Knowledge and Technology Transfer (KTT) Activities Between Universities and Firms in Switzerland: The Main Facts

an empirical analysis based on firm-level data

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Abstract

This study is part of a large project aiming at the investigation of a) extent and b) economic relevance of *knowledge and technology transfer* (KTT) between science institutions (universities, universities of applied science and other public research institutions) and private corporations. Under knowledge and technology transfer we understand very broadly any activities targeted at transferring knowledge and technology that may help a company or a research institution – depending on the direction of the transfer – to further promote its activities. In this paper we report on the results of a large postal survey of Swiss enterprises based on a questionnaire on the exchange of knowledge and technology with Swiss universities and other research institutions. The survey was addressed to about 6000 firms from all sectors of the economy (with exception of hotels/catering, retail trade, transportation and personal services) and from different size classes. We received answers from 2582 firms, i.e. 45.4% of the firms in the underlying sample. In this paper we undertake a c*haracterisation* of KTT activities from a *firm*'s point of view:

- Which are the main *characteristics* of firms conducting KTT (e.g. size, industry, R&D activities, R&D budget, research areas etc.)
- Which *forms* does KTT take (e.g. joint research projects, joint teaching courses, allocation of thesis or doctoral projects in collaboration with firms etc.), what is the *relative importance* of such forms?
- Which are the most important *transfer channels* (publications, patents, licenses, spin-offs) and *intermediating organisations* (technology transfer offices, KTI, SNF etc.)?
- Which are the most relevant *transfer partners* among the universities and other research institutions?
- Which are the most important *motives* for KTT activities (e.g. financial motives, access to academic knowledge, institutional motives etc.)
- Which are the most important *impediments* of KTT activities (lack of information, lack of conditions necessary for know-how transfer, costs and risks etc.)

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1 Introduction and Main Results

We are confronted with a „paradox“ picture in the field of science, technology and innovation. On the one hand Switzerland shows an outstanding performance in university research and on the other hand the innovation performance of Swiss firms is stagnating or in some areas even decreasing since the middle of the nineties. One possible reason for this descrepancy could be traced back to deficits with regard to knowledge and technology transfer (KTT) from university to industry. Thus, a number of national innovation policy measures aim at “valorising” university knowledge. Some observers express the opinion that the interface between universities and business firms has to be improved and as a consequence knowledge and technology transfer activities should be intensified (see e.g. Zinkl and Huber 2003). This is probably a step in the right direction. However, so far there does not exist a comprehensive study on the extent, the motivations, challenges, channels etc. of KTT in Switzerland. Research has been done on selected topics only[1]. Thus, there is a need for a more comprehensive view, in order to improve the empirical basis for policy decision makers in the field of KTT.

On behalf of the ETH Board we carried out a series of empirical studies aiming at constructing a comprehensive picture of KTT in Switzerland. This is the first paper of this series containing a detailed descriptive analysis of the data gained by means of a survey among Swiss enterprises that yielded data for 2582 firms.

In accordance to the investigation of Dosi (1982) on technological trajectories[2] we define KTT as follows: Knowledge and technology transfer between academic institutions and the business sector is understood in this study as any activities aimed at transferring knowledge or

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[1] Already existing studies for Switzerland focusing on certain aspects of KTT: Balthasar (1998) analysed the occupational impact of information networks of developers in the fields of machine tool building and plastics processing in Switzerland. On the same field of sciences, Wilhelm (2001) performed international comparisons between Switzerland, Austria and Baden-Württemberg. The Bulletin ETH-Zurich Nr. 285 (November 2001) described different perspectives on KTT under the heading “Hochschule-Industrie-Partnerschaften”. Thierstein et al. (2002) investigated spin-offs/start-ups from universities in the eastern part of Switzerland. Berwert et al. (2002) investigated the establishment and development of start-ups/spin-offs from technical universities in Switzerland. Zinkl and Huber (2003) pointed at challenges for tedhnology transfer offices in Swiss universities. Vock et al. (2003) carried out a survey on codified forms of KTT (patents, licences). This survey was addressed to technology transfer offices of the universities. The OECD data for Switzerland are based on this survey (see e.g. OECD 2002), which should be carried out periodically.

[2] We know from the literature on evolutionary economics that R&D activities of firms are following specific technological trajectories. They are very broad and diverse, and thus also an investigation of KTT activities – when KTT aims to improve the technological performance of a firm at least in a medium term perspective – has to be based on a broad definition of the object of investigation and should be not limited to quantitative indicators such as patents, licenses and start-ups/spin-offs. KTT has to be defined broadly in order to give consideration to the complex character of technological development. Dosi defined in his study on technological trajectories technology broadly as “a set of pieces of knowledge, both directly ‚practical‘ (related to concrete problems and devices) and ‚theoretical‘ (but practically applicable although not necessary already applied), know-how, methods, procedures, experience of successes and failures and also, of course, physical devices and equipment“ (see Dosi 1982, p. 151).

technology that may help either the company or the academic institute – depending on the direction of transfer – to further pursue its activities.

Thinking about KTT in a broad sense means also thinking about the interaction of public research institutions and private enterprises. In this study we analyse the main driving and hindering forces for turning science into business. This makes it necessary to investigate both the behaviour of firms and of scientific institutes at universities with respect to knowledge and technology transfer. In this study we focus on the firm side. The "stylised" model from Bozeman (2000) guides the analysis. It has been modified and adapted to our needs (see Figure 1-1). The model includes five broad-defined entities. The transfer agent (characteristics of scientific institutes), the transfer recipient (the characteristics of firms), transfer forms or media (e.g. informal contacts, personal exchange, research co-operations), transfer motives or objectives (e.g. access to human capital or research results) and transfer obstacles (e.g. firm deficiencies, organisational/institutional obstacles). Their interaction determines whether and to which degree KTT takes place and how effective it is with respect to several criteria (e.g. R&D abilities of firms, value added, share of new products, skill level).[3]

The descriptive analysis enables us to quantify the different entities in our "stylised" model. In this way we obtain detailed information about who is undertaking KTT; which channels/forms and services of mediating institutions are frequently used; what is the main motivation for KTT activities and what are the obstacles for KTT. Furthermore, we have information of the impact of KTT activities on firms, as evaluated by the firms themselves (subjective qualitative answers). Finally, some correlations of measures of KTT activities with various variables measuring innovation and economic performance are presented. This provides us first insights with respect to the economic effectiveness of KTT.

Table 1-1 gives a summary of the most important results of the descriptive analysis. In brief, 27.6% of Swiss firms are engaged in KTT activities. It was found that large and older firms, firms with skilled staff and more intense export activities are more frequently involved in KTT activities than firms without these characteristics. KTT-active firms are predominantly situated in Zurich region, Espace midland or East Switzerland. The high-tech sector and the knowledge-based service sector show the highest incidence of KTT activities. The number of KTT active firms definitely increased within the last few years. This is also valid for subsectors with relative low incidence of KTT active firms, indicating that the overall interest of firms for public research increases. Firms diversify their contacts with universities, focusing especially on informal contacts and educational aspects. Firms with intensified KTT activities appreciate the diversity of interaction forms more than firms with weakened KTT activities. Tacit forms for KTT are more frequently used than more codified ones. Mediating institutions (e.g. Transfer Offices, EU Framework programmes) are only of limited importance for KTT active firms. The most important obstacles for starting or intensifying KTT activities are deficiencies of firms as well as of universities and costs, risk and

[3] The "effectiveness of KTT" in Figue 1-1 refers primarily to the economic impact of KTT (and the public research sector) on the business sector, an important topic which is discussed in another paper (see Arvanitis et al. 2005a).

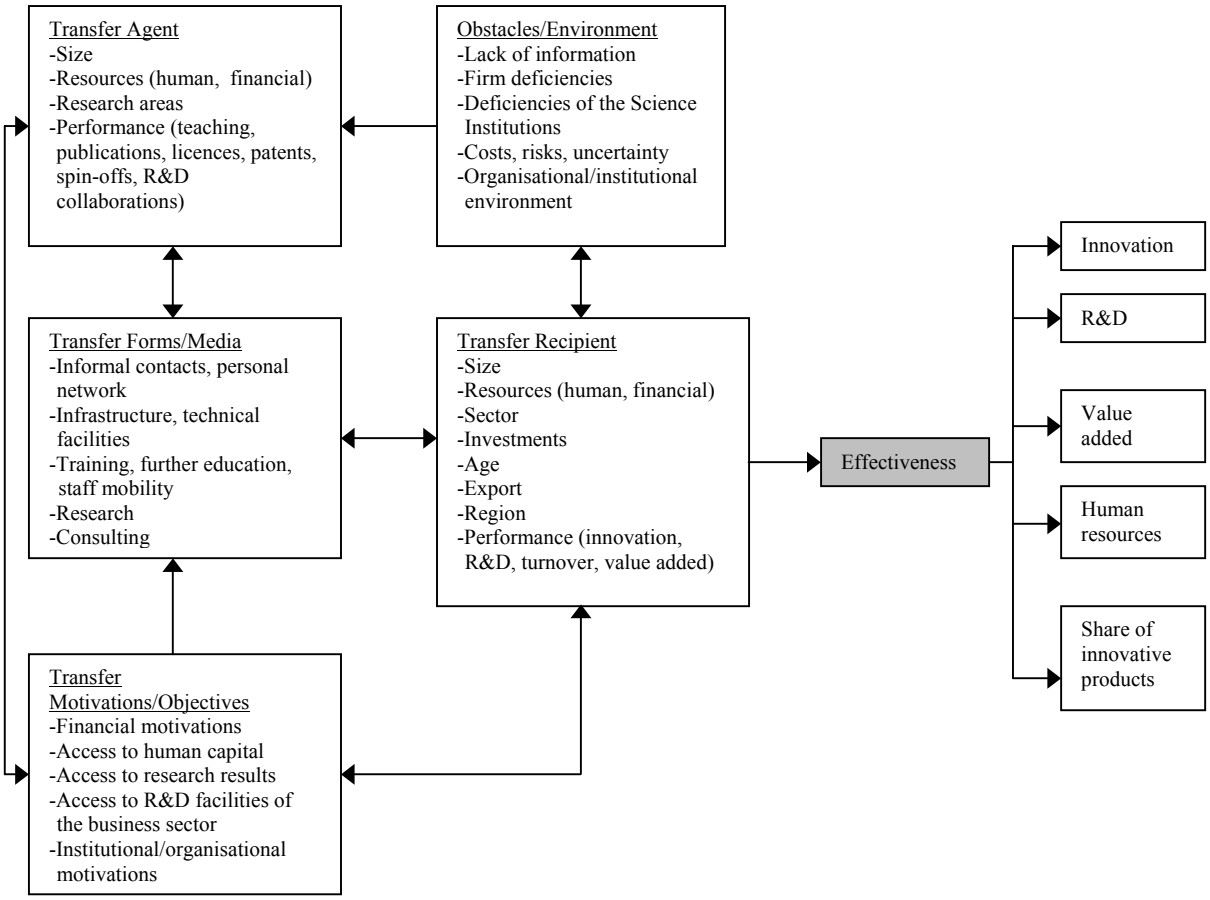
uncertainty aspects. Firms are motivated for KTT primarily by the perspective of more effective access to human capital followed by financial motives and access to research results. They emphasise that they are looking for abilities in addition to internal know-how and not for possibilities to substitute internal R&D capacities. The ETH-Domain, especially the ETH Zurich is an attractive partner for most of the KTT-active firms in Switzerland.

There are three additional points we would like to emphasise here. First, the positive correlation between KTT and the skill-level provides us with some interesting insights. On the one hand, high skill-level is an important precondition for a firm to be able to absorb new knowledge ("absorptive capacity"; see Cohen and Levinthal 1989). On the other hand, a large part of KTT takes place through educational activities such as the recruitment of graduates in R&D, the attendance of university training courses for firm employees etc. (see Table 3-7) and various informational activities, i.e. activities that improve the skill-level and raise the absorptive capacity of a firm. Thus, there is some self-reinforcing mechanism, which is working on the interface between firms and university. We also found that the most frequently reported group of obstacles of KTT activities refers to firm deficiencies that are closely related to the lack of firms' absorptive capacity (lack of qualified personnel and/or technical equipment, lack of interest for scientific projects etc.; see Table 3-21). Presumably it is this kind of deficiencies that is blocking up the above-mentioned self-reinforcing mechanism for many firms. Thus, a task for public policy aiming at strengthening KTT could be the support of the upgrading of the skill-level of firms as an important precondition for KTT activities.

Second, a further observation, which supports the idea of a wide diversified demand of university knowledge, is that many firms are involved in KTT activities with different types of universities, emphasising diversity in their contacts. Especially institutions from the ETH-Domain and Universities of Applied Sciences are quite often contacted by the same firm (see Table 3-16).

Third, with respect to the more codified forms of KTT related to research activities we found that firms pursue a wide spectrum of goals rather searching for knowledge complementary to their own than know-how that could substitute internal R&D for university research (see Table 3-20). On the whole, firms do not seem to be interested in more applied research in the universities as is often asserted by many observers. They rather prefer a division of labour between university and industry in terms of complementary knowledge assets than a kind of competitive situation with the public university sector at the knowledge market.

Figure 1-1: „Stylised" Model for Knowledge and Technology Transfer



Source: Bozeman (2000), authors' modification

Table 1-1: Main results

Transfer recipient:

- Large firms are more frequently involved in KTT activities than smaller ones. Also firms with higher skill-level, more innovative firms, firms with a high intensity of investment, firms with greater export shares, older firms and foreign-owned firms show a significantly higher frequency of KTT activities with institutions of the public science sector.(1)
- Firms in greater agglomarations are more likely involved in KTT activities than firms in regions with less industrial agglomeration.
- Firms in the high-tech subsector, particularly firms in the chemical industry and in electronics/instruments, are more often engaged in KTT activities than firms in other subsectors.

Transfer incidence, forms, and media:

- The number of KTT-active firms increased in the last few years; this is especially valid for subsectors with a relatively low absolute share of KTT active firms. Thus, university knowledge gains importance for a much broader spectrum of firms than e.g. only high-tech firms.
- Firms intensifying their KTT activities apply more than one form for KTT. They diversify their contacts and evaluate most of them as very important. In contrast, firms with weakened KTT activities may use more than one form, but these different forms are less often evaluated as very important than in the case of firms intensifying KTT activities.
- Tacit forms for KTT (e.g. scientific publications, informal contacts) are more important for firms than more codified ones (e.g. patents, spin-offs/start-ups).
- From a firm's perspective, mediating institutions are of limited and very specific importance for formal contacts with the universities. Single sectors or subsectors show preferences for specific mediating institutions.

Transfer motivations:

- Firms are motivated for KTT activities in order to gain knowledge complementary to internal know-how, particularly appreciating the access to human capital. Applied research results from the universities are of minor interest.

Transfer obstacles:

- Deficiencies on the firms' side and deficiencies of the science institutions are the main groups of obstacles for KTT. More concretely, many firms stated that their research questions are not interesting for university research. In contrast, problems with project management (e.g. communication problems) and/or lack of administrative support from universities are not important for starting or intensifying KTT activities.

Transfer agent:

- The ETH-Domain is the most interesting science partner for firms. KTT-active firms diversify their contacts and very frequently combine ETH contacts with contacts with Universities of Applied Sciences (UAS). The ETH-Domain is especially interesting for firms focusing on "research co-operations" in their KTT activity.

Effectiveness:

- KTT activities correlate positively with a high skill-level of firms.
- KTT activities correlate positively with a high intensity of innovation activities within a firm. Innovative products or processes are more likely if the firm co-operates with public research organisation.
- KTT activities correlate positively with important indicators of firm economic performance (e.g. sales per capita, value added)

(1): For an econometric analysis on the determinants of KTT activities see Arvanitis et al. (2005b).

2 Data Collection on Knowledge and Technology Transfer

2.1 Questionnaire

The data were collected by means of a survey carried out in Spring 2005. Based on the results of a comprehensive pilot study (see Arvanitis and Wörter 2004) we designed the questionnaire taking into account also several surveys form other countries. This allows for international comparisons of our research results - at least partly. Furthermore, we constructed a second survey for science institutions that is symmetrical to the one addressed to firms, so that we can compare the two points of view (firms and scientific institutes). The combined information allows for identifying the dis(incentive) structures for KTT and localise areas of problems that could be treated by technology policy. The questionnaires comprise the following topics (see Table 2-1):

Table 2-1: Main categories of the questionnaires in comparison

Questionnaire for firms:	Questionnaire for scientific institutes:
-Firm characteristics and performance indicators	-Characteristics of the institute and financial resources
-Innovation and R&D activities	-Performance in teaching and research
-Forms and media of KTT with scientific institutions	-Forms of KTT between institutes and the business sector, and channels used
-Scientific partners for KTT	-Motivation and objectives for KTT with the business sector
-Motivation and objectives for KTT with scientific institutions	-Impact of KTT with the business sector
-Impact of KTT with scientific institutions	-Obstacles to KTT with the business sector
-Obstacles to KTT with scientific institutions	

2.2 Composition of the sample and the response rate (firm survey)

The firm survey was based on the KOF firm-panel. It is a (with respect to firm size) disproportional stratified sample, drawn from the national census of enterprises (2001) and containing firms with more than five employees. The sample covers 29 2-digit industries (NOGA classification) form all sectors of the economy and - within each of industry - three different size classes with a complete coverage of large firms.[4] The limits for the three size classes (criterion: employment in full-time equivalents) are determined by "optimal stratification" (see Cochran 1977) that takes into account the different size distributions of firms within industries.

[4] For a detailed description of the panel see Donzé (1998).

The firm survey was addressed to all industries in the sample wit the exception of retail trade, hotels and restaurants, real estate and personal services. We excluded firms in these industries, since it is quite unlike that they have KTT activities with universities. After correcting for firm closings, firm mergers etc. we obtained a net sample of 5693 firms. After an intensive recall action we disposed of 2582 valid answers (45.4%; see Table 2-2.). The response rate is similar in the different sectors, with manufacturing reaching the highest level (46.8%) followed by services (44.7%) and construction (40.5%). Focusing on the single industries, we find the highest response rate in the computer service business (56.4%) and the lowest in the clothing/leather business (33.3%).

The overall response rate and the distribution of the responses between the different industries and sectors is very satisfactory, especially if we compare with similar surveys in other countries and if we take into account that the subject of the survey is rather specific and does not interest all firms equally. The very intensive recall action contributed heavily to yielding an overall quite satisfactory response rate.

In the subsequent chapters we distinguish four subsectors that defined as follows:

High-tech manufacturing: chemicals, plastics, machinery, electrical machinery, vehicles, electronics/instruments:

Low-tech manufacturing: food/beverage, textiles, clothing/leather, wood processing, paper, printing, glass/stone, clay, metal metalworking, watches, other manufacturing, energy/water;

Modern services: banking/insurance, computer services, business services, telecommunication;

Traditional services: wholesale trade, transport.

We also define three firm size classes:

Small-sized: 5 to 49 employees in full-time equivalents;

Medium-sized: 50 to 249 employees in full-time equivalents;

Large firms: 250 employees in full-time equivalents and more.

Table 2-2: Structure of the net sample and response rate

	Net sample (N)	*Responses (N)*	*Response rate (%)*
Industries			
Food/beverage	262	127	48.5
Textiles	71	30	42.3
Clothing/leather	33	11	33.3
Wood processing	104	56	53.9
Paper	64	31	48.4
Printing	189	91	48.2
Chemicals	246	93	37.8
Plastics/rubber	117	58	49.6
Glass/stone/clay	105	47	44.8
Metal	76	39	51.3
Metalworking	392	173	44.1
Machinery	508	269	53.0
Electrical machinery	169	87	51.5
Electronic/instruments	335	152	45.4
Watches	157	54	34.4
Vehicles	68	29	42.7
Other manufacturing	109	54	49.5
Energy/water	92	49	53.3
Construction	670	271	40.5
Wholesale	553	215	38.9
Transport	386	154	39.9
Banking/insurance	360	179	49.7
Computer services	140	79	56.4
Business services	442	216	48.9
Telecommunication	45	18	40.0
Sectors			
Manufacturing	3097	1450	46.8
Construction	670	271	40.5
Services	1926	861	44.7
Total	**5693**	**2582**	**45.4**

2.3 Missing values and weighting schemes

2.3.1 Non-response analysis

The high response rate and the relative equal distribution of responses across different industries do not exclude a possible selection bias for important questions. In order to address this problem we carried out a unit non-response analysis. For this purpose, we drew a sample of 287 non-responding firms that were asked by phone to answer three central questions ("Do you have KTT activities? Have you introduced innovations during the period under consideration? Do you have R&D activities?"). In this survey we reached a response rate of 90.9%.[5] Respondents and non-respondents gave different answers, but the differences are not large. This was taken into consideration through a unit non-response correction. Item non-response is another source of selection bias. Firms sometimes leave some questions unanswered, which may distort our results. This problem was addressed with the statistical method of "multiple imputation" (see Rubin 1987).

2.3.2 Weighting schemes

An adequate weighting procedure of the answers taking into consideration all available information on selection bias, on possible structural deviations from the sample (stratification) as well as from the population is a comprehensive work which is related to important theoretical as well as empirical questions (see e.g. Kish 1992). In the following paragraph we briefly present the weighting scheme used in our calculations. Step by step we take into account the statistical sampling plan (stratification), the non-response rate in total, the results of the non-response analysis and firm size specific weights for the different sample layers.

Sampling plan

For each observation (firm) i of layer h (h=1,…,84) we define a weight w_{hi}:

$$w_{hi} = 1/f_h = 1/(n_h/N_h) = N_h/n_h$$

f_h: sampling rate of layer h
n_h: number of firms in layer h in the sample
N_h: number of firms in layer h in the population 2001

Non-response rate:

For each firm i in the layer h we define a weight $1/r_{hi}$, where r_{hi} represents the probability that the firm i gives an answer. Actually this probability is not known, therefore we have to estimate it based on a logistic regression of the non-response rate[6] on the structural characteristics such as industry affiliation, size class or region. By taking into account r_{hi} we obtain the following weight:

$$w_{hi}^{*} = w_{hi}\ 1/r_{hi}$$

[5] For details on the procedure see Donzé (2002).
[6] Dependent variable: dummy variable (value 1 for responding firms and value 0 for not responding firms).

Non-response analysis:

The information from the non-response survey is used to estimate the calibrated weights $w_{hi}^{*(c)}$ (method „calibration on margins"; see Deville et al. 1993).[7] This weighting step can be summarised as follows:

$$w_{hi}^{*} \rightarrow w_{hi}^{*(c)} \qquad \text{(c: calibration)}$$

The overall weight $w_{hi}^{*(c)}$ is used for most of the calculations. In this way the sampling plan the non-response rate and the non-response analysis are taken into account.

Stratification weights:

$$k_h^{BE} = BESCH01_h/BESCH01_s \qquad \text{(employment weight)}$$

$BESCH01_h$ and $BESCH01_s$ refer to the employment - according to the federal census of enterprises (2001) - in layer h and sector h respectively.

[7] We used the programme CALMAR, which has been developed at INSEE; see Sautory (1993).

3 Knowledge and Technology Transfer Activities: Main Facts

3.1 Who is Transferring Knowledge and Technology from Universities?

3.1.1 Incidence of KTT Activities

Taking into account that our firm sample comprises all firms with more than 5 employees from the manufacturing sector, the construction sector and part of the sector of commercial services (excluding retail trade, hotels and restaurants, real estate and personal services), the overall number of firms with KTT is surprisingly high: 27.6% of all firms are undertaking KTT in Switzerland. Comparing the two time periods "before 2002" and "2002-2004" it becomes obviously that the overall incidence of KTT activities increased (see Table 3-1).

Certainly, there are differences between the sectors and the industries. Firms in the service sector show almost the same frequency of KTT activities as manufacturing firms (32.4% vs. 31.0%). Much less firms have KTT activities in the construction sector (14.2%) than in the other two sectors. In contrast to the manufacturing sector, the service sector and the construction sector show a relatively strong increase in frequency between the two time periods "before 2002" and "2002-2004". They are catching up in terms of KTT. Moreover, the service sector now leads the ranking with respect to domestic KTT activities. As to international activities the manufacturing sector outperforms the other sectors. Please notice that we excluded service sectors with a low probability of having KTT activities. This certainly contributes to the relatively high incidence of KTT in this sector.

Focusing on the sub-sectors it becomes obviously that firms in the high-tech industry and in the modern service sector (knowledge-based services) are responsible for the high incidence of KTT activities in manufacturing and in the service sector. In contrast, the share of firms with KTT is low in the low-tech sector and the traditional service sector. Remarkably, the number of firms with KTT activities increased in all sub-sectors relatively stronger than in the "leading" high-tech sector. This can be interpreted as a hint that an increasing interest in the research activities of the universities is emerging also in sectors with basically a lower affinity to science.

Changing the level of analysis again and looking at the different industries, one can see, not very surprisingly, that firms in the chemical industry and in electronics/instruments but also in business services have the highest incidence of KTT activities. Chemicals, textile and vehicles show the highest incidence of KTT activities abroad. This is easily understandable for chemicals and especially pharmaceuticals. They are very R&D-intensive industries and have to tap into R&D activities all over the world in order to remain competitive. Larger firms in

Table 3-1: Incidence of KTT activities; percentage share of firms by sector, industry and firm size class

	N	*KTT before 2002 and/or 2002-2004l*	*KTT before 2002*	*KTT 2002-2004*	*KTT Abroad*
Industries					
Food/beverage	127	33.0	26.1	29.5	10.2
Textile	30	30.1	25.0	27.9	22.1
Clothing/leather	11	0.0	0.0	0.0	0.0
Wood processing	56	26.5	8.1	25.9	7.0
Paper	31	31.2	6.6	26.5	3.8
Printing	91	26.7	19.4	26.7	0.9
Chemicals	93	41.9	20.5	34.6	26.6
Plastics/rubber	58	29.7	18.4	25.7	19.4
Glass/stone/clay	47	31.8	20.1	18.8	4.1
Metal	39	26.7	24.0	4.8	5.9
Metalworking	173	28.4	20.7	21.2	14.3
Machinery	269	35.8	24.7	28.1	17.0
Electrical machinery	87	33.9	18.2	25.6	18.4
Electronic/instruments	152	40.1	29.8	30.0	17.7
Watches	54	26.2	12.3	26.2	4.1
Vehicles	29	32.4	27.6	16.6	20.3
Other manufacturing	54	25.4	22.2	25.4	16.7
Energy/water	49	30.5	20.9	27.4	10.6
Wholesale	215	31.6	14.4	26.6	9.5
Transport	154	28.4	19.1	25.0	1.2
Banking/insurance	179	26.5	14.9	25.9	5.4
Computer services	79	26.4	24.0	17.2	4.8
Business services	216	37.9	22.2	30.1	11.6
Telecommunication	18	32.9	4.8	32.9	2.3
Sectors					
Manufacturing	1450	31.0	20.8	25.1	13.2
Construction	271	14.2	5.4	10.1	4.1
Services	861	32.4	18.4	26.7	8.3
Subsectors					
High-tech	688	36.7	24.2	28.3	18.9
Low-tech	762	28.0	18.9	23.4	10.1
Modern services	492	33.9	20.9	27.2	9.2
Traditional services	369	30.8	15.6	26.2	7.4
Size					
Small	1287	25.1	14.1	19.4	7.7
Medium	924	37.7	22.1	33.7	11.9
Large	371	47.1	38.3	44.9	18.3
Total	**2582**	**27.6**	**15.9**	**22.2**	**8.6**

Table 3-2: Incidence of KTT activities – regions

	N	*KTT before 2002 and/or 2002-2004l*	*KTT before 2002*	*KTT 2002-2004*	*KTT Abroad*
Swiss regions					
Lake of Geneva	302	20.8	12.7	12.9	8.5
Espace midland	590	30.0	14.8	22.4	9.3
North-western Switzer.	387	23.7	10.1	21.7	5.5
Zurich region	494	38.6	22.1	35.0	14.1
East Switzerland	445	27.6	21.3	19.9	8.6
Central Switzerland	248	24.4	16.1	21.4	3.5
Ticino	116	8.5	1.8	7.4	1.3
Total	**2582**	**27.6**	**15.9**	**22.2**	**8.6**

in the Swiss vehicle industry are mostly suppliers of automobile industry outside Switzerland and therefore have to rely often on R&D activities near the location of their customers. The Swiss textile industry is relatively technology-intensive and produces in many locations around the world; it also seems reasonable to be involved in R&D activities at these locations. There are several industries in which the share of firms with KTT activities strongly increased, most of them are situated in the low-tech subsector, e.g. paper, watches and wood processing but also in the modern services sector (e.g. telecommunication).

The differences with respect to the frequency of KTT activities among firms of different size classes are in line with the theoretical assumption that larger firms have a stronger propensity to KTT activities than smaller ones. In column 1 of Table 3-1("overall" KTT activities) 47.1% of all large firms in Switzerland have KTT activities with public science institutions in Switzerland, 18.3% also to science institutions abroad. The corresponding shares for medium-sized firms are 37.7% and 11.9% respectively, for small-sized ones 27.6% and 7.7% respectively.

Most of the firms with KTT activities are located in the Zurich region, in Espace midland and in East Switzerland followed by Central Switzerland, North-western Switzerland, Lake of Geneva and Tisino (Table 3-2). The differences among the regions are rather large, ranging from 38.6% for Zurich region to 8.5% in Ticino.

An international comparison of these results is difficult for at least two reasons. Firstly, empirical investigations in other countries or regions differ in the definition of KTT. Secondly, the period of investigation is different. As long as time-series data are not available and these kinds of surveys are not internationally co-ordinated, it is the only (third best) way to assess the Swiss data based on an ad-hoc comparison. Fritsch (2002) investigated if R&D co-operations differ among regions. He compared eleven regions[8], focusing on manufacturing firms only and he defined R&D co-operation quite broadly[9]. 30% of the manufacturing firms in his sample co-operated with publicly funded research institutions. Rather surprisingly, the Saxony and Slovenia regions are leading this ranking and show a share of firms with university co-operations between 34% and 38%, while the Barcelona area and Vienna area have the lowest shares between 18% and 22%. Lessmann and Rosner (2004) found in a more recent study for Saxony in Germany that 30.9% of the selected knowledge-based firms, mostly in manufacturing, are involved in KTT activities[10]. For comparison, Zurich region has a share of 38.6% and Espace midland of 30.0%of KTT-active firms.

Based on the findings in Table 3-1 and Table 3-2 we made some statements as to the increasing frequency of KTT activities between two time periods. Now we are looking at the development of the intensity of KTT for firms already active in KTT (question: "KTT

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8 Barcelona, Rotterdam, Stockholm, Vienna, Baden, Alsace, Gironde, Hanover, Saxony, Slovenia, South-Wales.

9 "Every relationship between actors that involves more than just a spot-market exchange but which is not subject to complete hierarchical control may be considered a co-operation" (see Fritsch 2002 p. 2).

10 The definition of KTT is not explicitly stated. However, it seems to be similar to ours, since they define the following forms of KTT: patents/licences, other forms of KTT, contracted product development, expertise, co-operation for product development, graduate/practical/PhD (see Lessmann and Rosner 2004).

activities have a) intensified, b) weakened or c) remained unchanged in the period 2002-2004") (see Table 3-3).

Swiss KTT-active firms intensified their KTT activities in 35.2% of the cases; 44.8% of the firms answered that their activities remained unchanged and only 20.0% said that they have been weakened.

Existing KTT activities were intensified mainly in the construction sector (59.2%), followed by manufacturing (39.8%) and, with some distance, by the service sector (27.1%). The share of firms that stated that their activities have been weakened differs not so much among the sectors; the respective figures vary between 13.4% (construction) and 22.8% (services).

KTT active firms in the low-tech subsector most frequently intensified their KTT contacts and relatively few firms registered that they have been weakened (15.2%). Firms in the other subsectors intensified their KTT contacts to a similar extent. In contrast, firms in the traditional service sector most frequently detected a weakening of the KTT contacts, followed by high-tech firms, modern services and low-tech firms.

Since in some of the industries the number of observations is rather low, figures at industry level have to be carefully interpreted. The telecommunication industry, printing, watches, the paper and the glass/stone/clay industry show the most extreme development. In these industries more than 60% of the firms stated that they have intensified their KTT activities. In contrast, firms in the metal industry, wholesale trade and computer services registered to more than 30% a weakening of the KTT activities**.**

Large, medium and small firms intensified their KTT activities to a similar extent, ranging between 33.6% (large firms) to 35.9% (small firms). More divergent are the figures for the "weaker intensity" category. In this case, only 5.4% of the large firms stated that their KTT relations have been weakened. The same did 12.7% of the medium sized firms and 22.9% of the small sized. This indicates that especially the KTT expectations of the large firms are matching reality.

Existing KTT activities have been intensified particularly in the regions of Ticino (74.2%) and of Lake of Geneva (47.8%). In all other areas the share of firms that intensified their activities is lies somewhere between 25.6% (East Switzerland) and Espace midland (36.3%) (see Table 3-4). The share of firms that have weakened their KTT activities is a bit more diverse. North-western Switzerland shows the lowest figure, followed by Lake of Geneva and Ticino.

Table 3-3: Change in KTT intensity; percentage share of firms by sector, industry and firm size class

	N	*No change*	*stronger*	*Weaker*
Industries				
Food/beverage	34	67.2	21.0	11.8
Textile	9	78.8	21.2	0.0
Wood processing	9	28.6	46.9	24.5
Paper	9	26.8	66.7	6.5
Printing	17	27.6	70.9	1.5
Chemicals	37	57.2	37.7	5.1
Plastics/rubber	13	95.0	2.1	2.9
Glass/stone/clay	13	7.4	66.4	26.2
Metal	9	48.5	9.8	41.8
Metalworking	37	18.2	59.2	22.7
Machinery	116	54.2	19.5	26.3
Electrical machinery	33	46.4	27.1	26.5
Electronic/instruments	67	36.4	35.7	28.0
Watches	6	31.3	68.7	0.0
Vehicles	9	54.1	42.2	3.8
Other manufacturing	12	90.6	9.4	0.0
Energy/water	15	67.8	31.1	1.2
Wholesale	35	28.8	31.3	39.9
Transport	21	79.8	20.2	0.0
Banking/insurance	35	65.9	26.5	7.6
Computer services	28	48.3	13.2	38.5
Business services	67	59.1	26.4	14.4
Telecommunication	6	6.9	88.0	5.1
Sectors				
Manufacturing	445	42.6	39.8	17.6
Construction	32	27.4	59.2	13.4
Services	192	50.1	27.1	22.8
Subsectors				
High-tech	275	51.9	26.9	21.2
Low-tech	170	36.3	48.5	15.2
Modern services	136	57.5	25.8	16.7
Traditional services	56	41.3	28.6	30.2
Size				
Small	182	42.0	35.1	22.9
Medium	288	51.4	35.9	12.7
Large	199	61.1	33.6	5.4
Total	**669**	**44.8**	**35.2**	**20.0**

Table 3-4: Change in KTT intensity – regions

	N	*no change*	*stronger*	*weaker*
Swiss regions				
Lake of Geneva	55	45.2	47.8	7.0
Espace midland	150	38.6	36.3	25.1
North-western Switzer.	105	60.1	35.2	4.6
Zurich	154	43.5	32.8	23.7
Eastern Switzerland	137	45.2	25.6	29.2
Central Switzerland	59	48.2	35.9	15.9
Ticino	9	16.9	74.2	8.9
Total	**669**	**44.8**	**35.2**	**20.0**

3.1.2 Various Forms of KTT Activities

Firms and universities interact through several forms of activities. All types of such activities show to some extent a "tacit" as well as a "codified" component. "Tacit" knowledge is tied to a person, based on his/her specific experiences and therefore it is very difficult to transfer (see Polanyi 1967). In contrast, "codified" knowledge is not tied to a person and can be transferred easily or further processed (see Cowan and Foray 1997). In order to transfer "tacit" knowledge personal contact is essential, for transferring "codified" knowledge it is not. Codified knowledge is easier to measure and therefore strongly emphasised by most of the empirical literature, however "tacit" knowledge seems to be more important for KTT. Table 3-5 gives an overview of empirical research in this area. It shows which forms of KTT activities were taken into consideration in a certain study; these are marked with x. Based on these studies we constructed our list of 19 forms for KTT applied in our questionnaire.

Main categories of KTT forms

We asked the respondents to report on the importance of 19 different forms of KTT activities on a five-point Likert-scale (value 1: "not important"; value 5: "very important"). The 19 items were pooled into 5 main groups, i.e. informal contacts related to informational activities, utilisation of infrastructure, forms related to university education, research co-operation and consulting. (Table 3-6) contains the shares of firms reporting 4 or 5 on a five-point Likert scale with respect to at least one out of a series of single forms belonging to the respective group of KTT activities (e.g. nine single forms of educational activities or three forms of research activities; see also Table 3-8).

Informal, personal contacts and KTT through graduates or the education activities of the universities are the most important forms of KTT independent of size, sector, subsector or region. More than 50% of the KTT active firms stated that these two categories are very important means of interaction. Research-related forms (e.g. joint R&D projects, long-term research contracts) are next in importance, followed by consulting and infrastructure. This general result can be also found in the service sector, to some extent also in manufacturing. In the latter case, use of joint technical infrastructure is more important then consulting and research. Educational activities are of great importance for firms in the construction sector. Forms related to technical infrastructure, consulting and research are clearly more important for the manufacturing sector than for the other two sectors.

Informal, personal contacts and education are the most important forms of KTT activities for all subsectors as well. High-tech firms evaluate infrastructure-related forms more important than other subsectors. Consulting activities and research-focused forms are especially emphasised by low-tech firms.

In general, similar results can be presented at industry level. Informal contacts and education are the most important forms for nearly every industry. Exceptions are the industries wood processing, metalworking and other manufacturing. As to the importance of the remaining forms of KTT activities, some differences can be detected. Research activities are comparably useful for the textile industry, printing, energy/water, computer services (more than 40%). Wood processing, printing and metalworking especially appreciate consulting activities.

Metalworking, watches, vehicles and telecommunication highlight the usage of infrastructure related forms of KTT.

In addition to informal and educational forms, large firms considered research contacts, infrastructure and consulting activities as being more important than on average. 23.7% of them stated that research-related forms are very important, 16.5% stated the same for consulting. In contrast, medium sized firms point out KTT forms related to infrastructure and small firms attach above-average importance to research and consulting.

KTT forms related to technical infrastructure are relatively less important for firms located in Ticino and Central Switzerland, while they are relatively more important for firms in Lake of Geneva and North-western Switzerland (Table 3-7). Research contacts are appreciated as being above average by firms located in Lake of Geneva, Central Switzerland and Zurich. Consulting is relatively important for firms in Central Switzerland and more or less of similar importance in all other regions; only firms in the Ticino area and in the Lake of Geneva region rank this form clearly below average.

Table 3-5: Overview of empirical literature on forms of KTT activities

Forms of KTT activities	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*L*
Joint laboratories	X									X		
Participation in research centres (third-party funded)										X		
Spin-offs	X			X					X		X	X
Licences	X				X			X	X		X	X
Joint research projects (planning and execution, including joint ventures)			X		X		X	X	X	X		
Research co-operations (every partner pays his own expenses)			X	X	X						X	
Research consortiums (one university, several firms)			X				X	X		X		
Staff mobility (employing graduates in R&D, staff exchange or formation of a company, etc.)				X	X	X	X	X	X	X	X	X
Research co-operations (funded by the business sector)			X									X
Institute staff/students participate in firms' R&D projects			X							X		
Joint teaching courses or programmes										X		
Contract research	X		X		X		X	X	X	X		X
Industrial fellowship	X		X									
Contact with graduates employed in the business sector	X	X					X	X	X	X		X
Exchange of publications							X					X
Contacts with former staff employed in the business sector				X								
Joint publications in scientific journals, patents	X			X					X	X		X
Joint articles in magazines, etc.				X								
Attending conferences, exhibitions, workshops etc.	X		X	X			X		X			X
Informal contacts (e.g. by phone, email)		X					X		X		X	X
Inspection of technical facilities, technical demonstrations												X
Use of technical facilities at universities		X	X						X			X
Use of technical facilities at firms (development of prototypes, fabrication, tests)			X			X						X
Consulting		X	X		X	X	X			X	X	X
Traineeship		X			X							
Thesis projects in collaboration between universities and firms		X			X		X					
Attendance of specialised courses or training programmes of the institute by business sector scientists		X	X		X	X			X			X
Teaching assignment for business sector staff		X	X	X			X		X			X
Donations for Universities			X				X					
Financial donations for Universities			X				X			X		X
On-the-job training for students			X		X					X		
Doctoral projects in collaboration with the business sector			X	X	X	X	X	X	X			X
Sabbaticals			X						X			
University staff being active in firms' advisory body(ies)							X					X
Firm representatives active in research board(s) of university										X		
Research Park (R&D co-operations)			X							X	X	
Research Park (informal interactions)			X									
Research Park (joint use of technical infrastructure)			X									
Research Park (contract research for business sector)			X									
Buying of prototypes and IPR (Intellectual Property Rights)									X		X	
Reading academic publications or patents, etc.									X		X	X
Expertise												X
Services from Transfer Offices					X				X			

A = OECD (2002), B = Blum/Fromm (2000), C = Geisler/Rubinstein (1989), D = Czarnitzki et al. (2000), E = Arthur D. Little (2000), F = Mayer (2000), G = Schmoch (2003), H = Schartinger et al. (2001), I = Schartinger et al. (2002), J = Santoro/Chakrabarti (2002), K = Bozeman (2000), L = Schmoch et al. (2000).

Table 3-6 Forms for KTT activities – main categories; percentage of firms with KTT activities by sector, industry and firm size class

	N	*Informa-tional*	*Infrastructure*	*Education*	*Research*	*Consulting*
Industries						
Food/beverage	34	85.3	30.3	67.7	2.1	9.6
Textile	9	85.0	4.1	75.5	68.0	2.1
Wood processing	9	95.9	22.4	6.2	22.4	44.9
Paper	9	77.0	10.0	76.7	13.1	0.0
Printing	17	69.4	0.0	79.3	61.1	68.0
Chemicals	37	69.7	31.7	54.0	29.3	25.4
Plastics/rubber	13	91.7	29.5	39.4	1.7	2.9
Glass/stone/clay	13	33.6	28.7	97.2	32.7	29.8
Metal	9	12.2	6.5	18.7	5.6	6.5
Metalworking	37	54.2	42.8	31.8	21.8	42.8
Machinery	116	44.7	30.7	68.3	24.0	23.2
Electrical machinery	33	57.2	16.4	58.2	10.4	4.0
Electronic/instruments	67	64.3	35.3	65.8	36.9	20.1
Watches	6	84.2	50.2	65.6	18.6	37.1
Vehicles	9	59.4	44.4	57.8	5.9	0.0
Other manufacturing	12	15.5	12.2	95.0	13.8	21.6
Energy/water	15	74.8	0.0	51.3	41.8	24.1
Wholesale	35	60.1	2.3	28.2	14.7	15.5
Transport	21	24.9	0.8	33.4	0.0	10.5
Banking/insurance	35	48.8	0.0	68.3	11.5	4.5
Computer services	28	90.2	1.0	92.2	44.3	1.9
Business services	67	60.2	9.0	62.5	12.2	11.7
Telecommunication	6	100.0	49.0	95.5	2.4	6.9
Sectors						
Manufacturing	445	61.4	29.0	56.1	25.1	28.2
Construction	32	39.1	2.2	51.1	16.6	1.7
Services	192	58.2	4.9	50.6	14.0	11.5
Subsectors						
High-tech	275	58.7	31.2	62.1	24.5	18.2
Low-tech	170	63.2	27.5	52.1	25.5	34.9
Modern services	136	63.8	7.4	68.2	16.5	9.2
Traditional services	56	51.5	1.9	29.5	11.1	14.2
Size						
Small	182	56.7	11.0	48.1	18.5	15.5
Medium	288	54.6	14.3	64.8	14.1	14.4
Large	199	66.0	16.4	64.2	23.7	16.5
Total	**669**	**56.6**	**11.9**	**52.3**	**17.8**	**15.3**

Table 3-7: Forms for KTT activities and regions – main categories

	N	*Informa-tional*	*Infrastructure*	*Education*	*Research*	*Consulting*
Swiss regions						
Lake of Geneva	55	39.6	15.2	51.5	28.6	7.0
Espace midland	150	63.1	12.4	58.6	12.7	14.6
North-western Switzerland	105	66.7	15.6	57.9	10.4	10.0
Zurich region	154	62.1	9.8	44.1	21.0	15.8
Eastern Switzerland	137	48.8	13.5	51.5	15.9	16.6
Central Switzerland	59	53.0	6.4	64.4	21.8	32.7
Ticino	9	9.4	7.4	16.2	3.1	6.5
Total	**669**	**56.6**	**11.9**	**52.3**	**17.8**	**15.3**

Single forms of KTT

Table 3-8 contains the shares of firms reporting 4 or 5 on a five-point Likert scale (1: "not important; 5: "very important") for one of the 19 single forms of KTT activities listed in this Table. If we change the analytical level and focus on these single forms of KTT activities, we see that referring to publications, attending conferences and informal contacts are the most important forms for KTT activities reported by the firms (more than 30%). In contrast, joint courses, joint laboratories, and research consortiums are less often considered as important (less than 5%). In addition to these three single forms, manufacturing firms assert a particular importance for the usage of university technical infrastructure, the employing of university graduates in R&D, R&D co-operation and consulting. This is to some extent in contrast to the construction and service sector, where "further educational and training possibilities" (construction, services), joint Ph.D.s (construction), joint diploma theses (services) and "employees' contacts to university" (construction) are important as well. "Employing university graduates in R&D" is a rather unusual form for KTT in the construction sector and of medium importance in the service sector. Joint laboratories are in both sectors construction and services of less importance than in the manufacturing sector and the same is valid for "employees' contacts to university" and joint PhDs for the manufacturing sector.

Firms in the high-tech sector see "employing university graduates in R&D" as the most important form of KTT. This contrasts to the overall result and to that for all other subsectors. Furthermore, technical infrastructure is emphasised clearly above average by firms in this subsector. Informal contacts, attending conferences and referring to publications are like in all other subsectors of great importance as well. The low-tech sector distinguishes itself through the clearly above-average importance of the forms "university researchers participate in firm R&D", joint R&D projects, and expertise and consulting. Neither of these KTT forms is of similar importance for firms in the modern service or traditional service sector. While firms in modern services highlight referring to publication and further education, firms in traditional services point at joint diploma theses as a form of particular importance.

For most of the single KTT forms a clear size pattern is not discernible. However, some differences among size classes may be of some relevance. Informal contacts are the most important form for KTT for large firms. "Attending conferences" is most important for medium-sized firms and referring to publications for small ones. In addition and in contrast to small firms, large and medium-sized firms emphasise stronger than smaller firms "employing university graduates in R&D" (large firms), joint diploma theses (medium-sized and large firms), joint Ph.D. (medium-sized firms) and "further educational and training possibilities" (medium-sized and large firms).

In sum, informal contacts and educational aspects are the most important forms for KTT in Switzerland. They can be characterised as tacit forms of KTT. More codified forms such as research, consulting and utilisation of technical facilities are of less importance.

Table 3-8: Single forms of KTT by sector, subsector and firm size class; percentage of firms reporting 4 or 5 on a five-point Likert scale (1: "not important"; 5: "very important")

KTT main forms / single forms	*Sectors*			*Subsectors*				*Size*			*Total*
	Manu-facturing	Con-struction	Services	High-tech	Low-tech	Modern services	Traditional services	Small	Medium	Large	
INFORMAL											
Informal contacts	35.4	17.3	30.7	33.4	36.8	35.3	25.1	30.7	26.9	42.5	30.4
Attending conferences	30.1	21.1	32.8	27.5	31.9	36.4	28.5	29.3	33.3	36.3	30.4
Reading of, referring to publications	32.6	21.5	36.2	28.9	35.1	47.4	22.7	33.8	30.2	35.1	33.1
INFRASTRUCTURE											
Joint laboratories	8.9	1.0	1.8	6.3	10.6	2.3	1.2	3.5	5.1	3.7	3.9
Use of university technical infrastructure	27.7	2.2	3.5	29.8	26.3	5.3	1.4	9.9	12.8	15.7	10.7
EDUCATION											
Employing graduates in R&D	25.5	1.3	18.6	36.0	18.3	25.4	10.5	17.0	20.5	33.5	18.4
Contact of graduates with university	8.5	15.6	9.6	17.5	2.5	13.2	5.3	7.9	16.6	16.0	10.1
Students' participation in firm R&D	14.4	2.1	11.0	18.1	12.0	10.6	11.5	9.1	15.9	16.1	10.9
Diploma theses	16.2	4.4	18.1	22.5	11.9	15.6	21.2	12.7	24.2	27.0	15.7
PhD	6.4	16.4	5.1	8.9	4.6	2.6	8.1	5.5	11.5	10.4	7.0
University researchers' participation in firm R&D	16.7	14.4	5.5	11.0	20.6	5.2	5.8	10.9	8.0	5.9	10.1
Joint courses	5.7	1.1	3.4	4.7	6.4	1.7	5.4	3.5	4.6	5.4	3.8
Teaching of firm researchers at the university	7.8	2.1	8.9	6.6	8.7	11.4	5.8	8.2	5.7	7.3	7.7
Attending university training courses	17.1	20.0	25.2	23.8	12.7	36.3	12.0	20.2	26.3	33.4	22.1
RESEARCH											
R&D joint projects	24.6	16.6	11.8	24.3	24.8	12.3	11.1	16.8	13.7	21.6	16.3
Long-term research contracts	6.7	1.3	5.0	5.2	7.7	4.8	5.3	5.1	4.6	6.6	5.0
Research consortium	4.6	1.3	4.6	7.0	2.9	4.0	5.3	4.3	3.0	7.8	4.1
CONSULTING											
Expertise	17.2	0.3	10.4	9.0	22.7	7.2	14.2	11.5	9.5	13.1	11.1
Consulting	25.6	1.7	10.2	16.0	32.0	6.8	14.2	13.8	13.4	14.3	13.8
N	445	32	192	275	170	136	56	182	288	199	669

Some more empirical literature and some implications

In Schartinger et al. (2001) firms ranked the recruitment of graduates as the most important form of KTT, followed by supervision/financing of PhD and master theses, contract research and joint research. The Lambert Review of Business-University Collaboration (2003) stated for England similarly that the best forms of knowledge transfer involve human capital transfer. They serve very often as a starting point for more codified and structured forms of KTT. Lessmann and Rossner (2004) found for Saxony that the supervision of graduates, trainees and PhDs are the most frequent forms of KTT (57.3% of knowledge-based firms). Blume and Fromm (2000) reached similar results for several universities in Germany[11]. KTT activities most frequently are related to educational aspects (graduates, students, diploma theses). They dominate other forms like consulting and R&D co-operations. In OECD (2002) is stated that formal mechanisms of KTT are rather rare and that the bulk of knowledge transfer takes place through informal forms (e.g. through personal network). Salter et al. (2000) found for the UK that almost half of the manufacturing firms considered universities as important sources of innovation but only 10% of them have developed formal relationships to the universities (e.g. R&D co-operations). The PACE-Report (see Arundel et al. 1995) stated already in 1995 that publications, informal contacts, trained staff, conferences are the most important forms for learning about research conducted in public institutes. We can confirm these early results also for Switzerland. We obtain a somewhat different picture, if we compare our results with a USA study about the influence of federal laboratory R&D on industrial research. The industrial R&D laboratories assessed inflows of ideas from government labs as important; test facilities in government laboratories and co-operative research and development agreement (CRADA) were next in frequency (see Adams et al. 2003). While "the inflows of ideas" may be comparable with our "informal" category, the other types of interactions stand for more intensive contacts, which are of lower importance for Swiss firms.[12]

The importance of informal contacts and educational aspects for KTT is closely related to the main mission of universities. They have to conduct basic research and to educate scientists; these are their "core-competencies". Of course, firms want to make use of these competencies in the first instance, since they are not available elsewhere. Furthermore, universities patent more codified research results and license them, which indicates that part of their research is of immediate commercial interest. So far such activities are of minor importance for the economy. However, it is questionable if a more applied orientation of university research is recommendable in order to increase its economic impact. Mansfield (1998) observed a decrease in the average time lag between academic research results and the first commercial

[11] These are: University of Kassel, Ludwig-Maximilians-University München, University of Hamburg (incl. University of Hamburg, TU Hamburg-Harburg, University of Applied Sciences (UAS) Hamburg, University for Economics and Policy, University of Federal Armed Forces, University of Arts, UAS Public Administration, UAS for Music and Theater, Protestant UAS for Social Pedagogy), University of Erlangen-Nürnberg.

[12] This study differs from ours in several respects (e.g. university vs. government laboratories, size of the laboratories and firms respectively, only manufacturing firms) which limits the comparability. Government R&D laboratories are different from university laboratories for which educational aspects are of much greater importance than for government laboratories.

introduction of new products and processes based on USA data for selected industries between the two periods 1975-1985 and 1986-1994. He wrote: “This decrease could be of considerable economic benefit if it represents a quicker utilisation of the findings of recent academic research, but it could have a quite different implication if it is due to a shift in academic research toward more applied and short-term work” (Mansfield 1998, p. 776). Johnson (1992) sees the stimulating effect of research co-operations in the different modes of behaviour and habits of thought of the partners. In fact, these factors are likely to be different in R&D co-operations between business and universities. Freeman (1992) argues that the experiences of users are very important for the incremental type of innovation and that the contribution of scientific institutions tends to be predominant in the early stages of more radical innovation. Kaufmann and Tödtling (2001) found that “pure” science stimulates advanced innovations more than applied research focusing on commercialisation. They also stated that personal contacts and publications are the most important mechanism for knowledge transfer. This can be claimed to be the case at least to some extent for Switzerland as well.

3.1.3 Intensity of KTT Activities

We constructed measures of the intensity of KTT activities through combinations of the five main groups of KTT activities distinguished in the section 3.2.1. First, we ranked the five main groups according to the “degree of codification” of transferred knowledge: “informal contacts” (“contacts” in Table 3-9) received the weight 1, “educational activities” (“education”) the weight 2, “consulting activities” (“expertise”) the weight 3, “technical infrastructure” (infrastructure”) the weight 4 and “research activities” (“research”) the weight 5 respectively (see Table 3-9). Second, we constructed all possible combinations of two, three, four and five main groups of forms of KTT activities. For every one of these 32 combinations we calculated the sum of the weights of the constituent main forms of KTT activities. These are also listed in Table 3-9. We consider this figure as a measure of the intensity of KTT activities. The more (high-valued) activities a firm pursues, the higher is the intensity of KTT activities as measured by this indicator. Finally, we calculated the shares of firms with a certain level of intensity for the five subsectors of the economy (columns 1 to 5 in Table 3-9).

Most frequently firms choose single forms or combinations of forms with a high share of tacit components, e.g. informal contacts, education or the combination of both of them (contacts+ education). However, the base category “no KTT form is very important” is the most frequent category in construction (45.6%) and in traditional services (36.6%), even in high-tech sector but in this case with a rather low firm share of 16.6%.

Among two-form combinations the combination (contacts+education) is the most frequent one for all subsectors. Among three-form combinations the combination (contacts+education+ infrastructure) is the most frequent one for high-tech firms, while this is the case for (contacts+expertise+infrastructure) for low-tech firms. The remaining subsectors show a zero share for all three-form combinations.

When four main categories of forms of KTT activities are combined, then the combination (contacts+education+infrastructure+research) is the most frequent one for high-tech firms as well as for construction firms. Low-tech firms appreciate at most the four-form combination (contacts+education+expertise+research). The same is valid for firms in the modern service subsector as well as in the traditional service subsector.

There are about 3% of the manufacturing firms (high-tech and low-tech), which combine all five forms of KTT activities. This is quite in contrast to the remaining sectors/subsectors, where the fivefold combination is clearly less frequent.

In sum, the combination of different KTT forms is characteristic for a subsector. A variety of ways to interact with universities and transfer knowledge is available, still many firms evaluate none of them as very important. Excluding the "none important" category, high-tech firms, firms in the modern service sector and construction firms most frequently combine two main categories; low-tech firms and traditional services rely predominantly on one main group. Rather surprisingly, firms in the low-tech subsector show the strongest tendency to combine four or five different main groups (22.1%), followed by the high-tech sector (15.8%).

Table 3-9: Intensity of KTT activities; percentage of firms reporting a certain combination of the main forms of KTT activities as listed in this table

Intensity levels		*High-tech*	*Low-tech*	*Modern service*	*Traditional service*	*Construction*
None important	0	16.6	12.8	14.3	36.6	45.6
Contacts	1	11.8	19.6	13.2	33.2	2.2
Education	2	7.6	12.2	13.4	8.0	0.0
Expertise	3	1.0	0.6	1.9	0.2	0.0
Infrastructure	4	1.8	0.6	0.0	0.0	0.0
Research	5	0.1	0.0	0.7	0.6	1.1
contacts+education	6	14.6	8.9	34.8	6.0	33.1
contacts+expertise	7	0.8	3.9	0.1	0.0	0.0
education+expertise	8	2.0	0.9	0.1	2.4	0.0
contacts+infrastructure	9	1.8	0.8	0.0	0.0	0.0
education+infrastructure	10	4.8	1.8	2.0	0.8	0.0
contacts+research	11	0.7	0.7	1.5	0.0	0.0
expertise+infrastructure	12	0.7	0.0	0.0	0.0	0.0
education+research	13	4.5	0.5	1.8	0.0	0.0
expertise+research	14	0.0	0.1	0.0	0.0	14.2
infrastructure+research	15	0.0	0.2	0.0	0.0	0.0
contacts+education+expertise	16	1.7	1.5	2.6	0.6	1.4
contacts+education+infrastructure	17	5.4	2.7	1.0	0.6	1.1
contacts+education+research	18	4.8	3.7	5.9	0.0	0.0
expertise+infrastructure+contacts	19	1.0	6.2	0.0	0.0	0.0
expertise+research+contacts	20	0.7	0.0	0.1	0.0	0.0
education+expertise+infrastructure	21	0.1	0.4	0.1	0.0	0.0
infrastructure+research+contacts	22	1.1	0.0	0.0	0.0	0.0
education+expertise+research	23	0.8	0.0	0.0	0.0	0.0
education+infrastructure+research	24	0.2	0.1	2.1	0.0	0.0
expertise+infrastructure+research	25	0.0	0.0	0.0	0.0	0.0
contacts+education+expertise+infrastructure	26	4.1	1.6	0.2	0.6	0.0
contacts+education+expertise+research	27	1.3	7.3	2.3	10.5	0.2
contacts+education+infrastructure+research	28	6.1	0.7	0.2	0.0	1.0
expertise+infrastructure+research+contacts	29	0.0	2.5	0.0	0.0	0.0
education+expertise+infrastructure+research	30	1.3	6.7	0.0	0.0	0.0
contacts+education+expertise+infrastructure+research	31	3.0	3.3	2.0	0.0	0.2
All		100.0	100.0	100.0	100.0	100.0

Table 3-10: Brief summary of incidence and forms of KTT activities

27.6% of all firms are involved in KTT activities. This figure is somewhat lower for small firms and raises to 47.1% for large firms. Firms in the high-tech sector and in the modern service sector show the highest incidence of KTT activities. Especially firms in the chemical industry, in electronics/instruments and in business services are most often engaged in KTT. The region of Zurich has the highest share of KTT-active firms among the seven regions. Changing our view from this static picture to a more dynamic perspective, it becomes obviously that comparing two periods in time (before 2002 and between 2002-2004) the number of KTT-active firms increased. Especially sectors with a rather low KTT incidence registered the greatest increase in KTT-active firms, these were the construction sector and the sector of traditional service industries. Firms with KTT activities intensified them in the last years in 35.2% of the cases (20% weakened them). Predominantly firms in the construction and in the manufacturing sector did so.

"Tacit" forms for KTT are more important than "codified" ones. This result is quite in line with studies for other countries. More than 50% of KTT-active firms in Switzerland find "informal, personal contacts" and KTT through graduates or educational activities with universities as the most important forms for KTT, independent of sector and size class. At a more detailed level, the respondents highlight particular single forms such as "referring to publications", "attending conferences" and "informal personal contacts". In contrast, "joint courses", "joint laboratories" and "research consortiums" are at least important. In fact, KTT active firms combine different forms for KTT. High-tech firms, firms in the subsector of modern service industries and construction firms most frequently combine two main groups of forms (i.e. informal contacts and education). Rater unexpectedly, 22.1% of low-tech firms (KTT active) combine four or five main groups of KTT forms.

3.2 Channels, Mediating Institutions and Partners of Knowledge and Technology Transfer Activities

3.2.1 Mediating Institutions

We asked the firms with KTT activities how important are the following mediating institutions for gaining formal contacts with universities: Technology Transfer Offices of the Universities, the Commission for Technology and Innovation (KTI), the Swiss Science Foundation (SNF), the Framework Programmes of The European Union and other Research Programmes of the European (e.g. EUREKA). 82.7% of KTT-active firms stated that none of the mentioned institutions is "very important" for gaining formal contacts with universities (i.e. they reported 1 or 2 or 3 on a five-point Likert-scale (1: "not important"; 5: "very important"; see Table 3-11). This result is valid for all firm size classes. Manufacturing firms appreciated the service of mediating institutions more frequently than other sectors. In contrast, 98.6% of the firms in the construction sector found that mediating institutions are not very important for their KTT activities. At the subsector level, high-tech firms perceived the service of mediating institutions more often as more relevant than firms in any other subsector.

The services of the KTI are highly appreciated by around 11% of KTT-active firms, while 9.5% ranked the services of the Transfer Offices as "very important" for gaining formal contacts with university (see Table 3-12). The EU Framework Programmes, other EU research programmes and the SNF are "very important" for a much lower number of firms. This is at least in the case of SNF, which mostly supports basic research, understandable.

Small-sized, medium-sized and large firms appreciate at most the services of the KTI, followed by those of Transfer Offices. The services from the EU Framework Programmes, the SNF and other EU research programmes are appreciated to a much lower extent than those of the first two categories of mediating institutions. Firms in the manufacturing sector (high-tech and low-tech to the same extent) and the service sector (mainly modern services) most frequently found the services of the KTI as very useful. Firms in the construction sector and in the subsector of traditional service industries appreciated more the services of Transfer Offices. The activities of the SNF in the field of KTT is more often appreciated by firms in the service sector and here especially in the subsector of modern service industries than in other ones. In contrast, firms in the high-tech subsector and in the sector of traditional services (for the "Framework Programmes" only) find the services of international programmes and institutions (EU) relatively often very helpful.

In sum, Technology Transfer Offices are more oriented to firms in the modern service sector and the construction sector. The KTI services are focusing to firms in the manufacturing sector (high-tech and low-tech), independent of firm size. The SNF is more relevant for large firms in the service sector (modern as well as traditional services). The EU programmes are predominantly interesting for large firms in the high-tech and to some extent in the traditional service subsector (EU Framework Programme).

Comparing the Swiss results with findings for Austrian firms, we arrive at a similar result. "Broker agencies" are also in Austria of minor importance (Schibany et al. 1999). Also for Austria but based on much older data for 1996, a study stated the rather low importance of Technology Transfer Organisations (Kaufmann and Tödtling 2001).

Table 3-11: Overall importance of mediating institutions; percentage of firms reporting 1, 2 or 3 at a five-point Likert-scale by sector, subsector and firm size class

	N	*Mediator not very important*
Sectors		
Manufacturing	445	74.0
Construction	32	98.6
Services	192	83.6
Subsectors		
High-tech	275	72.4
Low-tech	170	75.1
Modern services	136	84.2
Traditional services	56	82.9
Size		
Small	182	82.8
Medium	288	82.3
Large	199	82.9
Total	**669**	**82.7**

Table 3-12: Importance of single mediating institutions; percentage of firms reporting 4 or 5 at a five-point Likert scale by sector, subsector and firm size class

	N	*Transfer-offices*	*Innovation Promotion Agency (KTI)*	*Swiss National Science Foundation (SNF)*	*Framework Programmes EU*	*Other Research Programmes EU*
Sectors						
Manufacturing	445	13.7	17.7	1.5	3.0	2.7
Construction	32	1.4	0.2	0.2	0.3	0.2
Services	192	9.1	9.9	5.6	3.9	1.2
Subsectors						
High-tech	275	12.6	17.7	3.1	6.5	5.7
Low-tech	170	14.4	17.8	0.4	0.6	0.6
Modern services	136	6.7	9.5	6.0	2.8	2.3
Traditional services	56	11.9	10.5	5.3	5.3	0.0
Size						
Small	182	10.5	11.1	3.7	2.9	1.2
Medium	288	6.3	10.9	3.4	3.7	2.1
Large	199	6.6	10.4	2.6	5.0	4.0
Total	**669**	**9.5**	**11.0**	**3.6**	**3.2**	**1.5**

3.2.2 Channels

In the policy discussion about the economic impact of universities indicators such the number of like patents, licenses and/or spin-offs/start-ups are often used as performance measures. These three indicators are considered as important vehicles of commercialisation of university inventions. We asked firms to assess the relevance of these channels for their own KTT activities and included scientific publications as an additional channel of information exchange.

More than half of the KTT active firms stated that at least one of these channels is "very important" for transferring knowledge. This figure is clearly higher for firms in the high-tech industry and lower for firms in the traditional service subsector and the construction sector (see Table 3-13).

Scientific publications are the most important channel for KTT from a firms' perspective, independent of firm size, sector or subsector. 33.6% of the KTT-active firms stated that scientific publications are "very important" for transferring knowledge. In contrast, patents are very important for only 8.5% of the firms, licenses for 5.4% and spin-off/start-ups for 5.3%. This ranking is valid for medium-sized and large firms and for firms of the manufacturing and the construction sector. Firms of the service sector emphasises licenses and spin-offs/start-ups more than patents. At the subsector level, high-tech and low-tech firms appreciate patents clearly above average. So do firms of the traditional service industries, high-tech and low-tech manufacturing in the case of spin-offs/start-ups. Licenses seem to be of particular importance for high-tech firms and firms of modern services.

Table 3-13: Importance of channels of KTT activities; percentage of firms reporting 4 or 5 at a five-point Likert scale by sector, subsector and firm size class

	N	*Scientific Publications*	*Patents*	*Licenses*	*Spin-offs/Start-ups*
Sectors					
Manufacturing	445	34.1	20.0	8.2	7.5
Construction	32	19.3	1.3	0.2	0.0
Services	192	36.8	3.9	5.2	5.2
Subsectors					
High-tech	275	30.4	20.7	13.8	6.8
Low-tech	170	36.6	19.6	4.3	8.0
Modern services	136	48.5	6.6	9.5	4.7
Traditional services	56	22.8	0.7	0.0	5.8
Size					
Small	182	32.9	8.2	5.4	6.1
Medium	288	36.0	8.1	5.8	2.7
Large	199	34.4	14.8	4.2	3.6
Total	**669**	**33.6**	**8.5**	**5.4**	**5.3**

3.2.3 Partners

Firms reported also the institutions(s) (Federal Institutions, Canton Universities and Universities of Applied Sciences) with which they interacted. Many firms reported more than one institution. The information on the frequency of contacts of firms with Swiss science institutions is presented in Table 3-14. About 31.5% of KTT-active firms reported that they had KTT activities with the Federal Institute of Technology in Zurich (ETHZ), 25.4% of the firms are in contact with the Swiss Federal Laboratories for Materials Testing and Research (EMPA) and 19.1% stated that they have KTT contact(s) with the Federal Institute of Technology Lausanne (EPFL). Outside the ETH-Domain, the University of St. Gallen was mentioned by 17.1% of the KTT-active firms and 12.1% of the firms have KTT contacts with the University of Zurich and the University of Bern. As to the Universities of Applied Sciences (UAS), 9.1% stated to have KTT contacts with the UAS Zurich (Winterthur) and 8.7% mentioned the UAS Aargau.

We distinguish three domains of science institutions: the ETH-domain, the University-domain and the domain of the Universities of Applied Science. Table 3-15 shows the shares of firms reporting contacts to at least one institutions of a domain by sector, industry and firm size class. 56.7% of all KTT-active firms have at least one contact with institutions of the ETH-domain. 55.6 % of the firms do so with the UAS-Area and 37.5% of the firms have contacts with at least one University. This ranking of the three groups of institutions is also valid for small-sized and medium-sized firms. Large firms are most frequently involved in KTT activities with UAS (74.5%) but the difference to the ETH-domain is small (70.8%). At sector or subsector level, firms show quite different affinities to one or the other domain/area. The construction sector emphasises the ETH-Domain, while manufacturing, especially the low-tech subsector, focuses on the UAS-Domain. ETH-Domain and UAS-Domain are of equal importance for firms in the service sector. Traditional services show the same ranking as construction: ETH-Domain comes first, followed by the University-Area and the UAS-Domain.

As to single industries the picture is rather heterogeneous, which might be also caused by the great differences in number of observations in the respective industry. Banking/insurance emphasise more the University-Area compared to UAS-Domain and ETH-Domain. KTT-active firms in twelve industries reported more frequently conacts with the ETH-Domain than with the UAS-Domain or the University-domain. These are e.g. firms in the textile industry, plastics/rubber, metal, electrical machinery, energy/water, transport, computer services. In contrast, firms of the remaining eleven industries, e.g. in the paper industry, printing, chemicals, metalworking, machinery, electronic/instruments, or telecommunication emphasise more the UAS-Domain.

We constructed also an indicator of the intensity of the contacts to public research institutions based on the number of contacts of a firm to single science institutions (see the list of institutions in Table 3-14). KTT-active firms have had 2019 contacts with the public research area on the total. 39.2% of all contacts involved institutions of the ETH-domain, 37.1% institutions of the UAS-domain and 23.7% of the University-domain (see Table 3-16). It is qualitatively the same picture as in table 3-15. This ranking of the three groups of science

institutions is valid also for small-sized and medium-sized firms. Large firms have more contacts with the UAS-domain than with other domains. Also at the sector and subsector level we see a similar picture as in Table 3-15. Manufacturing firms most frequently have contacts with the UAS-domain, construction firms and service firms emphasise the ETH-domain. Remarkably and in contrast to Table 3-15 high-tech firms more frequently have contacts with the UAS-domain than low-tech firms. This indicates that high-tech firms have usually more than one and more diverse contacts with science institutions than low-tech firms. Traditional services have relatively more contacts with the University-domain than with any other domain. We obtain a slightly different picture at industry level, if we compare the results based on the "share of firms" (see Table 3-15) with the results based on the "shares of contacts" (see Table 3-16). Firms in the textile industry, energy/water industry and glass/stone/clay industry most frequently are engaged in KTT activities with institutions of the ETH-domain according to the criterion "share of firms". The same is valid for banking/insurance, transport and wholesale with respect the Universities-domain. Firms in the telecommunication industry, vehicles and paper industry show the highest shares of contacts with the UAS-domain. The following industries show different preferences depending on the concept applied ("number of firms" vs. "number of contacts"), electrical machinery and other manufacturing switch from ETH-Domain to UAS-Domain and wholesale and transport switch from ETH-Domain to University-Domain.

In sum, if we compare the two approaches we detect differences at the subsector level as well as at the industry level. According to the second approach (shares of contacts), the dominance of the ETH-domain decreases and also traditional services emphasise more the University-domain than the ETH-domain. This may be due to the fact that firms diversify their contacts and that these contacts are not equally distributed. Thus, it is likely that e.g. one contact with the ETH-domain is combined with several contacts of the UAS-domain.

We also investigated whether specific transfer forms are related to KTT contacts with a specific domain. Table 3-17 contains information on the relative importance of the three domains of KTT partners for each of the five types of forms of KTT activities distinguished earlier in this study (see section 3.1.2). This table can be read in several ways. Firstly, firms reporting that informal contacts or research are very important forms for KTT most frequently are in contact with the ETH-domain. Firms emphasising infrastructure or consulting are mostly engaged in the UAS-domain. As to the University-domain no clear profile can be found. Secondly, large differences between the categories "very important" and "less important" may indicate whether the respective form is a specific characteristic of a certain area/domain. Applying a criterion of 10%-difference, it can be seen that the importance of research and consulting may be a specific trait of the ETH-domain, while the same is true for infrastructure, education and consulting for the UAS-Domain. The University-Domain does not show any specific profile fulfilling the chosen criterion.

Table 3-14: Percentage of firms with KTT activities with a certain science institution as KTT partner

Science institutions	*Total*
Federal Institute of Technology Zurich	31.5
Federal Institute of Technology Lausanne	19.1
Paul Scherrer Institute (PSI)	7.9
Swiss Federal Institute of Aquatic Science and Technology (EAWAG)	3.2
Swiss Federal Laboratories for Materials Testing and Research (EMPA)	25.4
Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)	7.5
University of	
Berne	12.1
Basle	3.3
Fribourg	3.7
Geneva	3.1
Lausanne	2.4
Neuchatel	3.4
St.Gallen	17.1
Italian Switzerland	0.0
Zurich	12.1
University of Applied Sciences of North-western Switzerland:	
School of Aargau	8.7
School of Basle	7.4
School of Solothurn	2.4
University of Applied Sciences of Italian Switzerland	2.0
University of Applied Sciences of Berne:	
School of Engineering St. Imier	0.8
School of Engineering & Architecture Berne	4.0
School of Engineering & Architecture Biel	6.0
School of Engineering & Architecture Burgdorf	5.7
School of Business & Administration	0.9
School of Business (private)	0.6
School of Business Berne (private)	0.1
School Wood Technology	3.8
School of Agriculture	0.5
University of Applied Sciences of Eastern Switzerland:	
School of Buchs	5.8
School of St.Gallen	3.7
School of Rapperswil	0.2
University of Applied Sciences of Central Switzerland:	
School of Social Work Luzern	0.3
School of Engineering & Architecture Luzern	7.0
School of Business Luzern	3.2
University of Applied Sciences of Western Switzerland:	
School of Engineering Changins	0.7
School of Engineering Canton Neuchâtel	2.3
School of Engineering Canton Vaud	2.1
School of Engineering & Architecture Fribourg	2.3
School of Administration Fribourg	0.2
School of Valais	3.0
School of Geneva	0.3
University of Applied Sciences of Zurich:	
School of Engineering, Business & Administration Zurich	3.7
School of Wädenswil	2.8
School of Zurich Winterthur	9.1
N	**669**

Table 3-15: Percentage of firms with KTT activities with institutions of a certain domains of science institutions as KTT partners; by sector, industry and firm size class

	N	*ETH-domain*	*University-domain*	*Univ.Appl.Science-domain*
Industries				
Food/beverage	34	58.5	22.7	77.8
Textile	9	100.0	2.1	75.5
Wood processing	9	95.9	67.3	75.5
Paper	9	13.7	66.7	86.6
Printing	17	25.6	71.9	80.4
Chemicals	37	51.5	43.3	64.3
Plastics/rubber	13	97.1	32.7	94.2
Glass/stone/clay	13	61.6	0.7	37.9
Metal	9	55.0	48.5	57.2
Metalworking	37	58.6	28.6	92.8
Machinery	116	56.6	24.6	73.2
Electrical machinery	33	97.9	27.8	70.6
Electronic/instruments	67	54.8	26.7	62.3
Watches	6	47.1	68.4	81.5
Vehicles	9	19.4	5.9	57.8
Other manufacturing	12	95.0	81.2	82.8
Energy/water	15	80.5	28.3	53.0
Wholesale	35	41.4	36.7	38.6
Transport	21	66.0	64.9	45.8
Banking/insurance	35	3.6	83.6	48.8
Computer services	28	82.9	25.4	52.7
Business services	67	66.8	22.6	65.8
Telecommunication	6	10.0	4.8	95.5
Sectors				
Manufacturing	445	61.9	35.5	75.9
Construction	32	56.4	45.4	23.3
Services	192	53.9	36.7	52.3
Subsectors				
High-tech	275	60.8	27.8	69.6
Low-tech	170	62.7	40.7	80.1
Modern services	136	59.3	31.0	62.2
Traditional services	56	47.4	43.6	40.4
Size				
Small	182	53.6	31.4	53.2
Medium	288	64.9	54.8	60.5
Large	199	70.8	57.5	74.5
Total	**669**	**56.7**	**37.5**	**55.6**

Table 3-16: Percentage of contacts with different domains; by sector, industry and firm size class

	ETH-domain	*University-domain*	*Univ.Appl.Sciences-domain*
Industries			
Food/beverage	31.7	13.2	55.1
Textile	67.6	0.5	32.0
Wood processing	45.5	21.4	33.1
Paper	9.8	27.3	62.8
Printing	13.3	25.8	60.9
Chemicals	29.9	30.9	39.2
Plastics/rubber	49.9	16.5	33.6
Glass/stone/clay	57.8	0.6	41.6
Metal	35.5	28.3	36.2
Metalworking	47.0	11.1	41.9
Machinery	37.5	14.3	48.2
Electrical machinery	42.0	9.0	49.0
Electronic/instruments	32.3	16.8	50.9
Watches	20.6	22.8	56.6
Vehicles	21.9	7.9	70.2
Other manufacturing	34.0	29.3	36.7
Energy/water	64.1	12.3	23.6
Wholesale	30.0	39.9	30.1
Transport	35.7	40.8	23.5
Banking/insurance	1.9	60.7	37.5
Computer services	47.9	20.0	32.1
Business services	46.1	10.7	43.3
Telecommunication	13.3	16.0	70.7
Sectors			
Manufacturing	38.5	16.2	45.3
Construction	55.7	28.9	15.5
Services	36.9	27.4	35.8
Subsectors			
High-tech	36.8	16.2	47.0
Low-tech	39.7	16.2	44.2
Modern services	40.8	18.2	41.1
Traditional services	31.4	40.2	28.4
Size			
Small	40.5	21.9	37.7
Medium	36.6	27.8	35.6
Large	35.7	27.6	36.7
Total	**39.2**	**23.7**	**37.1**

Table 3-17: Main forms of KTT activities by domain of science Institutions; percentage of firms

	ETH-domain	*University-domain*	*Univ.Appl.Science-domain*
Informal contacts			
Very important	58.8	39.7	56.4
Less important	54.0	34.6	54.6
Infrastructure			
Very important	62.4	38.0	81.4
Less important	55.9	37.4	52.1
Education			
Very important	59.2	41.0	62.8
Less important	54.0	33.7	47.8
Research			
Very important	65.3	42.0	63.0
Less important	54.9	36.5	54.0
Consulting			
Very important	46.2	45.9	71.7
Less important	58.6	36.0	52.7

Percentage share of firms reporting “informal contacts”, “infrastructure”, “education”, “research” or “consulting” as “very important” for KTT activities with institutions of a certain domain as KTT partners.

Table 3-18: Brief summary of the section on mediating institutions, channels and partners of KTT activities.

82.7% of KTT-active firms stated that none of the KTT-mediating institutions (i.e. Technology Transfer Offices, KTI, SNF, Framework Programmes of the EU, other EU research programmes) is of great relevance for entering into relationship to a university. This figure is lower for firms in the manufacturing sector, especially in the high-tech subsector. The services of the KTI are most frequently evaluated as very important. Transfer offices seem to be more important for firms in the modern services and in the construction sector than in other sectors. The KTI is most useful for firms in the manufacturing sector (high-tech and low-tech), independent of firm size. The SNF is most useful for large firms in the modern service subsector. EU programmes are predominantly interesting for large firms in the high-tech sector.

More than half of the KTT active firms stated that at least one of the KTT channels (i.e. scientific publications, patents, licenses, spin-offs/start-ups) is very important for KTT. "Scientific publications" is the most important channel, independent of firm size and sector.

31.5% of KTT active firms stated that they have at least one KTT contact with the ETH Zurich. 25.4% are in contact with EMPA and 19.1% have contact(s) with the EPFL. As to the University-area, University of St. Gallen (17.1%), University of Bern (12.1%) and University of Zurich (12.1%) were quoted most frequently. As to the UAS-area KTT-active firms also named very often, UAS Zurich Winterthur (9.1%) and UAS Aargau (8.7%).

56.7% of all KTT-active firms have at least one contact with the ETH-domain. 55.6% do so with the UAS-area and 37.5% have contacts with the University-domain. Firms diversify their contacts between different areas/domain, e.g. a contact with the ETH-Domain is often combined with several contacts with institutions of the UAS-Domain.

Firms stating that informal contacts or research are very important forms for KTT, are most frequently in contact with the ETH-domain. Firms emphasising infrastructure or consulting are predominantly engaged in the UAS-domain.

3.3 What are the Motives for Knowledge and Technology Transfer Activities?

Based on existing empirical literature we collected the most important motives for KTT activities (see Table 3-19). Finally, we transformed the available information to 20 different motives. The KTT-active firms were asked to evaluate the importance of these 20 different motives and objectives for KTT activities on a five-point Likert-scale ranging from 1 ("not important") to 5 ("very important"). We consider a motive as important if the respondent reported 4 or 5 on the given scale. The 20 different motives were pooled into 4 main groups: "access to human capital (tacit knowledge)", "access to research results (codified knowledge)", "financial motives", and "institutional/organisational motives". Table 3-20 contains the shares of firms reporting 4 or 5 on a five-point Likert scale with respect to at least one out of a series of single motives belonging to the respective main group of motives (e.g. five single motives referring to "access of tacit knowledge" or five "financial motives" and so on; see also Table 3-22).

"Access to human capital (tacit knowledge)" is by far the most important main group of motivation for KTT activities (65.9% of KKT-active firms). "Financial motives" (41.1%) and "access to "research results (codified knowledge)" (29.3%) are next in importance followed by "institutional/organisational motives" (25.0%). This ranking in importance is valid independent of firm size and the affiliation to a specific subsector or sector.

Do firms that intensified or weakened their KTT activities show a specific profile as to the main groups of motives? In fact, all main groups of motives were assessed as important more frequently by firms that intensified their KTT activities compared to firms that weakened them (see Table 3-21). The motive group "access research results" as well as "financial motives" are by far more important motives for firms that intensified their KTT activities than for firms that weakened them.

Table 3-22 contains the percentage shares of firms reporting 4 o5 on a five-point Likert scale for 20 single motives for KTT activities. Focusing on the three most important ones, we can see that "access to abilities in addition to internal know-how" (46.3% of all KTT-active firms) is the most important single motive for KTT independent of any categorisation with the exception of firms in the modern service sector, which slightly feel stronger motivated by university offerings for "further educational and training possibilities for firm employees" (47.2%). On total, "further educational and training possibilities for firm employees" and "project characteristics require co-operation with science institutions" are next in importance (29.5% and 25.6% respectively).

"Project characteristics require co-operation with science institutions" and "insufficient firm R&D resources" are second and third in importance for firms in the manufacturing sector. In contrast, "further educational and training possibilities for firm employees" and "access to research results for developing new processes" are important motives for firms in the construction sector and "further educational and training possibilities for firm employees" and "new research ideas" are of second and third importance for the service sector.

Firms in the low-tech subsector reflect the motivation structure of the manufacturing sector. In contrast, firms in the high-tech subsector are stronger attracted by the objectives "further educational and training possibilities for firm employees" and "access to research results for developing new products". For firms of modern as well as traditional service industries is the motive "further educational and training possibilities for firm employees" the second most important one. Third most important motive is for modern services the "access to basic research", for traditional services gaining "new research ideas".

Small-sized as well medium-sized firms assess similarly the two most important motives. However "project characteristics require co-operation" is of third importance for small firms, "insufficient firm R&D resources" third most important motive for medium sized firms and "recruiting graduates in R&D" for large firms.

What is the weakest motive for KTT activities? Rather unexpected, only 3.7% of all KTT-active firms feel motivated to contact a university to "build up a new research field". This means that contrary to a popular opinions among observers most firms seem to be looking for knowledge of immediate use and complementary to knowledge already available or newly generated in their labors.

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.

Short discussion of some empirical literature and some implications

According to a survey in Austria, firms' main motivation for KTT is "the capacity to solve problems" (see Schartinger et al. 2000). Given the tacit character of university knowledge, this emphasises – like in Switzerland – the human factor. As a consequence well-educated graduates can be seen as the most important output of the Austrian university system. Quite different are research results for the USA. Hall (2004) found that US firms' greatest motivation for KTT is "access to new research" followed by "development of new products". "Solving technical problems" and "improving products and recruiting students" are of minor importance. This indicates that transfer activities are more dedicated to research than to educational aspects. The opposite is true for European countries like Switzerland and Austria.

Swiss firms expect from the universities well-educated graduates and access to first-class research results. These are the two most important groups of motives for KTT activities. Subsectors with great affinity to science (e.g. high-tech manufacturing) are more frequently motivated to get engaged in KTT in order to develop new products and/or by the fact that an increasing number of firms undertake KTT activities also from sectors that are not closely related to any scientific discipline (e.g. the service sector). Furthermore, 32.5% of KTT-active firms increased their activities within the last two years (2002-2004). Thus, more firms are engaged in KTT and already active firms intensified their activities. Most of them diversify their forms of contact. Informal contacts and education related forms are most frequently combined. Although the interaction is intensified in several ways, mostly firms seek to transfer knowledge through education and informal contacts and to a much lesser extent through more codified forms like patents/licenses or concrete research co-operation.

Table 3-19: Overview of empirical literature on motives for KTT Activities

Motives	*A*	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*
Access to human capital (in general)	X	X	X	X	X	X			X		
Access to specific skills		X						X			
Training		X									X
Recruiting graduates							X			X	
Access to technical facilities/specific technologies			X		X			X			X
Networking	X						X		X		
Opportunities for problem solving	X	X					X		X	X	
Access to new complementary knowledge/technology	X	X	X			X	X	X	X	X	X
Assure technological „state of the art“		X	X			X			X		
Scientists participation in business conferences		X									
Accelerating internal technological advancement (catch up)		X	X								
Focused co-operations (start-ups, patents)		X					X				
Access to universities (basic research)		X			X		X		X		
Research stimulus			X	X	X	X	X				
Share R&D costs (technical R&D risks)			X			X			X		X
R&D time saving											X
Enhancing/improving knowledge base (external knowledge)			X		X				X		
Improving image through co-operations wit the university			X	X		X					
Lacking material resources				X		X					
Co-operation with university as condition for public funding				X							X
Direct support of R&D process					X		X				
Consulting					X						
Indirect access to the knowledge of the competitor						X					
Building-up new field of investigation						X	X		X		
„Outsourcing“ of R&D									X		

A = OECD (2002), B = Geisler/Rubinstein (1989), C = Arthur D. Little (2000), D = Mayer (2000),
E = Schartinger et al. (2001), F = Onida/Malerba (1989), G = Lee (2000), H = Santoro/Chakrabarti (2002),
I = Schibany/(2001), J = Schmoch (2003), K = Arvanitis et al. (2001).

Table 3-20: Main categories of motives for KTT activities; percentage of KTT-active firms pursuing strongly a certain category of motives (see the text for a detailed description of the main categories of motives) by sector, subsector and firm size class

	N	*Access human capital ("tacit knowledge")*	*Access research results ("codified knowledge"*	*Financial motives*	*Institutional/organisational motives*
Sectors					
Manufacturing	445	73.2	45.2	58.7	36.4
Construction	32	38.6	19.4	30.6	16.1
Services	192	68.3	23.0	34.1	21.0
Subsectors					
High-tech	275	68.4	41.8	47.6	24.9
Low-tech	170	76.5	47.4	66.1	44.1
Modern services	136	84.4	30.5	39.7	28.2
Traditional services	56	49.0	14.0	27.3	12.3
Size					
Small	182	66.1	29.0	39.8	25.6
Medium	288	64.1	31.4	48.5	24.7
Large	199	70.7	23.8	26.9	16.4
Total	**669**	**65.9**	**29.3**	**41.1**	**25.0**

Table 3-21: Change of KTT Activities and main groups of motives; percentage of KTT-active firms

Motives (main groups)	*Change of KTT activities over time*		
	no change	intensified	weaker
Access human capital ("tacit knowledge")	61.2	71.6	66.3
Access research results (codified knowledge")	25.3	41.0	17.7
Financial motives	41.9	54.2	16.5
Institutional/organisational motives	19.2	34.3	21.7

Table 3-22: Single motives for KTT activities; percentage of firms reporting 4 or 5 on a five-point Likert scale for a certain single motive by sector, subsector and firm size class

Motives	*Sectors*			*Subsectors*				*Size*			*Total*
	Manu-facturing	Con-struction	Services	High-tech	Low-tech	Modern services	Traditional services	Small	Medium	Large	
ACCESS TO HUMAN CAPITAL ("TACIT KNOWLEDGE")											
Access to specific skills in addition to internal know-how	56.6	36.6	43.0	57.4	56.0	46.3	39.1	45.3	48.1	56.0	46.3
New research ideas	20.5	2.7	20.3	13.3	25.4	25.2	14.5	18.3	17.7	14.3	18.0
Further education, training possibilities	22.8	21.9	35.0	27.1	19.8	47.2	20.3	29.5	28.0	36.6	29.5
Recruitment of graduates	18.9	0.3	17.3	21.9	16.9	24.8	8.2	14.0	18.2	29.2	15.5
Access to basic research	15.5	2.6	16.8	14.4	16.3	26.0	5.8	16.5	7.9	13.1	14.5
ACCESS TO RESEARCH RESULTS ("CODIFIED KNOWLEDGE")											
Access to patents/licenses	10.6	0.3	4.3	10.8	10.5	3.0	5.8	5.9	5.7	2.8	5.7
Access to research results for subsequent internal use	20.4	1.7	9.4	17.1	22.7	7.9	11.1	11.8	11.7	10.9	11.7
Access to research results for developing new products	26.7	16.9	11.3	28.8	25.3	15.2	6.5	16.3	18.9	13.4	16.7
Access to research results for developing new processes	15.6	19.0	14.6	11.7	18.2	20.7	7.4	14.6	18.6	15.1	15.5
Access to R&D infrastructure	17.9	2.4	8.1	15.4	19.6	10.3	5.4	10.9	9.1	6.8	10.3
FINANCIAL MOTIVES											
Cost-saving in R&D	12.9	0.6	11.2	16.0	10.8	13.2	8.7	10.1	12.0	5.5	10.3
Reduction of technical R&D risks	10.2	0.6	7.6	14.2	7.5	13.3	0.9	7.0	8.9	9.1	7.5
Time-saving in R&D	24.0	1.7	10.4	24.8	23.4	14.6	5.4	13.6	13.2	11.6	13.4
Insufficient firm R&D resources	32.9	14.2	17.4	17.7	43.2	25.1	8.2	21.3	26.5	5.2	21.7
Project characteristics require co-operation with scientific institutions	43.1	16.6	18.1	24.6	55.6	23.4	11.9	27.3	21.4	15.3	25.6
INSTITUTIONAL/ORGANIZATIONAL MOTIVES											
Building up a new research field	5.1	0.5	3.7	2.5	6.8	2.4	5.3	4.2	1.9	3.7	3.7
R&D outsourcing as strategic measure	11.8	0.5	4.2	9.9	13.2	3.4	5.3	6.6	4.6	4.0	6.1
R&D co-operation as condition for public funding	7.4	0.5	9.7	9.8	5.9	12.9	5.8	8.7	4.7	6.9	7.8
Improvement of firm image through co-operation with scientific institutions	15.0	2.4	15.0	7.8	19.9	17.7	11.7	15.1	8.1	8.2	13.3
Indirect access to knowledge of competitors	6.9	14.6	3.3	4.7	8.4	5.6	0.6	4.0	13.4	2.3	5.9
N	445	32	192	275	170	136	56	182	288	199	669

3.4 What are the Impediments of Knowledge and Technology Transfer Activities?

Based on existing empirical literature we collected the most important motives for KTT activities (see Table 3-23). Finally, we transformed the available information to 26 different obstacles. All firms, i.e. not only the KTT-active firms, were asked to evaluate the importance of these 26 different impediments of KTT activities on a five-point Likert-scale ranging from 1 ("not important") to 5 ("very important"). We consider an obstacle as important if the respondent reported 4 or 5 on the given scale. The 26 different obstacles were pooled into 5 main groups: "lack of information", "firm deficiencies", "deficiencies of the science institutions", "costs, risks, uncertainty", "organisational and institutional obstacles". Table 3-24 contains the shares of firms reporting 4 or 5 on a five-point Likert scale with respect to at least one out of a series of single obstacles belonging to the respective main group of obstacles (e.g. three single obstacles referring to "lack of information", four single obstacles belonging to the main group of obstacles "firm deficiencies" and so on; see also table 3-29).

"Firm deficiencies" (49.2% of all firms), "costs, risks and uncertainty" (42.4%) as well as "deficiencies of the science institutions" (42.0%) are the main categories of impediments as stated by all firms independent of firm size and sector (see Table 3-24). At subsector level there is a deviation from this ranking of the three most important obstacles: firms of the high-tech subsector rank "costs, risks, uncertainty" as the most important impediment of KTT activities. "Lack of information" and "organisational/institutional" obstacles are of minor importance independent of sector and firm size class.

We also take a look at the regional differences with respect to the five main groups of obstacles (see Table 3-25). The most prominent ones refer to the "deficiencies of science institutions" (Eastern Switzerland: 37.9% vs. Ticino: 55.9%) and "cost, risks, uncertainty" (Eastern Switzerland : 38.3% vs. Ticino: 54.3%).

Firms engaged in KTT activities have a different profile with respect to the perceived obstacles of KTT activities compared to firms without KTT activities (see Table 3-26). The group of obstacles "costs, risks, uncertainty" received the greatest attention by KTT-active firms (44.5%), while firms without KTT activities assessed most frequently "firm deficiencies" as the greatest obstacle for starting KTT activities (53.8%). "Deficiencies of science institutions" are for both groups of firms the second most important obstacle. One might conclude that the basic problem for KTT activities from a firms' perspective is that "science institutions do not understand what we are doing and we do not understand what they are doing".

Do firms that intensified or weakened their KTT activities show a specific profile as to the main groups of obstacles? For firms that intensified their KTT activities the obstacle "firm deficiencies" was of least importance (see Table 3-27). In contrast, this is the most important obstacle for firms with weakened KTT activities. Firms that have increased their KTT activities perceived most frequently "costs, risks, uncertainty" as very important.

By bringing the different mediating institutions in relation to the main groups of obstacles we obtain a rather interesting additional insight. Firms evaluating the services of transfer offices as very important find most frequently that "firm deficiencies" are a very important group of obstacles (see Table 3-28). Firms particularly appreciating the services of the KTI as well as those especially preferring the services of SNF report most frequently that "costs, risks, uncertainty" are a very important hindrance of (an intensification of) KTT activities. Firms finding the research programmes from the European Union (Framework Programmes and other research programmes) as very important for KTT activities emphasise most frequently organisational/ institutional obstacles.

A more detailed analysis of the impediments based on 26 items is found in (see Table 3-29). "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 commercialised" (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/organisational 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.

There are also some size-specific as well as sector-specific assessments of the importance of various obstacles. Large firms do not complain so often about "lack of finance", instead they emphasise the impediment "additional work for implementation of public R&D results is too comprehensive". Manufacturing firms report more often than firms form other sectors that they have particular "difficulties to find contact persons". This is especially the case for firms in the high-tech subsector (21.7%). On the contrary, these firms attach much less importance than firms form other subsectors to the obstacle "lack of interest in scientific projects on part of the firm", which is in line with the greater science affinity of firms in this subsector compared to other subsectors.

If we differentiate firms with KTT activities from firms without KTT activities the picture changes slightly (see table 3-30). While the impediment pattern for non-active firms corresponds quite well to the overall pattern, KTT-active firms consider the single obstacles "difficulties to find contact persons" more essential than "lack of interest in scientific projects on part of the firm". This is quite understandable, if we take into account that they answered these questions although they were not engaged in KTT activities.

In sum, the most important obstacles of KTT activities can be localised 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.

An Austrian study confirms the Swiss results only to some extent. The obstacle "lack of information on research conducted in universities" is besides the impediment "academic research is not application-oriented"[13] the most important barrier for KTT in Austria (see Schibany et al. 1999). The obstacle "lack of information" is only of minor importance for Switzerland and "academic research is not application-oriented" may be similar to our obstacle " R&D orientation of university is uninteresting (firm)", which is among the most important ones.

[13] The fact that academic research is not application-oriented may be not seen as an obstacle, moreover it could be an inspiring challenge, if we take into account the above mentioned studies from Mansfield (1998), Johnson (1992), Freeman (1992) and Kaufmann and Tödtling (2001).

Table 3-23: Overview of empirical literature on the obstacles of KTT activities

Obstacles	*A*	*B*	*C*	*D*	*E*
Lack of information about research activities at universities	X		X		
Technological dependency upon public research institutions	X				
Lack of R&D abilities on part of industry (few or insufficient R&D personnel)	X		X	X	
Lack of R&D abilities on part of universities			X		
Lack of equipment (technical capacities)			X	X	
Lack of abilities to define the technical problem to be solved in a R&D co-operation	X				
Comprehensive follow-up work is necessary in order to commercialise the research outcomes	X				
Interface university – industry is ill-equipped (e.g. lacking capacity of the Technology Transfer Office)	X				
Insufficient consideration of possible applications of the outcomes of research projects	X				
Lack of administrative support on part of the university	X				
Resistance of academics to accept restrictions with respect to the publication of research findings.	X				
No need for KTT		X			
Co-ordination is too difficult		X			
Public research institutions are competitors rather than co-operation partners.		X			
It is unusual in our field of research		X			
Lack of financial means on part of the industry			X	X	
Lack of financial means on part of science			X		
Different objectives			X		
Different time-schedules			X		
“Cultural” differences			X		X
Confidentiality with respect to results			X		
Geographic distance			X		
Differences in productivity (costs)				X	
Lack of trust				X	
Problems with the Property Rights				X	
Legal constraints				X	
Administrative burdens				X	
Management problems (e.g. with respect to team-co-ordination)				X	
Communication problems				X	
University research is focusing on one discipline				X	
Profitability					X
Suitable only to large companies					X
Suitable only to specific forms of co-operations					X
Lack of adequate partners			X		
Lack of incentives/motivations			X		
Lack of administrative support			X		
Lack of entrepreneurial thinking on part of the academic partner			X		
Lack of scientific interests on part of the industry			X		
Co-operation results are too uncertain			X		

A = Arthur D. Little (2000), B = Mayer (2000), C = Schartinger et al. (2000), D = Onida/Malerba (1989), E = Geisler (1997)

Table 3-24: Main categories of obstacles of KTT activities; percentage of KTT-active firms perceiving a certain category of obstacles as important (see the text for a detailed description of the main categories) by sector, subsector and firm size class

	N	*Lack of Information*	*Firm deficiencies*	*Deficiencies of the science institutions*	*Costs, risks, uncertainty*	*Organisational/institutional obstacles*
Sectors						
Manufacturing	1450	30.3	52.8	44.0	49.6	30.0
Construction	271	21.8	47.0	41.7	40.1	23.7
Services	861	21.7	48.3	41.0	39.6	21.8
Subsectors						
High-tech	688	33.4	49.6	44.1	52.0	33.8
Low-tech	762	28.6	54.5	43.9	48.3	28.0
Modern services	492	27.5	50.0	46.0	47.3	28.0
Traditional services	369	15.4	46.6	35.6	31.2	15.2
Size						
Small	1287	23.3	49.2	42.0	41.8	24.0
Medium	924	28.1	49.4	41.5	46.5	26.7
Large	371	24.5	46.9	44.1	39.2	28.3
Total	**2582**	**24.1**	**49.2**	**42.0**	**42.4**	**24.5**

Table 3-25: Regional differences with respect to the main categories of obstacles; percentage of firms

Regions	*N*	*Lack of Information*	*Firm deficiencies*	*Deficiencies of the science institution*	*Costs, risks, uncertainty*	*Organisational/institutional obstacles*
Lake of Geneva	302	17.0	52.3	38.0	41.2	22.4
Espace midland	590	23.2	48.1	39.7	41.2	22.3
North-western Switzerland	387	29.0	52.6	49.1	43.8	28.2
Zurich	494	24.4	50.2	40.9	41.0	22.7
Eastern Switzerland	445	28.3	46.6	37.9	38.3	25.9
Central Switzerland	248	24.8	48.2	45.7	49.1	28.5
Ticino	116	20.4	41.9	55.9	54.3	26.9
Total	**2582**	**24.1**	**49.2**	**42.0**	**42.4**	**24.5**

Table 3-26: Main groups of obstacles; percentage of firms with/ without KTT activities

Obstacles (main groups)	*Knowledge and technology transfer:*		*All firms*
	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
Organisational/institutional obstacles	32.5	21.7	24.5
N	669	1913	2582

Table 3-27: Change of KTT activities and main groups of obstacles; percentage of firms

Obstacles (main groups)	*Change of KTT activities over time:*		
	no change	intensified	weaker
Lack of Information	33.1	32.5	22.8
Firm deficiencies	44.1	25.3	37.1
Deficiencies of the science institutions	36.1	41.0	32.7
Costs, risks, uncertainty	44.8	52.6	29.7
Organisational/institutional obstacles	34.8	37.4	18.9

Table 3-28: Main obstacles of KTT activities and mediating institutions; percentage of firms

Mediating institutions	*N*	*Main groups of obstacles*				
		Lack of information	Firm deficiencies	Deficiencies of the science institutions	Costs, risks, uncertainty	Organisational/institutional obstacles
Transfer Offices	73	41.9	62.0	24.9	50.4	37.6
Commission for Technology and Innovation (KTI)	103	36.8	38.7	27.3	56.2	42.7
Swiss National Science Foundation (SNF)	22	23.7	25.7	29.1	67.4	59.6
Framework Programmes (EU)	39	10.8	8.1	12.7	64.2	76.7
Other Research Programmes EU	27	20.4	17.8	18.9	49.6	75.2

Table 3-29: Single obstacles of KTT activities; percentage of firms reporting 4 or 5 on a five-point Likert scale for a certain single obstacle by sector, subsector and firm size class

Obstacles (all categories)	*Sectors*			*Subsectors*				*Size*			*Total*
	Manu-facturing	Con-struction	Services	High-tech	Low-tech	Modern services	Traditional services	Small	Medium	Large	
LACK OF INFORMATION											
Difficulties to get information about R&D activities in science institutions	17.5	12.5	12.5	20.5	15.8	17.4	7.3	13.6	15.7	13.3	13.9
Difficulties to find contact persons	22.4	16.0	16.4	27.1	19.9	20.5	11.9	17.8	19.1	14.5	17.9
Lack of resources for “interface” (e.g. transfer office)	12.6	7.6	9.0	12.8	12.5	12.6	5.2	9.6	9.5	10.9	9.7
FIRM DEFICIENCIES											
Lack of qualified staff	13.4	13.4	12.1	13.2	13.5	11.7	12.5	12.7	13.4	11.7	12.8
Lack of technical equipment	11.9	14.5	5.8	11.2	12.3	3.5	8.4	10.0	8.0	6.7	9.6
Lack of interest in scientific projects	22.8	23.1	27.1	20.1	24.3	23.8	30.7	25.0	25.3	20.7	25.0
Firms’ R&D questions are not interesting for science institutions	37.4	39.6	33.2	31.5	40.6	33.9	32.4	36.3	34.4	33.3	35.9
DEFICIENCIES OF THE SCIENCE INSTITUTIONS											
Lack of scientific staff for transfer activities	12.1	14.0	10.2	12.2	12.1	11.4	9.0	12.1	9.4	9.1	11.7
Lack of entrepreneurial spirit	12.7	9.9	11.7	14.4	11.8	13.4	9.9	11.5	11.7	12.8	11.5
R&D orientation of science institutions is uninteresting for firms	26.0	28.4	23.9	24.5	26.7	28.7	18.8	25.6	25.0	29.3	25.6
Possible R&D results cannot be commercialised	22.2	30.4	24.5	21.5	22.6	26.7	22.2	25.8	23.5	21.4	25.3
COST, RISKS, UNCERTAINTY											
Confidentiality with respect to firms’ know-how is not guaranteed	15.2	10.0	7.7	17.8	13.7	9.6	5.7	9.4	14.8	12.0	10.3
Need of comprehensive additional follow-up work in order to implement public R&D results	17.3	7.0	12.1	20.7	15.5	14.2	9.8	11.6	15.4	17.9	12.3
Lack of firm financial resources for transfer activities	32.5	27.9	24.3	29.1	34.3	30.6	17.5	27.7	28.0	15.1	27.4
Lack of financial resources of science institutions for co-operation on an equal basis with firms	15.5	12.2	10.6	11.6	17.6	14.6	6.4	12.8	10.5	6.7	12.3
Insufficient efficiency of university staff compared to firms’ staff	10.3	13.3	10.0	14.9	7.9	12.5	7.4	10.8	11.6	10.4	10.9
Technological dependency from external institutions	8.1	4.7	6.1	9.9	7.1	7.0	5.1	6.7	4.1	5.2	6.3
Uncertainty about outcomes of co-operations	14.3	8.6	9.9	15.9	13.4	11.8	7.7	11.1	9.2	11.0	10.8
INSTITUTIONAL/ORGANISATIONAL OBSTACLES											
Costly administrative and approval procedure	19.7	11.9	13.9	16.9	21.3	15.8	11.8	14.9	15.8	11.6	15.0
Lack of administrative support of joint R&D projects on part of the university	9.1	5.5	5.9	8.8	9.2	7.0	4.7	6.6	7.5	3.4	6.7
Lack of administrative support of commercialisation of R&D outcomes on part of the university	9.9	11.6	6.5	11.8	8.9	8.7	4.1	8.7	8.8	5.9	8.7
Problems with Property Rights	7.7	5.5	6.2	10.0	6.5	8.0	4.4	6.1	8.2	8.0	6.4
Problems with project management at universities (e.g. communication problems)	5.9	7.6	4.4	6.3	5.6	5.6	3.2	5.5	5.6	8.5	5.6
Different understanding of priorities	14.0	7.9	8.9	16.0	12.9	13.8	3.7	9.5	12.2	15.7	10.1
Lack of trust on part of the firm	4.9	4.6	3.3	5.0	4.8	3.5	3.1	4.2	3.2	3.3	4.1
Loss of reputation on part of the firm	1.8	0.1	2.3	2.5	1.4	3.4	1.2	1.8	0.8	2.2	1.6
N	1450	271	861	688	762	492	369	1287	924	371	2582

Table 3-30: Single obstacles: with-/without KTT activities; percentage of firms with-/ without KTT activities

Single obstacles	*Knowledge and technology transfer:*		*All firms*
	yes	no	
LACK OF INFORMATION			
Difficulties to get information about R&D activities in science institutions	15.2	13.4	13.9
Difficulties to find contact persons	24.0	15.8	17.9
Lack of resources for "interface" (e.g. transfer office)	12.5	8.7	9.7
FIRM DEFICIENCIES			
Lack of qualified staff	14.3	12.3	12.8
Lack of technical equipment	9.4	9.7	9.6
Lack of interest in scientific projects	19.0	27.1	25.0
Firms' R&D questions are not interesting for science institutions	24.5	39.9	35.9
DEFICIENCIES OF THE SCIENCE INSTITUTIONS			
Lack of scientific staff for transfer activities	9.2	12.5	11.7
Lack of entrepreneurial spirit	17.2	9.5	11.5
R&D orientation of science institutions is uninteresting for firms	20.7	27.3	25.6
Possible R&D results cannot be commercialised	19.8	27.3	25.3
COST, RISKS, UNCERTAINTY			
Secrecy with respect to firms' know-how is not guaranteed	13.1	9.3	10.3
Need of comprehensive additional follow-up work in order to implement public R&D results	14.6	11.5	12.3
Lack of firm financial resources for transfer activities	26.0	28.0	27.4
Lack of financial resources of science institutions for co-operation on an equal basis with firms	13.8	11.8	12.3
Insufficient efficiency of university staff compared to firms' staff	12.1	10.5	10.9
Technological dependency from external institutions	5.3	6.6	6.3
Uncertainty about outcomes of co-operations	7.8	11.8	10.8
INSTITUTIONAL/ORGANISATIONAL OBSTACLES			
Costly administrative and approval procedure	19.7	13.3	15.0
Lack of administrative support of joint R&D project son part of the university	9.4	5.7	6.7
Lack of administrative support of the commercialisation of R&D outcomes on part of the university	9.1	8.5	8.7
Problems with Property Rights	9.2	5.5	6.4
Problems with project management at universities (e.g. communication problems)	7.3	5.0	5.6
Different understanding of priorities	16.3	7.9	10.1
Lack of trust on part of the	5.4	3.6	4.1
Risk loosing reputation on part of the firm	0.3	2.1	1.6
N	669	1913	2582

Table 3-31: Brief summary of motives and impediments for KTT

„Access to human capital (tacit knowledge)“ is the most important main group of motives for KTT followed by “financial motives” and “access to research results (codified knowledge)”. Out of 20 single items “access to abilities in addition to internal know-how” is the most important single motive for KTT. “Further educational and training possibilities for firm employees” and “project characteristics require co-operation” are next in importance. Rather unexpected, only 3.7% of all KTT active firms feel motivated to contact a university in order to “investigate a new field of research”. “Access to (university) patents/licenses” are also of minor importance.

“Firm deficiencies”, “costs, risks and uncertainty” and “deficiencies of science institutions” are the most important main groups of impediments as reported stated by the firms. The group of obstacles “costs, risks and uncertainty” receives the greatest attention by firms with KTT activities, while “firm deficiencies” are most important for firms without KTT activities. This implicates that firms very often might not be able to interprete the potential input from university research, presumably because of the lack of “knowledge absorptive capacity”. Out of 26 single items “our R&D questions (firm) are not interesting for universities” is the greatest single obstacle of KTT activities independent of sector and firm size. Obstacles of least importance are “loss of reputation”, “lack of trust”, “problems with project management at universities (e.g. communication problems)” and “lack of administrative support (R&D project) on part of the university”. KTT-active firms do not differ much with respect to the assessent of obstacles from firms which are not KTT-active. There is one mentionable exception: KTT-active firms consider the single obstacle “difficulties to find a contact person” as more relevant than “lack of interest in scientific projects on part of the firm”. Firms that intensified KTT activities evaluate the main groups of impediments somewhat differently. “Firm deficiencies” are of least importance for these firms, while it is the most important group of obstacles for firms with weakened KTT.

4 Impact Assessment of Knowledge and Technology Transfer Activities on Innovation and Economic Performance: Descriptive Analysis

4.1 Firms' Assessment of KTT Impact on Innovation Performance

We asked our respondents about their experiences with KTT activities and how firms' R&D activities and innovation behaviour have been affected by such activities. They reported for 13 impact factors their assessment on a five-point Likert-scale (1: "not important"; 5: "very important"). In case the respondents reported 4 or 5 we considered the respective factor as "important". We pooled the factors into the following five main groups: "*adoption* of new technologies", "*generation* of new technologies", "impact on research orientation", "reduction of internal R&D capacity", "impact on R&D costs" and "impact on human capital endowment in R&D". Table 4-1) contains the shares of firms reporting 4 or 5 on a five-point Likert scale with respect to at least one out of a series of single impacts belonging to the respective main group of impacts (e.g. five single impacts referring to "adoption of new technologies", four impacts belonging to the main group of impacts "generation of new technologies" and so on see also Table 4-2).

28.1% of KTT-active firms reported that technology transfer increased and/or upgraded *considerably* their know-how. This means that considerably more firms than those involved in research co-operations with a university (i.e. 17.8% of KTT-active firms, see Table 3-6) benefited significantly from KTT. Obviously these benefits was realised by focusing to forms of KTT activities other than research, e.g. to educational activities, consulting etc. 19.9% of KTT-active firms stated that the adoption of new technology helped them significantly to develop new products, 17.0% to develop new processes. The *generation* of new technology was less frequently the outcome of technology transfer. However, 13.5% of KTT-active firms reported a significant increase of their know-how due to new knowledge generation with the help of KTT activities, 14.9% ascertained that transfer-induced generation of new knowledge led to the development of new products, 9.4% of new processes. The recruitment of R&D personnel (15.3% of firms) and/or university-based training courses and/or sabbaticals (7.2%) contributed considerably according to firms' assessment to the increase of firms' human capital. 12.0% of firms re-oriented their R&D activities towards more applied research as a result of co-operation with universities. For 7.9% of firms KTT activities resulted to a considerable increase of R&D expenditure (complementarity effect). For only 2.8% of firms a reduction of R&D expenditure or even a reduction of internal R&D capacity (0.7%) (substitution effect) took place as a consequence of KTT activities.

In general, the above-mentioned effects were stronger in manufacturing, particularly in the high-tech sector than in the economy as a whole (see Table 4-2). For firms in knowledge-based service industries the human capital effect was considerably higher than the average of the economy. There is a tendency for smaller firms to benefit more from KTT activities than large firms with respect to the acquisition of new knowledge and the development of product and process innovations; large enterprises seem to benefit more than small ones with respect to the recruitment of R&D personnel.

In sum, the development of new products and/or new processes as well as the augmentation of human capital were according to firms' assessment the most relevant impacts of KTT activities on R&D and innovation. Thus, there is some preliminary empirical evidence that KTT activities do have a discernible positive impact on innovation performance.

Table 4-1: Main groups of impacts of KTT activities on innovation performance; percentage of KTT-active firms perceiving a certain category of impacts as important (see the text for a detailed description of the main categories) by sector, subsector and firm size class

	N	*Adoption of new technologies*	*Generation of new technologies*	*Impact on research orientation*	*Reduction of internal R&D capacity*	*Impact on R&D costs*	*Impact on human capital endowment in R&D*
Sectors							
Manufacturing	445	48.0	32.5	16.1	2.2	19.1	22.7
Construction	32	34.1	2.5	17.1	0.0	1.1	2.1
Services	192	30.2	21.9	10.0	0.1	8.4	22.2
Subsectors							
High-tech	275	46.5	32.8	16.4	4.1	24.4	28.0
Low-tech	170	49.0	32.2	15.9	0.9	15.5	19.1
Modern services	136	32.5	26.8	14.0	0.1	7.9	31.4
Traditional services	56	27.4	16.2	5.3	0.0	9.0	11.2
Size							
Small	182	36.3	22.4	11.2	0.5	10.2	19.6
Medium	288	36.7	24.7	17.6	1.4	12.6	18.8
Large	199	30.3	16.0	17.6	1.4	10.6	25.1
Total	**669**	**36.1**	**22.6**	**12.8**	**0.7**	**10.7**	**19.7**

Table 4-2: Single impacts of KTT activities on innovation performance; percentage of firms reporting 4 or 5 on a five-point Likert scale for a certain single obstacle by sector, subsector and firm size class

Effects	*Sectors*			*Subsectors*				*Size*			*Total*
	Manu-facturing	Con-struction	Services	High-tech	Low-tech	Modern services	Traditional services	Small	Medium	Large	
Technology adoption to supplement our know-how	32.6	34.1	24.2	31.2	33.5	29.1	18.3	29.2	25.3	21.5	28.1
Technology adoption to develop new products	33.0	15.6	13.8	33.7	32.5	16.4	10.6	21.1	17.6	10.2	19.9
Technology adoption to develop new processes	19.3	17.4	15.7	15.0	22.2	16.9	14.3	18.0	14.2	13.1	17.0
Technology generation to supplement our know-how	19.6	0.6	13.2	20.0	19.3	17.5	8.0	13.3	14.6	11.1	13.5
Technology generation to develop new products	26.9	1.1	11.7	25.6	27.8	14.4	8.4	14.8	17.0	6.0	14.9
Technology generation to develop new processes	8.2	1.9	11.9	7.5	8.6	10.4	13.7	9.1	10.7	9.3	9.4
Orientation towards: more applied research	15.4	17.1	9.0	14.8	15.9	12.1	5.3	10.3	17.1	17.4	12.0
more basic research	1.0	0.0	4.5	2.4	0.1	3.9	5.3	3.7	0.4	0.5	2.9
Reduction of internal R&D capacities	2.2	0.0	0.1	4.1	0.9	0.1	0.0	0.5	1.4	1.4	0.7
Decrease of R&D costs	2.8	0.0	3.4	4.4	1.8	4.1	2.6	3.2	1.4	3.0	2.8
Increase of R&D costs	16.2	1.1	5.0	20.0	13.7	3.8	6.4	7.0	11.2	7.6	7.9
Huma capital increase through the recruitment of graduates in R&D	19.6	0.2	16.6	25.4	15.6	25.5	5.9	14.5	16.6	24.3	15.3
Human capital increase in R&D through training courses, sabbaticals, etc.	4.5	1.9	9.9	5.8	3.6	13.8	5.3	8.4	3.0	6.0	7.2
N	445	32	192	275	170	136	56	182	288	199	669

4.2 Knowledge and Technology Transfer Activities, Innovation and Economic Performance: A First Glance

In this section we investigate the relationship between the propensity to KTT activities and a number of innovation and performance indicators by calculating the Spearman partial correlation coefficient, controlling for firm size and industry affiliation. In this way we get a first impression about the "nearness" of KTT activities to innovation and other economic activities at firm level.

For the correlations we use a number of KTT variables (e.g. KTT activities in the period 2002-2004 yes/no, KTT activities before 2002 yes/no) indicating whether a firm in involved in KTT activities, for how long it is active and whether the KTT connections are focused on national universities, universities abroad or both. Further, we have several indicators for a firm's innovation performance (e.g. introduction of product and/or process innovations yes/no, number of patents yes/no, R&D expenditures/sales), its overall economic performance (e.g. export intensity, sales per employee, value added) and its human capital intensity (see Table 4-3) for the definition of the variables taken into account in this section).

We expect that the proximity between KTT activities, innovation performance and skill-level is greater than it is between KTT activities and indicators for the overall firm performance. Although we are expecting for all groups of performance indicators a positive correlation with KTT activities, we are aware that firms' performance are determined by many other factors (e.g. marketing, business cycles) we can not control for. In Table 4-5 we present the results of the correlation analysis

KTT activities and human capital intensity

The correlation coefficients between all different types of KTT variables and the variable measuring human capital intensity are in every case significantly positive. The coefficients are of a similar magnitude, ranging from 0.146 (variable "KTT abroad+") to 0.217 (variable "KTT all"). This indicates that the existence of KTT activities is positively related to the human capital intensity of a firm, independent of the type of KTT variable. Human capital intensity is a proxy for absorptive capacity, thus it makes quite sense that firms with a high human intensity show also a high propensity to KTT activities.

KTT activities and innovation performance

All indicators for the innovation performance of a firm are positively correlated with the KTT variables, although not all of them are statistically significant at the 5% test level. The largest coefficients are found for the three innovation variables, the two patent variables and the variable "R&D activities yes/no". Positive but considerably smaller are the correlation coefficients for the variables "R&D expenditures/sales", "sales share of new products" and "cost reduction due to process innovation". Obviously, the impact on output-oriented indicators such as the sales share of new products and the innovation-induced reduction of average variable cost is weaker than on indicators that directly related to the innovation process such the existence of R&D activities, the introduction of innovations and the filing of

patents (exception: the quantitative indicator R&D expenditure/sales). The strongest correlations are found for firms with continuous KTT activities "KTT all" and "KTT 02-04".

Focusing on single indicators, the indicator "R&D activities yes/no" show the largest coefficients. They are ranging from 0.259 (variable "KTT abroad+") to 0.407 (variable "KTT all"). The correlation coefficients for the two patent variables are also relatively large ranging from 0.281 (variables "KTT all", "KTT before 2002") to 0.327 (variable "KTT abroad +"). The correlation coefficients for the innovation variables are somewhat lower (0.125 to 0.287) than those for patents and R&D activities. The coefficients of the indicator "sales share of new products" are all significant positive, independent of the KTT category. Compared to the qualitative innovation variables the correlation is somewhat weaker, ranging from 0.073 (KTT abroad+) to 0.157 (KTT all). This is basically in line with our results in Table 4-4 where it is shown that KTT-active firms have on average a higher sales of new products than firms without KTT activities.[14]

Also for the variable "cost reduction due to process innovation" we find a significant positive coefficient with all KTT variables except for the two indicators referring to KTT activities abroad.

The overall positive correlation of variables for KTT activities with measures of innovation performance confirms to some extent earlier results on R&D co-operation between universities and firms employees in full-time equivalents. Arvanitis et al. (2001) found that co-operations between firms and scientific institutions in Switzerland (cross-section data for the period 1997-1999) resulted more frequently in patent applications, prototypes, new products or new processes than in the case of vertical or horizontal R&D co-operations between private enterprises.

KTT and economic performance

All indicators of a firm's economic performance are positively correlated with KTT indicators. In only one case the coefficient is not statistically significant at the 10% level ("investments per capita", "KTT abroad+").

The "share of exports" shows the highest coefficients, ranging from 0.138 (variable "KTT 02-04") to 0.198 (variable "KTT abroad only"). Not surprisingly, stronger export-oriented firms show a greater affinity to international KTT activities than firms with lower export intensity.

In general, the indicators of economic performance show considerably lower correlation coefficients than the indicators of innovation performance.

In sum, we want to highlight two main results of the correlation analysis. Firstly, most of the chosen indicators for firm innovation performance, firm economic performance and the indicator for human capital intensity are significantly positively correlated with the various

[14] Kaufmann and Tödtling (2001) found for Austria that the more advanced product innovators are also interacting more often with universities.

variables for KTT activities. This is a first hint that KTT activities should contribute significantly to the overall performance of a firm. Secondly, comparing the magnitude of coefficients it becomes obviously that they become lower the greater the distance of the indicated activities (e.g. sales, investment an so on) from core R&D activities, which are the part of a firm's activities that is, directly linked to KTT.

Table 4-3: Definition of variables

Indicators for Knowledge and Technology Transfer (KTT) activities:

KTT all: Knowledge and Technology Transfer (KTT) activities before 2002 *or* between 2002/2004 yes/no

KTT before 02: KTT before 2002 *only* yes/no

KTT 02/04: KTT activities between 2002/2004 yes/no

KTT abroad only: KTT activities *only* with scientific institutions abroad yes/no

KTT 02 and 02/04: KTT activities before 2002 *and* also between 2002/2004 yes/no

KTT abroad+: KTT activities before 2002 *and* between 2002/2004 *and* with scientific institutions abroad yes/no?

Indicators for innovation performance:

Innovation all: introduction of product and/or process innovations in the period 2002/2004 yes/no

Innovation product: introduction of product innovation(s) in the period 2002/2004 yes/no

Innovation process: introduction of process innovation(s) in the period 2002/2004 yes/no

Patents: patent(s) filed in the period 2002/2004 yes/no

Number of patents: number of patents filed in the period 2002/2004.

R&D activities: R&D activities in the period 2002/2004 yes/no

R&D expenditures/sales: R&D expenditures as percentage of total sales in 2004.

Sales share of new products: sales of new products as percentage of total sales in 2004.

Cost reduction: cost reduction due to process innovation as a percentage of average variable costs in 2004.

Indicators for economic performance:

Value added: sales minus intermediate inputs.

Share exports: exports as percentage of sales 2004.

Investments per employee: gross investments divided by the number of employees in full-time equivalents in 2004.

Sales per employee: sales divided by the number of employees in full-time equivalents in 2004.

Indicator for human capital intensity:

Higher education: Proportion of employees with university or non-university tertiary degree (e.g. polytechnics degree, degree in non-university business administration).

Table 4-4: KTT activities and sales shares of innovative products

Type of product – share in turnover	*Without KTT*	*With KTT*
Share of new products	8	15
Share of considerably improved products	11	14
Share of unmodified existing products	81	71
Number of Firms	1420	641

Table 4-5: Partial Correlation between KTT variables and various performance indicators; Spearman partial correlation coefficient

	KTT all	*KTT before 02*	*KTT 02-04*	*KTT abroad only*	*KTT 02 and 02/04*	*KTT abroad+*
Indicators of Innovation Performance						
Innovation all	0.28734	0.21318	0.25013	0.17099	0.18704	0.12276
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Innovation product	0.27694	0.22006	0.24739	0.18613	0.2008	0.14101
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Innovation process	0.22715	0.1762	0.20656	0.14788	0.16397	0.12541
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Patent(s) yes/no	0.28183	0.28124	0.28686	0.29482	0.28518	0.30704
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Number of patents	0.29259	0.29736	0.29846	0.31167	0.30369	0.32664
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
R&D activities yes/no	0.40701	0.34799	0.37894	0.28766	0.3232	0.25923
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
R&D expenditure/sales	0.00566	0.02984	0.02046	0.08681	0.04105	0.12001
	0.873	0.399	0.5631	0.014	0.2459	0.0007
Sales share of new products	0.15669	0.11791	0.13697	0.1	0.10879	0.07374
	<.0001	<.0001	<.0001	<.0001	<.0001	0.0008
Cost reduction	0.09141	0.07363	0.08224	0.04085	0.05885	0.03792
	0.002	0.0129	0.0055	0.1683	0.0471	0.201
Indicators of Economic Performance						
Sales per employee	0.05372	0.04548	0.04866	0.09798	0.0576	0.07233
	0.0067	0.0218	0.0141	<.0001	0.0037	0.0003
Value added	0.0611	0.04591	0.05475	0.08413	0.05604	0.05764
	0.0021	0.0206	0.0058	<.0001	0.0047	0.0036
Share exports	0.17112	0.15703	0.13805	0.19797	0.1416	0.16534
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Investments per employee	0.06043	0.03589	0.05865	0.05414	0.04354	0.02791
	0.0023	0.0704	0.0031	0.0063	0.0281	0.1594
Indicator of human capital intensity						
Share of employees with higher education	0.21674	0.18886	0.19548	0.16233	0.18692	0.14626
	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Table 4-6: Brief summary of KTT impact assessment

36.1% of KTT-active firms stated that a new technology has been *adopted* as a result of KTT activities. More concretely, the adoption of new technologies predominantly supplements internal know-how (28.1% of KTT-active firms). 19.9% reported that new products have been developed as a consequence of KTT and 17.7% succeeded in developing new processes. 22.6% of KTT-active firms reported that new technologies were even *generated* as a consequence of KTT activities. Thus, the descriptive analysis yields some first hints that KTT activities and innovativeness in terms of new market products go hand in hand.

The correlation analysis showed that measures for humn capital intensity, the innovation performance as well as the economic performance of a firm are positively correlated with KTT activities. Furthermore, we found that the correlation coefficients become lower the greater the distance of the indicated activities (e.g. sales, investment an so on) from core R&D activities which are the part of a firm's activities that is directly linked to KTT.

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