and/or regional concentration of science institutions a firm’s geographical location could be a relevant determinant of its propensity to KTT activities.

Further firm characteristics which we expect to be related to KTT activities are the degree of exposition to international competition (positively; higher know-how requirements for international oriented firms), firm size (positively; possible existence of scale effects with respect to the utilization of scientific knowledge), firm age (positively; older firms possess a longer experience in co-operations); status as a subsidiary of a foreign mother-company (a priori not clear effect).

Given its technological profile a firm intending to get involved in KTT activities would have to consider the benefits and costs of this involvement. Possible benefits should not be restricted to the outcomes of joint R&D projects but also cover e.g. knowledge gains through

the recruitment of qualified R&D personnel, specific training courses, joint doctoral dissertations etc., financial benefits through time-saving in R&D and reduction of technological risks, and other not directly economic benefits like image improvement, indirect access to competitors' know-how and so on. Possible costs would include high transaction costs due to deficiencies on the interface between firm and science institution either on the side of the firm or the science institution, high information asymmetries, high financial risks due to the uncertainty of research outcomes, property rights problems and costs of possibly arising technological dependence from science partner.

3. Data

The data used in this study were collected in the course of a survey among Swiss enterprises using a questionnaire which included questions on the incidence of KTT activities among firms, forms, channels, motives and impediments of the KTT activities of Swiss firms as well on some basic firm characteristics (innovation and R&D activities, investment, sales, exports, employment and employees' vocational education).³ The survey was based on a (with respect to firm size) disproportionately stratified random sample of firms with at least 5 employees covering all relevant industries of the manufacturing sector, the construction sector and selected service industries (excluding industries with an expected very low propensity of KTT activities such hotels/catering, retail trade, real estate/leasing, personal services) as well as firm size classes (on the whole 25 industries and within each industry three industry-specific firm size classes with full coverage of the upper class of large firms). Answers were received from 2582 firms, i.e. 45.4% of the firms in the underlying sample. The response rates do not vary much across industries and size classes with a few exceptions (over-representation of wood processing, energy industry and machinery, under-representation of clothing/leather industry; see table A.1 in the appendix for the structure of the used data set by industry and firm size class). The non-response analysis (based on a follow-up survey of a sample of the non-respondents) did not indicate any serious selectivity bias with respect to the incidence of KTT activities with science institutions. A careful examination of the data of these 2582 firms led to the exclusion of 154 cases with contradictory or non-plausible answers; there remained 2428 valid answers which were used for this analysis.

Further, we used the multiple imputations technique by Rubin (1987) to substitute for missing values in the variables due to item non-response (see Donzé 2001 for a detailed report on the procedure used). The estimations were based on the mean of five imputed values for every missing value of a certain variable.

Finally, the data presented in the descriptive part of the paper in section 4 were weighted according to the weighting procedure described in Donzé (2002); this procedure takes into

³ Versions of the questionnaire in German, French and Italian are available in www.kof.ethz.ch.

consideration all available information on possible deviations of the structural composition of the responses from sample stratification and from the structure of the underlying population, further on information on possible selection bias gained through a non-response analysis of a sample of 287 non-responding firms.

4. Knowledge and Technology Transfer Activities between Firms and Science Institutions in Switzerland: Some Facts

Incidence of KTT Activities

According to the results presented in table 1 27.6% of all firms were involved in KTT activities with science institutions (see column 2). This figure is somewhat lower for small firms (25.1%) and grows up to 47.1% for large firms. Firms in high-tech manufacturing and in the knowledge-based services showed the highest incidence of KTT activities. Especially firms in the chemical industry, in electronics/instruments and in business services were most often engaged in KTT. 8.6% of all firms were involved in KTT activities with foreign universities and/or other research institutions (column 3 in table 1).

The KTT-active firms were asked to evaluate the importance of 19 different single forms of KTT activities on a five-point Likert scale ranging from 1 (“not important”) to 5 (“very important”). These 19 single forms were classified in five categories: informal informational activities, educational activities, activities related to technical infrastructure, research activities and consulting (see table 2). “Tacit” forms of KTT were more important than “codified” ones. More than 50% of KTT-active firms in Switzerland found (a) informal, personal contacts which aim at gaining some general information on technological opportunities and/or (b) a wide spectrum of education activities as the most important forms of KTT activities (see row 1 and 8 in table 2). Between 12% and 18% had a focus to research, infrastructure and consulting activities (see row 5, 18 and 22 in table 2).

At a more detailed level, firms reported “reading of and referring to publications” (33.1% of KTT-active firms), “attending conferences and workshops” (30.4%) and “informal contacts” (30.4%) as the most important single KTT activities (see table 2). Other important activities were “attending university training courses by firm employees” (22.1%), and “employing graduates in R&D” (18.4%). Among educational activities writing diploma theses on a subject of special interest for a firm was also of a certain importance (15.7%). Finally, co-operation in R&D was very important for 16.3% of KTT-active firms.

In fact, KTT-active firms combined different forms of KTT. High-tech firms as well as firms in the knowledge-based services and in construction most frequently combined two main groups of forms, namely informal informational and educational activities.

Goals of / Motives for KTT Activities

The KTT-active firms were asked to evaluate the importance of 20 different single motives of and objectives for KTT activities on a five-point Likert scale ranging from 1 (“not important”) to 5 (“very important”). The 20 different motives were pooled into 4 main groups of motives, i.e. “access to human capital (“tacit” knowledge)” (containing the information for 3 single motives; see table 3), “access to research results (“codified” knowledge)” (7 single motives), “financial motives” (5 single motives) and “institutional/organizational motives” (5 single motives). We used the share of firms reporting 4 or 5 on the Likert scale for any of the single motives in a certain group of motives to characterize the overall importance of this group of motives.

“Access to human capital (“tacit” knowledge)” through the access to specific skills, the utilization of the possibilities for further education and training offered by the scientific institutions as well as the recruitment of university graduates was by far the most important main group of motivation for KTT activities: 65.9% of KTT-active firms reported a high importance of this motive. This ranking in importance was valid independent of firm size and the affiliation to a specific sub-sector or sector. Financial motives (41.1%) and access to research results (29.3%) were next in importance, followed by institutional/organisational motives (25.0%). Access to “codified” knowledge is especially relevant for manufacturing for the development of new products (rather “development-oriented”) and for firms of the knowledge-based service industries for gaining new research ideas and the access to basic research (rather “research-oriented”). Financial motives, particularly the financial and technological necessity to co-operate with science institutions, time-saving in R&D as well as insufficient firm R&D resources are particularly important for manufacturing firms. Finally, institutional and/or organizational factors (e.g. R&D co-operation with science institutions as condition for public funding) do not seem to build an important motive behind KTT activities.

Focusing on the four most frequently reported single motives (for more than 20% of all KTT-active firms), we can see that the motive “access to abilities in addition to internal know-how” was the most important individual motive for KTT (46.3% of all KTT-active firms). The single motives “further education and training possibilities” (29.5%), “project characteristics require co-operation with science institutions” (25.6%) and “insufficient firm R&D resources” (21.7%) are next in importance. All other single motives are relevant for less than 20% of all KTT-active firms.

In sum, firms seemed to pursue a series of motives at the same time. However, access to tacit knowledge seemed to be their most preferred motive.

Obstacles of KTT Activities

All firms were asked to evaluate the importance of 26 different possible single obstacles of KTT activities on a five-point Likert scale ranging from 1 (“not important”) to 5 (“very

important”). The 26 different obstacles were pooled into 5 main groups of obstacles, i.e. “lack of information” (containing the information for 3 single obstacles; see table 4), “firm deficiencies” (4 single obstacles), “deficiencies of the science institutions” (4 single obstacles), “costs, risks, uncertainty” (7 single obstacles) and “institutional/ organizational obstacles” (8 single obstacles). We use the share of firms reporting 4 or 5 on the Likert scale for any of the single motives in a certain group of motives to characterize the overall importance of this group of motives.

“Firm deficiencies” are most frequently perceived as a category of severe impediments of KTT activities with science institutions (49.2% of all firms; 53% of firms that were not involved in KTT activities, but only 36.1% of the KTT-active ones; see table 5). “Firm’s questions being not interesting for science institutions” (25.0% of all firms) and “lack of interest for scientific projects” (35.9%) are the most frequently reported single obstacles of importance in this category. The obstacle categories “cost, risks, uncertainty” (42.4% of all firms) and “deficiencies of the science institutions” (42.0%) are somewhat less important than “firm deficiencies”. The differences between KTT-active and non-active firms is in this case not significant. The largest single obstacle in the category “cost, risks, uncertainty” is “lack of firm financial resources for transfer activities” (27.4% of all firms). “R&D orientation of science institutions not interesting for firms” (25.6%) and “possible R&D outcome cannot be commercialized” (25.3%) are the two most frequently reported single obstacles of relevance in the category “deficiencies of the science institutions”. At least important for the firms are the categories “lack of information (24.1% of all firms) and “institutional/organizational obstacles (24.5%). Both obstacle categories are assessed considerably more severe by the KTT-active firms than the non-active ones. No single obstacle in these two categories is perceived as a severe impediment by more than 20% of all firms.

The ranking of importance of the five main categories of obstacles resulting for all firms is valid also for all sectors and firm sizes with the exemption of high-tech manufacturing in which “costs, risks, uncertainty” is the most important obstacle category.

In sum, the most important obstacles of KTT activities could be localized on the interface between firms and science institutions. Many firms, especially those without KTT activities, thought that their R&D questions would not find any interest among academicians, while on the other hand many firms, however less than in the former case, had the impression that the research interests of science institutions do not correspond to their presumably more application-oriented interests.

5. Model Specification and Variable Construction

Dependent Variables

We specified three 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. Second, we specified model B for the determinants of five specific forms of KTT activities. The five different dependent variables for model B were also binary variables and were constructed in the same way as follows: variable INFO: 3 variables for single forms of KTT referring to informal contacts, attendance of conferences, workshops of science institutions 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 firms which reported a value 4 or 5 for any of the three original variables, value 0 to those firms 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; 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 specified model C for an alternative estimation of the relative importance of the determinants for various specific forms of KTT activities. To this end, we constructed a 3-level nominal variables: level 1: firms with any value for the variables INFO, INFR, CONS, and the value 0 for the variables EDUC and REAS (group 1; 220 firms); 2: firms with any value for the variables INFO, INFR, CONS, the value 1 for the variable EDUC and the variable 0 for the variable REAS (group 2; 297 firms); 3: firms with any value for the variables INFO, INFR, CONS and the value 1 for the variables EDUC and REAS (group 3; 154 firms).

Independent Variables

Most of the independent variables to be discussed below were included in all three 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 all three models.

A first group of variables related to the resource endowment of the firm contains the following three single variables: a measure of human capital intensity LQUAL (logarithm of the share of employees with tertiary-level vocational education 2004 (universities, universities of applied sciences, other business and technical schools at tertiary level)); a measure of physical capital intensity LCI (logarithm of gross investment per employee 2004); a measure of knowledge capital RD (binary variable: existence of R&D activities in the period 2002-2004) for model A or RDI (ordinal variable for R&D intensity: 0: no R&D; 1: occasional R&D; 2: permanent R&D) for model B and C. Particularly the variables QUAL, RD (model A) and RDI (model B, C) respectively should be considered as proxies at least some aspects

of a firm's capacity to absorb new technological knowledge and utilize it in its own innovation activities. Thus, we consider a high human capital intensity and the existence of in-house R&D activities as important preconditions for KTT activities. Consequently, we expect a positive effect for each of these variables.

A second group of variables is related to a firm's position in international competition: a measure of the degree of exposition to international competition LEXP (logarithm of exports as a share of sales); a dummy variable for foreign firms operating in Switzerland (FOREIGN). We expect a positive effect for LEXP. The sign of the variable FOREIGN is not a priori clear. It is difficult to predict the attitude of foreign firms to domestic science institutions. Some of them may still maintain ties to science institutions of their home countries, mostly via their mother-corporations; some others may have already build up a relationship to domestic science institutions.

Two measures of structural characteristics were also included all three models: LAGE (logarithm of firm age); six dummies for firm size (measured by the number of employees in full-time equivalents). We also used an alternative specification for firm 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 firm size to be positively correlated to the propensity to KTT activities with science institutions. Firm size is considered as an important determinant representing factors which favour KTT activities but are not specified in our model. We postulate that larger firms anticipate more and better possibilities for KTT activities than small ones, due presumably to their higher knowledge absorptive capacity (e.g. specialized R&D departments, "knowledge and technology monitoring" units, use of advanced methods of knowledge management). With respect to firm age we hypothesize that older firms are generally better embedded in their environment ("networking") than younger ones, so that their propensity to KTT activities should be larger than for young firms, all other things being equal. Thus we expect a positive sign for the coefficient of LAGE.

Further, we consider the possible influence that the choice of the science partner and/or the mediating partner could exert on the propensity to a specific KTT activity (educational activities, research projects, consulting etc.) (model B and C). We constructed a dummy variable for Swiss Federal Institute of Technology and/or Swiss Federal Institute of Technology Lausanne as science partners (ETH), a dummy variables for Technology Transfer Offices as "very important" mediating partners, and a dummy variable for the "Commission of Technology and Innovation" (KTI) as a "very important" mediating partner. The two Federal Institutes of Technology are the most important Swiss science institutions committed exclusively to research in engineering and natural sciences. The role of the "Technology Transfer Offices" has been investigated in the empirical literature for some countries, thus we would like to cast some light on this subject also for Switzerland. The "Commission of Technology and Innovation" (KTI) is the most important Swiss government

agency for the support of applied research. We do not have any sign expectations for these variables.

For model B and C we also included four variables measuring several aspects of the motivation of the firms for undertaking KTT activities with science institutions. As already discussed in section 4, firms with KTT activities reported their assessment for 20 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 in R&D, time-saving in R&D, reduction of technological risks) and institutional and organizational motives (e.g. “outsourcing” of R&D as firm strategy, co-operation with science institutions as condition for public subsidies). We consider these motives to reflect to a large extent the *expected benefits* of KTT activities from a firm’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 the relative importance of each of them. With the help of a main component factor analysis we compressed these 20 single motives to four main groups (access to “tacit” knowledge; access to ”codified” knowledge; financial motives; institutional and organizational motives) by means of a principal component factor analysis. The factor values of a four-factor solution were inserted as independent variables in the estimation equations of model B and C (see table A.1 in the appendix).

Both firms with KTT and without KTT activities reported their assessment for 26 single possible obstacles of KTT activities with science institutions. These obstacles reflect *costs* of realizing KTT activities from a firm’s point of view. They include impediments due to firm deficiencies or due to deficiencies of the science institutions, due to lack of information on the technological possibilities of the science institutions, financial, institutional and organizational obstacles (see section 4). With the help of a main component factor analysis we compressed these 26 single obstacles to five main groups by means of a principal component factor analysis. The factor values of a five-factor solution were inserted as independent variables in the estimation equations of all three models (see table A.2 in the appendix). 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.

Finally, we used several control variables for sectors (all three models), 2-digit industries (model A), firm size and geographic region (all three models).

6. Empirical Results

Propensity to KTT Activities (Model A)

Table 6 contains the results of the probit estimates of model A for all firms (column 1) as well as for the firms of four sub-sectors (high-tech and low-tech manufacturing; knowledge-based and traditional services) (columns 2, 3, 4 and 5 respectively). 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 (see section 2) could possibly indicate the direction of causal links. The overall fit of the model (Pseudo R^2 between 0.294 and 0.366) is rather satisfactory for a cross-section investigation.

The variables for human capital intensity (LQUAL) and the propensity to R&D activities (R&D) have throughout table 6 highly significant positive coefficients. For example, an increase of the share of high-qualified employees by one percent is related to a 0.3 percent increase of the probability of having KTT activities. Both variables are closely related to a firm's ability to absorb new knowledge from its environment. Thus, a high human capital intensity and the existence of in-house R&D activities seem to be important preconditions for unfolding KTT activities. On the contrary, capital intensity (LCI), the third variable in our model referring to firms' resource endowment, does not look to be relevant for distinguishing between firms with KTT activities and those without this type of activities.

Export intensity (LEXP) taken as a measure of a firm's degree of exposition to international competition shows no stable effects. Firm age (LAGE) is relevant only for the high-tech firms, older firms having a greater experience in co-operating with science institutions than younger ones. There is no difference between domestic and foreign firm with respect to KTT activities (FOREIGN).

The statistically significant negative coefficients of the variables for firm deficiencies and deficiencies of science institutions show that both kinds of obstacles can prevent firms from developing KTT activities. Firm deficiencies such as lack of qualified personnel, technical equipment and lack of interest for scientific problems are important obstacles for firms of the high-tech sector and the sector of knowledge-based services. On the contrary, firms from low-tech manufacturing and traditional service industries assess deficiencies of science institutions such as lack of research fields which are relevant for the firm, lack of possibilities of the commercialization of research outcomes and so on to be serious impediments of KTT activities.

Lack of information on the activities of science institutions is a problem particularly of the service firms, but as the positive coefficient of the corresponding variable shows, it is a problem for firms having KTT activities, not for firms without such activities, therefore it is not a proper obstacle of *getting involved* in KTT.

Too high costs and/or risks (e.g. too high follow-up investment needed for the commercialization of research outcomes, uncertainty with respect to research outcomes) do not seem to hamper KTT activities seriously. Only in the case of high-tech firms we obtain a statistically significant positive effect for the variable for costs and/or risks which we interpret as a hint that cost and risk problems can emerge for firms which are already involved in KTT activities.

Finally, organizational and institutional obstacles (such as problems with property rights, lack of support of commercialization of outcomes, management problems of the science partner etc. that are often considered as a main source of mismatching between enterprises and science institutions in empirical literature are not important in the case of Swiss firms.

There is a positive relationship between firm size and the propensity to KTT activities. Estimates based on an alternative specification of firm size with a linear and a quadratic term with respect to the number of employees showed a relationship of an inverse U-shape. It is important to emphasize that this relationship remains valid even after we have controlled for size-dependent variables such as the share of high-qualified employees and the propensity to R&D. Thus, it seems that firm size is a further important determinant representing factors which favour KTT activities, but are not specified in our model. Obviously larger firms anticipate more and better possibilities for KTT activities than small ones, presumably due to their higher knowledge absorptive capacity (e.g. specialized R&D departments, “knowledge and technology monitoring” units, use of advanced methods of knowledge management).

Propensity to Specific Forms of KTT Activities (Model B)

Table 7 contains the probit estimates for model B for the five main forms of KTT activities we distinguish in this study. 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 by estimating 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.

We find a pattern of explanation which differs in some aspects from that in model A. Particularly, the variables for resource endowment are not equally important for the *specific* forms of KTT activities (model B). The human capital intensity (LQUAL) is a precondition for specific informational (INFO), educational (EDUC) as well as research (REAS) activities in relation to science institutions, but not for consulting or infrastructure-oriented activities. The intensity of R&D activities (RDPERM) is not relevant for any specific form of KTT activities. Which firm is pursued depends thus not on the intensity of R&D activities. Firms with a high export intensity show a specific interest for infrastructure and research activities. All other variables of this first group of determinants (LCI, LAGE, FOREIGN) are not relevant.

A further important group of explanatory variables refers to goals of and motives for KTT activities. A striking feature of the “motive pattern” in table 7 is the wide spectrum of goals pursued by firms which undertake KTT activities in connection with science institutions. 17 out of total 20 coefficients of the variables for the four groups of motives in the five estimates of model B in table 7 are positive and statistically significant. As we have already seen in

table 2 firms undertake several forms of KTT activities at the same time. Thus, it is natural that we find that they pursue several goals with respect to their co-operation with science institutions at the same time, even if we focus our analysis to a specific form of activities. As a consequence, the overall picture we depict, is not one of firms turning to universities for a specific goal but for a wide palette of goals.

However, some focussing to specific goals can also be observed: the goal “access to tacit knowledge” is somewhat more relevant for educational activities (largest positive coefficient of the corresponding variable) than for the other types of activities; the goal “access to codified knowledge” is more important for research activities (also in this case largest positive coefficient of the corresponding variable); financial motives are important for infrastructure activities but not for educational activities.

What about the influence of the various impediments of KTT? According to the results in table 7 “lack of information” is a problem for research and consulting activities, “firm deficiencies” for informational and educational activities, cost and risk obstacles are important only for consulting activities. Finally, institutional and organizational obstacles are relevant for research and consulting activities.

Firm size is not relevant in order to answer the question which type of firms undertakes a specific type of KTT activities. Most of the coefficients of the firm size dummies are not statistically significant in four out of five estimates in table 7. We find a negative relationship to firm size only for the variable INFR. We assume that the reason for smaller firms showing a greater interest than larger ones to utilize technical infrastructure in co-operation with of public science institutions is that smaller firms cannot afford to acquire themselves some kinds of expensive infrastructure.

Propensity to Specific Forms of KTT Activities (Model C)

Table 8 contains the estimates of a multinomial logistic regression (model C) for the following three specific cases: (a) for the firms of group 2 focusing to educational activities *without* much research activities, in comparison to the firms of group 1 (column 1 in table 8); (b) for the firms of group 3 focusing to educational *and* research activities, in comparison to the firms of group 1 (column 2 in table 8); (c) for the firms of group 3 focusing to educational *and* research activities, in comparison to the firms of group 2 concentrating primarily to educational activities *without* research focus (column 3 in table 8).

With respect to the cases (a) and (b) we comment here only on the differences from the results for the variables EDUC and REAS in table 7. This alternative approach yields some additional insights. Firms with “pure” educational activities (group 2) pursue more intensive than other firms motive1 (access to tacit knowledge) and motive2 (access to codified knowledge). They are hampered primarily by obstacle2 (firm deficiencies). There is some evidence that foreign firms belong less frequently to this firm group than domestic firms.

Firms with up to 200 employees seem to be particularly prone to this type of KTT activities. Firms of group 3 (educational *and* research activities) show a higher human capital intensity than other firms. All four motives are pursued at the same time in this case. Organizational and institutional obstacles seem to be the most relevant group of impediments for these firms. Obstacle2 (firm deficiencies) or obstacle3 (deficiencies of science institutions) do not seem to hinder KTT activities in this case. Firm size does not play any role for this category of activities. Finally, the government agency for supporting applied R&D KTI is the most relevant mediating institution for these firms. The comparison of firms with educational *and* research activities (group 3) with those having *only* educational activities (group 2) shows that firms of group 3 are using more human capital and are exporting more than firms of group 2. Access to codified knowledge (motive2), financial motives (motive3) as well as institutional and organizational motives (motive4) are more relevant for firms of group 3 than those of group 2. On the contrary, motive1 (access to tacit knowledge) seems to be more relevant for firms with “pure” educational activities. Lack of information (obstacle1) and organizational and institutional problems (obstacle 5) are more important for group 3 than group 2. These results confirm the findings in table 7 with respect to the impediments of specific forms of KTT activities by clearly showing that the presumed mismatch between industry and science (obstacle1 and obstacle2) is not so important for firms focusing to research activities.

7. Discussion and Summary

We found that 28% of all firms were involved in KTT activities with science institutions in the period 2002-2004 and/or already before 2002. KTT-active firms are concentrated in the above-average innovative industries chemicals, machinery, electronics and instruments, computer and business services. “Tacit” forms of KTT such as informal contacts with university researchers, reading of and referring to publications, attending conferences as well university training courses, employing university graduates in R&D etc., are more important than “codified” ones such as joint R&D projects, long-term research contracts or joint use of technical infrastructure. More than 50% of KTT-active firms in Switzerland find informal contacts aiming at gaining some general information on technological opportunities and/or broadly defined education activities as the most important forms of KTT activities. Between 12% and 18% of KTT-active firms are involved primarily in research, infrastructure-related activities and consulting, mostly parallel to informational and educational activities.

The propensity to KTT activities is significantly positive correlated with human capital intensity (measured by the share of employees with tertiary-level education), the existence of R&D activities (but not with R&D-intensity, also not with capital intensity – measured by gross investment per employee), in high-tech manufacturing also with firm age. In sum, the ability to absorb new knowledge, measured by human capital intensity and the existence of R&D activities, is an important precondition for KTT activities.

Access to “tacit” knowledge through the access to specific skills, the utilization of the possibilities for further education and training offered by the scientific institutions as well as the recruitment of university graduates seems to be the most important motive for KTT activities independent of sector and firm size. Access to “codified” knowledge is especially relevant for manufacturing firms for the development of new products (rather “development-oriented”) and for firms of the knowledge-based service industries for gaining new research ideas and having access to basic research (rather “research-oriented”). Financial motives, particularly the financial and technological necessity to co-operate with science institutions, time-saving in R&D and insufficient firm R&D resources are particularly important for manufacturing firms. Finally, institutional and/or organizational factors (e.g. R&D co-operation with science institutions as condition for public funding) do not seem to build an important motive behind KTT activities. As the econometric results show, on the whole, firms are not driven by a specific motive when getting involved in KTT activities but they seem to pursue a series of parallel goals covering quite diverging areas of activities.

The most important obstacles of KTT activities can be localized on the interface between firms and science institutions. Many firms, especially those without KTT activities, think that their R&D questions would not find any interest among academicians, while on the other hand many firms, however less than in the former case, have the impression that the research interests of science institutions do not correspond to their presumably more application-oriented interests. This mismatch of business and science expectations is also confirmed by the econometric results. Is this mismatch a hint for an *overall* “dys-functionality” of industry-science interface, as some observers think? There are two arguments which rather speak against such a “pessimistic” interpretation of our results. First, most enterprises seem to have a “knowledge portfolio”, therefore they prefer to pursue several single goals at the same time when collaborating with science institutions. In this process some goals may remain unfulfilled or may be only partly accomplished, so we can expect that the efficiency of the one or other specific form of KTT activities has to be improved. The analysis of the five different forms of KTT activities shows that the mismatch of expectations can be traced back mainly to problems related to informational and educational activities. Firms with a focus to research activities do not seem to be seriously hampered by this category of impediments. Second, the econometric evidence also shows that besides this mismatch other important firm characteristics do exist, e.g. the endowment with human capital and in-house R&D activities, that enable a firm to utilize new scientific information. Which econometric factor is more relevant – mismatch or absorptive capacity as measured e.g. by human capital intensity – is not discernible at this stage of research. As a consequence, it is too early to derive specific recommendations for technology policy. However, the assertion of a largely insufficient knowledge and technology transfer between corporations and science institutions in Switzerland is not supported by empirical evidence.

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Table 1: Incidence of overall KTT activities by industry, sector and firm size class

<i>Industries</i>	Number of firms	Percentage of firms with KTT activities	Percentage of firms with KTT activities abroad
Food/beverage	127	33.0	10.2
Textile	30	30.1	22.1
Clothing/leather	11	0.0	0.0
Wood processing	56	26.5	7.0
Paper	31	31.2	3.8
Printing	91	26.7	0.9
Chemicals	93	41.9	26.6
Plastics/rubber	58	29.7	19.4
Glass/stone/clay	47	31.8	4.1
Metal	39	26.7	5.9
Metalworking	173	28.4	14.3
Machinery	269	35.8	17.0
Electrical machinery	87	33.9	18.4
Electronic/instruments	152	40.1	17.7
Watches	54	26.2	4.1
Vehicles	29	32.4	20.3
Other manufacturing	54	25.4	16.7
Energy/water	49	30.5	10.6
Wholesale	215	31.6	9.5
Transport	154	28.4	1.2
Banking/insurance	179	26.5	5.4
Computer services	79	26.4	4.8
Business services	216	37.9	11.6
Telecommunication	18	32.9	2.3
<i>Sectors</i>			
Manufacturing	1450	31.0	13.2
Construction	271	14.2	4.1
Services	861	32.4	8.3
<i>Subsectors</i>			
High-tech	688	36.7	18.9
Low-tech	762	28.0	10.1
Knowledge-based services	492	33.9	9.2
Traditional services	369	30.8	7.4
<i>Firm size classes</i>			
Small (5-49 employees)	1287	25.1	7.7
Medium (50-249 employees)	924	37.7	11.9
Large (250 and more employees)	371	47.1	18.3
<i>Total</i>	<i>2582</i>	<i>27.6</i>	<i>8.6</i>

Note: KTT activities in the period 2002-204 and/before 2002.

Table 2: Forms of KTT activities

<i>KTT main forms / single forms</i>	Percentage of KTT-active firms reporting 4 or 5 on a five-point Likert scale (1: 'not important'; 5: 'very important')
<i>INFORMAL (variable INFO)⁽¹⁾</i>	56.6
Informal contacts	30.4
Attending conferences	30.4
Reading of, referring to publications	33.1
<i>TECHNICAL INFRASTRUCTURE (variable INFR)⁽¹⁾</i>	11.9
Common laboratory	3.9
Use of university technical infrastructure	10.7
<i>EDUCATION (variable EDUC)⁽¹⁾</i>	52.3
Employing graduates in R&D	18.4
Contacts with university of graduates employed in R&D	10.1
Students' participation in firm R&D	10.9
Joint diploma theses	15.7
Joint PhDs	7.0
University researchers' participation in firm R&D	10.1
Common courses	3.8
Teaching of firm researchers at the university	7.7
Attending university training courses	22.1
<i>RESEARCH (variable REAS)⁽¹⁾</i>	17.8
Joint R&D projects	16.3
Long-term research contracts	5.0
Research consortium	4.1
<i>CONSULTING (variable CONS)⁽¹⁾</i>	15.3
Expertise	11.1
Consulting	13.8
N	669

Note: (1): percentage of firms reporting a value 4 or 5 on a five-point Likert scale (1: 'not important'; 5: 'very important') at least in one of the single forms belonging to the corresponding main category of forms of KTT activities.

Table 3: Motives for KTT activities

<i>Motives</i>	Percentage of KTT-active firms reporting 4 or 5 on a five-point Likert scale (1: 'not important'; 5: 'very important')
<i>ACCESS TO "TACIT KNOWLEDGE":</i>	65.9
Access to specific skills in addition to internal know-how	46.3
Further education, training possibilities	29.5
Recruitment of graduates	15.5
<i>ACCESS TO "CODIFIED KNOWLEDGE":</i>	29.3
New research ideas	18.0
Access to basic research	14.5
Access to university patents, licenses	5.7
Access to research results for subsequent internal use	11.7
Access to research results for developing new products	16.7
Access to research results for developing new processes	15.5
Access to R&D infrastructure	10.3
<i>FINANCIAL MOTIVES:</i>	41.1
Cost-saving in R&D	10.3
Reduction of technical R&D risks	7.5
Time-saving in R&D	13.4
Insufficient firm R&D resources	21.7
Project characteristics require co-operation with science institutions	25.6
<i>INSTITUTIONAL, ORGANIZATIONAL MOTIVES:</i>	25.0
Building up a new research domain	3.7
R&D outsourcing as strategic measure	6.1
R&D co-operation as condition for public funding	7.8
Improvement of firm image through co-operation with science institutions	13.3
Indirect access to knowledge of competitors	5.9
N	669

Table 4: Obstacles of KTT activities

<i>Obstacles</i>	Percentage of KTT-active firms reporting 4 or 5 on a five-point Likert scale (1: 'not important'; 5: 'very important')
<i>LACK OF INFORMATION</i>	<i>24.1</i>
Difficulties to get information about R&D activities in science institutions	13.9
Difficulties to find contact persons	17.9
Lack of resources for "interface" activities in the science institutions (e.g. transfer office)	9.7
<i>FIRM DEFICIENCIES</i>	<i>49.2</i>
Lack of qualified staff	12.8
Lack of technical equipment	9.6
Lack of interest in scientific projects	25.0
Firms' R&D questions are not interesting for science institutions	35.9
<i>DEFICIENCIES OF THE SCIENCE INSTITUTIONS</i>	<i>42.0</i>
Lack of scientific staff for transfer activities	11.7
Lack of entrepreneurial spirit	11.5
R&D orientation of science institutions not interesting for firms	25.6
Possible R&D outcomes cannot be commercialized	25.3
<i>COSTS, RISKS, UNCERTAINTY</i>	<i>42.4</i>
Secrecy with respect to firms' know-how not guaranteed	10.3
Need of comprehensive additional follow-up work in order to implement public R&D results	12.3
Lack of firm financial resources for transfer activities	27.4
Lack of financial resources of science institutions for co-operation on an equal basis with firms	12.3
Insufficient efficiency of university staff compared to firms' staff	10.9
Technological dependency from external institutions	6.3
Uncertainty about outcomes of co-operations	10.8
<i>INSTITUTIONAL, ORGANIZATIONAL OBSTACLES</i>	<i>24.5</i>
Costly administrative and approval procedures	15.0
Lack of administrative support of joint R&D project from science institutions	6.7
Lack of administrative support of commercialization of R&D result from science institutions	8.7
Problems with Property Rights	6.4
Problems with project management in science institutions (e.g. communication problems)	5.6
Different understanding of priorities	10.1
Lack of trust (firm)	4.1
Risk of losing reputation (firm)	1.6
N	2582

Table 5: Main Categories of Obstacles: Firms with / without KTT

<i>Main categories of Obstacles</i>	<i>KTT activities:</i>		<i>All Firms</i>
	yes	no	
Lack of Information	30.8	21.7	24.1
Firm deficiencies	36.1	53.8	49.2
Deficiencies of the science institutions	37.2	43.7	42.0
Costs, risks, uncertainty	44.5	41.7	42.4
Organizational / institutional obstacles	32.5	21.7	24.5
N	669	1913	2582

Table 6: Determinants of Knowledge and Technology Transfer Activities (KTT) in the Swiss Business Sector (Model A)

Explanatory Variables	KTT ⁽¹⁾ All Firms	KTT High-tech Manu- facturing	KTT Low-tech Manu- facturing	KTT Knowledge- based Services	KTT Traditional Services
LQUAL ⁽²⁾	(probit) 0.323*** (0.043)	(probit) 0.322*** (0.090)	(probit) 0.444*** (0.081)	(probit) 0.356*** (0.099)	(probit) 0.190** (0.091)
LCI ⁽³⁾	0.015 (0.020)	0.041 (0.046)	0.025 (0.037)	0.016 (0.045)	0.064 (0.056)
LEXP ⁽⁴⁾	0.013 (0.022)	0.078* (0.047)	0.059 (0.041)	0.026 (0.055)	-0.148** (0.073)
LAGE ⁽⁵⁾	0.095** (0.042)	0.172** (0.080)	0.055 (0.091)	0.126 (0.091)	0.119 (0.132)
R&D ⁽⁶⁾	1.144*** (0.076)	1.222*** (0.146)	1.036*** (0.141)	1.254*** (0.177)	1.806*** (0.294)
FOREIGN ⁽⁷⁾	-0.007 (0.091)	0.085 (0.146)	-0.336 (0.229)	-0.217 (0.237)	0.078 (0.261)
<i>Impediments⁽⁸⁾:</i>					
OBSTACLE 1 Lack of information	0.078** (0.021)	-0.084 (0.064)	0.045 (0.061)	0.320*** (0.079)	0.248** (0.104)
OBSTACLE 2 Firm deficiencies	-0.110*** (0.035)	-0.228*** (0.068)	-0.074 (0.065)	-0.188** (0.086)	0.051 (0.104)
OBSTACLE 3 Deficiencies of science institutions	-0.111*** (0.035)	-0.106 (0.074)	-0.199*** (0.069)	-0.127 (0.080)	-0.189** (0.085)
OBSTACLE 4 Costs, risks	0.060* (0.032)	0.128** (0.062)	0.030 (0.062)	-0.041 (0.088)	0.706 (0.105)
OBSTACLE 5 Organizational/institutional obstacles	0.008 (0.033)	0.065 (0.061)	-0.018 (0.066)	-0.063 (0.076)	0.051 (0.117)
<i>Sector:</i>					
High-tech Manufacturing ⁽⁹⁾	-0.013 (0.145)	//	//	//	//
Low-tech Manufacturing ⁽¹⁰⁾	-0.052 (0.135)	//	//	//	//
Knowledge-based Services ⁽¹¹⁾	-0.119 (0.140)	//	//	//	//
Traditional Services ⁽¹²⁾	0.153 (0.145)	//	//	//	//
<i>Industry:</i>					
Chemicals	//	0.445 (0.297)	//	//	//
Machinery	//	0.611** (0.258)	//	//	//
Electrical machinery	//	0.561* (0.296)	//	//	//
Electronics, instruments	//	0.667**	//	//	//

		(0.283)			
Vehicles	//	0.665*	//	//	//
		(0.368)			
Food, beverage	//	//	-0.104	//	//
			(0.226)		
Textiles	//	//	-0.302	//	//
			(0.330)		
Wood	//	//	-0.086	//	//
			(0.287)		
Paper	//	//	-0.188	//	//
			(0.327)		
Printing	//	//	-0.065	//	//
			(0.225)		
Glass, stone, clay	//	//	0.110	//	//
			(0.309)		
Metals	//	//	-0.282	//	//
			(0.354)		
Metal working	//	//	-0.107	//	//
			(0.214)		
Watches	//	//	-0.829**	//	//
			(0.335)		
Computer Services	//	//	//	-0.079	//
				(0.257)	
Business Services	//	//	//	0.408**	//
				(0.188)	
Wholesale trade	//	//	//	//	-0.147
					(0.221)
<i>Firm size:</i>					
20-49 employees	0.196*	0.325	0.181	0.101	0.559*
	(0.105)	(0.257)	(0.215)	(0.208)	(0.290)
50-99 employees	0.467***	1.294***	0.648***	0.512**	0.022
	(0.107)	(0.239)	(0.198)	(0.238)	(0.391)
100-199 employees	0.409***	1.443***	0.649***	0.425	0.384
	(0.113)	(0.236)	(0.213)	(0.306)	(0.374)
200-499 employees	0.762***	2.020***	0.847***	0.431	1.243***
	(0.117)	(0.239)	(0.223)	(0.278)	(0.348)
500-999 employees	1.067***	2.759***	0.954***	0.885**	1.407**
	(0.181)	(0.324)	(0.367)	(0.421)	(0.577)
1000 and more employees	1.115***	3.301***	2.196***	0.771**	0.945*
	(0.205)	(0.394)	(0.572)	(0.387)	(0.538)
<i>Region:</i>					
Lake of Geneva	0.666***	0.728	1.061**	0.214	-0.670
	(0.239)	(0.458)	(0.541)	(0.506)	(0.450)
Espace-midland	1.021***	1.094***	1.175**	1.028**	0.035
	(0.226)	(0.421)	(0.517)	(0.490)	(0.396)
Northwestern Switzerland	0.942***	1.206***	1.281**	0.860*	0.286
	(0.229)	(0.429)	(0.527)	(0.485)	(0.415)
Zurich	1.074***	1.342***	1.387***	0.764	0.798**

	(0.227)	(0.421)	(0.531)	(0.470)	(0.346)
Eastern Switzerland	1.080***	1.269***	1.321**	0.829*	0.044
	(0.228)	(0.426)	(0.527)	(0.502)	(0.437)
Central Switzerland	0.807***	1.055**	1.174**	0.384	//
	(0.239)	(0.451)	(0.544)	(0.540)	
Const.	-3.841***	-8.354***	-4.394***	-4.151***	-3.234***
	(0.355)	(0.731)	(0.705)	(0.763)	(0.847)
N	2428	651	717	446	348
N (KTT-active)	635	265	162	120	53
Pseudo R ²	0.300	0.366	0.297	0.294	0.316
Wald statistic (χ^2)	604***	212***	186***	125***	91***

Note: (1): KTT: knowledge and technology transfer activities in the period 2002-2004 and/or in the period before 2002; (2): LQUAL: logarithm of the share of employees with tertiary-level vocational education 2004 (universities, universities of applied sciences, other business and technical schools at tertiary level); (3): LCI: logarithm of gross investment per employee 2004; (4): LEXP: logarithm of exports as a share of sales; (5): LAGE: logarithm of firm age; (6): dummy variable for R&D activities; (7): FOREIGN: dummy variable for foreign firms; (8): impediments: factor values of a five-factor solution of a principal component factor analysis of the original 26 variables for single impediments of KTT, which were measured at a five-point Likert scale (1: "not important"; 5: "very important") (see table 4); (9): dummy variable for high-tech manufacturing: chemicals, plastics, machinery, electrical machinery, electronics, instruments and vehicles; (10): dummy variable for low-tech manufacturing: all other manufacturing industries; (11): dummy variable for knowledge-based services: banks, computer services, business services; (12): dummy variable for traditional services: wholesale trade, transportation; reference sector: construction; dummy variables for 2-digit industries, firm size and geographical region; reference firm size class: 5-19 employees; reference region: Ticino; ***, **, * denote statistical significance at the 1%, 5% and 10% test level, respectively; heteroscedasticity-robust standard errors (White procedure).

Table 7: Determinants of Various Forms of Knowledge and Technology Transfer Activities (KTT) in Swiss Business Sector (Model B)

Explanatory Variables	INFO ⁽¹⁾	INFR ⁽¹⁾	EDUC ⁽¹⁾	REAS ⁽¹⁾	CONS ⁽¹⁾
	(probit)	(probit)	(probit)	(probit)	(probit)
LQUAL ⁽²⁾	0.194**	-0.105	0.183**	0.202**	0.025
	(0.081)	(0.094)	(0.087)	(0.102)	(0.0.087)
LCI ⁽³⁾	0.033	-0.055	0.022	0.043	-0.028
	(0.042)	(0.050)	(0.049)	(0.056)	(0.053)
LEXP ⁽⁴⁾	0.011	0.126**	-0.042	0.122**	0.007
	(0.042)	(0.049)	(0.045)	(0.053)	(0.046)
LAGE ⁽⁵⁾	-0.051	-0.013	0.003	-0.056	-0.018
	(0.067)	(0.081)	(0.070)	(0.078)	(0.077)
RDPERM ⁽⁶⁾	0.002	-0.065	0.062	0.058	-0.054
	(0.081)	(0.108)	(0.086)	(0.111)	(0.093)
FOREIGN ⁽⁷⁾	-0.087	0.043	-0.249	0.030	0.095
	(0.144)	(0.161)	(0.157)	(0.174)	(0.161)
<i>Motives⁽⁸⁾:</i>					
MOTIVE1	0.462***	0.140**	0.544***	0.023	0.222***
Access to human capital ("tacit knowledge")	(0.062)	(0.070)	(0.068)	(0.072)	(0.066)
MOTIVE2	0.217***	0.315***	0.227***	0.626***	0.265***
Access to research outcomes ("codified knowledge")	(0.071)	(0.081)	(0.077)	(0.083)	(0.077)
MOTIVE3	0.110*	0.324***	0.078	0.247***	0.151**
Financial motives	(0.064)	(0.071)	(0.071)	(0.071)	(0.065)
MOTIVE4	0.141**	0.065	0.182***	0.331***	0.298***
Institutional, organizational motives	(0.060)	(0.074)	(0.067)	(0.072)	(0.067)
<i>Impediments⁽⁹⁾:</i>					
OBSTACLE 1	-0.046	-0.026	0.038	-0.154**	-0.138*
Lack of information	(0.061)	(0.070)	(0.064)	(0.075)	(0.073)
OBSTACLE 2	-0.101*	-0.059	-0.161**	-0.057	-0.025
Firm deficiencies	(0.061)	(0.074)	(0.069)	(0.077)	(0.071)

OBSTACLE 3	-0.141**	-0.076	0.006	0.112	0.077
Deficiencies of science institutions	(0.063)	(0.076)	(0.069)	(0.077)	(0.070)
OBSTACLE 4	0.005	0.053	0.087	0.089	-0.171**
Costs, risks	(0.068)	(0.076)	(0.072)	(0.080)	(0.075)
OBSTACLE 5	-0.014	-0.066	0.107	-0.148*	-0.185***
Organizational/institutional obstacles	(0.063)	(0.068)	(0.065)	(0.077)	(0.069)
<i>Science partner:</i>					
ETH ⁽¹⁰⁾	0.209***	-0.129	0.218*	0.057	-0.120
	(0.116)	(0.135)	(0.125)	(0.146)	(0.131)
<i>Mediating Institutions:</i>					
Technology Transfer Offices ⁽¹¹⁾	0.073	0.190	0.432*	-0.157	0.584***
	(0.210)	(0.199)	(0.227)	(0.228)	(0.186)
KTI ⁽¹²⁾	0.171	0.478***	0.273	0.843***	-0.166
	(0.181)	(0.183)	(0.222)	(0.186)	(0.176)
<i>Sector:</i>					
High-tech Manufacturing ⁽¹³⁾	-0.816***	0.093	-0.112	-0.439	0.024
	(0.283)	(0.357)	(0.307)	(0.412)	(0.317)
Low-tech Manufacturing ⁽¹⁴⁾	-0.540**	-0.032	-0.187	-0.127	0.190
	(0.258)	(0.339)	(0.286)	(0.390)	(0.293)
Knowledge-based Services ⁽¹⁵⁾	-0.767***	-0.435	-0.117	0.019	-0.126
	(0.281)	(0.386)	(0.300)	(0.407)	(0.323)
Traditional Services ⁽¹⁶⁾	-0.499*	0.051	-0.308	-0.482	-0.185
	(0.288)	(0.410)	(0.309)	(0.501)	(0.347)
<i>Firm size:</i>					
20-49 employees	-0.188	-0.486*	0.439*	0.256	0.037
	(0.219)	(0.255)	(0.230)	(0.284)	(0.254)
50-99 employees	-0.281	-0.513**	0.457**	-0.078	0.180
	(0.211)	(0.248)	(0.224)	(0.274)	(0.243)
100-199 employees	-0.198	-0.860***	0.302	-0.462	-0.328
	(0.225)	(0.254)	(0.228)	(0.296)	(0.261)

200-499 employees	-0.368*	-0.411*	0.206	0.089	0.137
	(0.220)	(0.251)	(0.226)	(0.600)	(0.243)
500-999 employees	-0.420	-0.537*	0.448	0.600*	0.315
	(0.268)	(0.295)	(0.289)	(0.332)	(0.294)
1000 and more employees	-0.020	-1.147***	0.056	0.427	0.132
	(0.314)	(0.396)	(0.287)	(0.334)	(0.329)
Const.	1.148	1.000	-0.932	-2.163**	-0.257
	(0.811)	(0.961)	(0.828)	(0.942)	(0.866)
N	632	632	632	632	632
N (intensively KTT-active)	384	122	414	149	119
Pseudo R ²	0.158	0.234	0.248	0.358	0.146
Wald statistic (χ^2)	127***	134***	173***	195***	87***

Note: (1): INFO: 3 variables for single forms of KTT referring to informal contacts, attendance of conferences, workshops of science institutions 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 firms that reported a value 4 or 5 for any of the three original variables, value 0 to those firms reporting 1, 2 or 3 for any of the three original variables; INFR: similar construction as INFO based on the variables for two single forms of KTT referring to technical infrastructure; 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 3.2 for details; (2): LQUAL: logarithm of the share of employees with tertiary-level vocational education 2004 (universities, universities of applied sciences, other business and technical schools at tertiary level); (3): LCI: logarithm of gross investment per employee 2004; (4): LEXP: logarithm of exports as a share of sales; (5): LAGE: logarithm of firm age; (6): RDPERM: ordinal variable for R&D intensity (0: no R&D; 1: occasional R&D; 2: permanent R&D; (7): FOREIGN: dummy variable for foreign firms; (8): motives: factor values of a four-factor solution of a principal component factor analysis of the original 20 variables for single motives for KTT, which were measured on a five-point Likert scale (1: "not important"; 5: "very important") (see table 3 for details); (9): impediments: factor values of a five-factor solution of a principal component factor analysis of the original 26 variables for single impediments of KTT, which were measured on a five-point Likert scale (1: "not important"; 5: "very important") (see table 4 for details); (10): ETH: dummy variable for Swiss Federal Institute of Technology and/or Swiss Federal Institute of Technology Lausanne as science partners; (11): Technology Transfer Offices: dummy variable for Technology Transfer Offices as "very important" mediating partners; (12): KTI: dummy variable for the "Commission of Technology and Innovation" (KTI) as "very important" mediating partners; (13): chemicals, plastics, machinery, electrical machinery, electronics, instruments and vehicles; (14): all other manufacturing industries; (15): knowledge-based services: banks, computer services, business services; (16): traditional services: wholesale trade, transportation; reference sector: construction; dummy variables for firm size and geographical region; reference firm size class: 5-19 employees; reference region: Ticino; the coefficients of the region dummies are not included in the table; ***, **, * denote statistical significance at the 1%, 5% and 10% test level, respectively; heteroscedasticity-robust standard errors (White procedure).

Table 8: Determinants of Various Forms of Knowledge and Technology Transfer Activities (KTT) in Swiss Business Sector (Model C) (multinomial logistic regression)

Explanatory variables	group 2 ⁽¹⁾ (focus to education)	group 3 ⁽¹⁾ (focus to education and research)	group 3 ⁽¹⁾ (focus to education and research)
LQUAL ⁽²⁾	0.205 (0.149)	0.560** (0.226)	0.354* (0.210)
LCI ⁽³⁾	0.044 (0.086)	0.113 (0.124)	0.070 (0.115)
LEXP ⁽⁴⁾	-0.099 (0.080)	0.155 (0.109)	0.255*** (0.098)
LAGE ⁽⁵⁾	0.053 (0.153)	-0.038 (0.173)	-0.091 (0.153)
RDPERM ⁽⁶⁾	0.174 (0.155)	0.181 (0.2229)	0.007 (0.202)
FOREIGN ⁽⁷⁾	-0.531* (0.296)	-0.292 (0.364)	0.238 (0.320)
<i>Motives:</i> ⁽⁸⁾			
MOTIVE1	0.897*** (0.126)	0.609*** (0.165)	-0.289** (0.148)
Access to humancapital("tacit knowledge")			
MOTIVE2	0.291* (0.155)	1.319*** (0.197)	1.028*** (0.165)
Access to research outcomes ("codified knowledge")			
MOTIVE3	0.103 (0.127)	0.494*** (0.163)	0.390*** (0.137)
Financial motives			
MOTIVE4	0.177 (0.135)	0.670*** (0.165)	0.493*** (0.135)
Institutional/organizational motives			
<i>Impediments:</i> ⁽⁹⁾			
OBSTACLE1	0.098 (0.117)	-0.161 (0.164)	-0.258* (0.144)
Lack of information			
OBSTACLE2	-0.274** (0.122)	-0.238 (0.166)	0.037 (0.150)
Firm deficiencies			
OBSTACLE3	0.025 (0.121)	0.236 (0.165)	0.211 (0.147)
Deficiencies of science institutions			
OBSTACLE4	0.020 (0.130)	0.179 (0.168)	0.159 (0.148)
Costs, risks			
OBSTACLE5	0.165 (0.124)	-0.149 (0.163)	-0.314** (0.138)
Organizational/institutional obstacles			
<i>Science partner:</i>			
ETH ⁽¹⁰⁾	0.259 (0.225)	0.318 (0.308)	0.059 (0.276)
<i>Mediating institutions:</i>			
Technology Transfer Offices ⁽¹¹⁾	0.685 (0.496)	0.227 (0.590)	-0.459 (0.414)
KTI ⁽¹²⁾	0.650 (0.540)	1.998*** (0.551)	1.348*** (0.342)

<i>Sector:</i>			
High-tech manufacturing ⁽¹³⁾	-0.194 (0.566)	-1.239 (0.818)	-1.045 (0.749)
Low-tech manufacturing ⁽¹⁴⁾	-0.307 (0.515)	-0.794 (0.779)	-0.487 (0.731)
Knowledge-based services ⁽¹⁵⁾	0.159 (0.555)	-0.129 (0.808)	-0.288 (0.737)
Traditional services ⁽¹⁶⁾	-0.485 (0.560)	-1.394 (1.115)	-0.909 (1.103)
<i>Firm size:</i>			
20-49 employees	0.810* (0.426)	1.065* (0.597)	0.255 (0.556)
50-99 employees	1.031** (0.415)	0.698 (0.590)	-0.333 (0.545)
100-199 employees	0.759* (0.427)	-0.304 (0.629)	-1.063* (0.586)
200-499 employees	0.431 (0.421)	0.480 (0.594)	0.050 (0.549)
500-999 employees	0.479 (0.563)	1.410* (0.729)	0.932 (0.643)
1000 and more employees	-0.146 (0.600)	0.727 (0.781)	0.872 (0.718)
Const.	-1.212 (1.162)	-3.910** (0.737)	-2.698* (1.603)
N	627		
Pseudo R ²	0.289		
LR statistics (χ^2)	386***		
Comparison group	group1 ⁽¹⁾	group 2 ⁽¹⁾	group 2 ⁽¹⁾

Note: (1): We constructed a 3-level nominal variable: level 1: firms with any value for the variables INFO, INFR, CONS, and the value 0 for the variables EDUC and REAS (group 1; 220 firms); 2: firms with any values for the variables INFO, INFR, CONS, the value 1 for the variable EDUC and the variable 0 for the variable REAS (group2; 297 firms); 3: firms with any value for the variables INFO, INFR, CONS, and the value 1 for the variables EDUC and REAS (group 3; 154 firms); see note in the tables 6 and 7 for the definition of the variables INFO, INFR, CONS, EDUC, and REAS; (2): LQUAL: logarithm of the share of employees with tertiary-level vocational education 2004 (universities, universities of applied sciences, other business and technical schools at tertiary level); (3): LCI: logarithm of gross investment per employee 2004; (4): LEXP: logarithm of exports as a share of sales; (5): LAGE: logarithm of firm age; (6): RDPERM: ordinal variable for R&D intensity (0: no R&D; 1: occasional R&D; 2: permanent R&D; (7): FOREIGN: dummy variable for foreign firms; (8): motives: factor values of a four-factor solution of a principal component factor analysis of the original 20 variables for single motives for KTT, which were measured on a five-point Likert scale (1: “not important”; 5: “very important”) (see table 3 for details); (9): impediments: factor values of a five-factor solution of a principal component factor analysis of the original 26 variables for single impediments of KTT, which were measured on a five-point Likert scale (1: “not important”; 5: “very important”) (see table 4 for details); (10): ETH: dummy variable for Swiss Federal Institute of Technology and/or Swiss Federal Institute of Technology Lausanne as science partners; (11): Technology Transfer Offices: dummy variable for Technology Transfer Offices as “very important” mediating partners; (12): KTI: dummy variable for the “Commission of Technology and Innovation” (KTI) as “very important” mediating partners; (13): chemicals, plastics, machinery, electrical machinery, electronics, instruments and vehicles; (14): all other manufacturing industries; (15): knowledge-based services: banks, computer services, business services; (16): traditional services: wholesale trade, transportation; reference sector: construction; dummy variables for firm size and geographical region; reference firm size class: 5-19 employees; reference region: Ticino; the coefficients of the region dummies are not included in the table; ***, **, * denote statistical significance at the 1%, 5% and 10% test level, respectively.

APPENDIX:

Table A.1: Principal Component Factor Analysis of the Motives for KTT Activities

<i>Motives</i>	<i>Rotated Factor Pattern (factor loadings)</i>			
	<i>Factor 1</i>	<i>Factor 2</i>	<i>Factor 3</i>	<i>Factor 4</i>
Access to specific qualifications	0.50			
Access to training possibilities	0.83			
Recruitment of R&D personnel	0.55			
New research impulses		(1)		
Access to university basic research results		0.61		
Access to university patents, licences		(2)		
Direct use of research outcomes for:				
Further application in own R&D		0.76		
Development of new products		0.58		
Development of new processes		(3)		
Cost reduction in R&D			0.78	
Risk reduction in R&D			0.72	
Reduction of the duration of R&D projects			0.71	
Insufficient own R&D funds			0.75	
Certain R&D projects feasible only in co-operation with science			0.52	
Building up of a new research domain				0.59
Outsourcing of R&D as strategic option				0.61
Co-operation with science as precondition for public funds				0.61
Image improvement				0.71
Indirect access to rivals' know-how				0.62
<i>Statistics</i>				
Number of observations	671			
Kaiser's measure of sampling adequacy (MSA)	0.912			
Root mean square off-diagonal residuals (RMSE)	0.061			
Variance explained by each factor	6.96	1.72	1.24	1.13
Final communality estimate	11.1			

Characterization of the four factors based on the factor pattern

Factor 1: Access to human capital ("tacit knowledge")

Factor 2: Access to research outcomes ("codified knowledge")

Factor 3: Financial motives

Factor 4: institutional, organizational motives

Note: the table shows only factor loadings of 0.5 and more; (1): 0.46; (2): 0.44; (3): 0.35.

Table A.2: Principal Component Factor Analysis of the Impediments of KTT Activities

<i>Impediments</i>	<i>Rotated Factor Pattern (factor loadings)</i>				
	<i>Factor 1</i>	<i>Factor 2</i>	<i>Factor 3</i>	<i>Factor 4</i>	<i>Factor 5</i>
Lack of information on research activities of science institutions	0.84				
Difficulties to find an adequate science partner	0.85				
Inadequate services of existing transfer offices	0.79				
Lack of qualified personnel		0.79			
Lack of technical equipment		0.79			
Lack of interest for scientific projects		0.65			
Assessing firm's problems to be not so interesting for scientists		0.50			
Lack of personnel for performing KTT			0.51		
Lack of entrepreneurial attitude of scientists			0.51		
Lack of research fields which are relevant for the firm			0.77		
No possibility of commercialization of research outcomes			0.75		
Secrecy not guaranteed				0.68	
Too high follow-up investment needed for commercialization of research outcomes				0.70	
Lack of funds of firms for KTT				0.58	
Lack of funds of science institutions for KTT				0.61	
Insufficient efficiency of scientists compared to firm's R&D personnel				0.52	
Technological dependence from external institutions				0.63	
Uncertainty with respect to co-operation outcome				0.67	
Costly administrative procedures, legal restrictions					0.62
Lack of project management support from the science institutions					0.72
Lack of support of commercialization of outcomes from the science institutions					0.72
Problems with property rights					0.69
Management problems of the science partners					0.73
Differing opinions with respect to the urgency of finishing a project					0.66
Lack of trust					0.71
Risk of damaging reputation					0.73
<i>Statistics</i>					
Number of observations	2583				
Kaiser's measure of sampling adequacy (MSA)	0.941				

Root mean square off-diagonal residuals (RMSE)	0.047				
Variance explained by each factor	10.2	2.2	1.5	1.4	1.2
Final communality estimate	16.4				
<i>Characterization of the five factors based on the factor pattern:</i>					
Factor 1: Lack of information					
Factor 2: Deficiencies of the firm					
Factor 3: Deficiencies of the science institutions					
Factor 4: Costs, risks					
Factor 5: Organizational, institutional impediments					

Note: the table shows only factor loadings of 0.5 and more.