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Author(s):
Arvanitis, Spyridon; Wörter, Martin

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Spyros Arvanitis and Martin Wörter

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An Empirical Analysis Based on Firm-level Data

Spyros Arvanitis

KOF Institute for Business Cycle Research KOF, ETH Zurich
8092 Zurich, Switzerland
Phone: +41 44 / 632‘51‘68
Fax: +41 44 / 632‘13‘52
E-Mail: arvanitis@kof.ethz.ch

Martin Woerter

KOF Institute for Business Cycle Research, ETH Zurich
8092 Zurich, Switzerland
Phone: +41 44 / 632‘51‘51
Fax: +41 44 / 632‘13‘52
E-Mail: woerter@kof.ethz.ch

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*Corresponding Author: Martin Woerter (woerter@kof.ethz.ch). The study was funded by the ETH-Board. We thank the participants of the Technology Transfer Society Annual Conference 2006 in Atlanta for their valuable comments.

Abstract

Based on a representative firm sample for Switzerland we empirically investigated strategic approaches for knowledge and technology transfer (KTT) activities between business firms and public research organisations. Based on cluster analysis of 19 different forms for KTT, three types of KTT strategies were identified, each of them correspond with a specific combination of some of the 19 different forms for KTT activities. It was found that they are determined mainly by variables related (a) to the absorptive capacity of a firm and (b) to the degree of appropriability of the returns of innovation, indicating that the followed strategy reflects the resource base of a firm. Further, it was shown that a firm's obstacle profile with respect to KTT activities is related to the applied strategy. Firms with more intensive contacts emphasise risk-related factors and financial restrictions, while firms with less intensive contacts emphasise a mismatch between firm and university requirements with respect to KTT. Furthermore and most importantly, it was found that strategy matters for the impact of KTT on the innovation performance of a firm. In fact, KTT strategies related to the core R&D activities of a firm showed a greater impact compared to strategies related to 'softer' forms of transfer activities, e.g. informal contacts or education related contacts.

1. Introduction

Firms are searching for ways to connect external knowledge resources to their own knowledge production. Beside other enterprises (suppliers, customers, competitors, etc.) public research organisations increasingly serve as a valuable source for in-house research and development (R&D) activities and innovation activities (see Nelson 1986, Mansfield 1991, 1998, Beise und Stahl 1999). Public research institutions may serve to support the technology generation or the adoption of a new technology. Furthermore, they may act as a competent research partner for concrete R&D problems or advise on technology strategies. All in all knowledge and technology transfer (KTT) between public research organisations and private firms is conducted in various forms. Thus, it is advisable to define transfer activities very broadly. Our definition of KTT comprises 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. This way 28% of all Swiss firms (with more than 5 employees) are involved in KTT activities.

The increasing importance of universities for private R&D activities is mostly not mirrored adequately in the analysis of strategies for R&D co-operations. In most empirical investigations, KTT with universities is usually analysed in context with other types of R&D co-operation, e.g. with suppliers, competitors or customers. Freeman (1992) argues that the contribution of scientific institutions tends to be predominant in the early stages of more radical innovation, while the experiences of users are very important for the incremental type of innovation at later stage. Similar, Kaufmann and Tödtling (2001) found that co-operation with scientific institutions increases firms' abilities to realise more radical innovation and to introduce products, which are "new to the market". Universities are not important for the generation of incremental innovations. Moreover, Belderbos et al. (2004) showed that R&D co-operations with universities are more focused on radical innovation and the creation of new products. In contrast, R&D co-operations with suppliers are more focused on reducing input costs and improving assembly processes, thus increasing labour productivity. Adams et al. (2003) found that co-operative research with federally funded laboratories stimulated industrial patents and company-financed R&D; no other channel of technology transfer yielded a comparable effect. Mohnen and Hoareau (2003) used pooled CIS-2 data for France, Germany, Ireland and Spain to investigate the factors that allow firms to benefit from knowledge developed in universities and government labs or that drive them to collaborate with these institutions. Conditional on innovating and co-operating in R&D with other firms they found that the probability to co-operate with research institutions is positively correlated with firm size, government support for a firm's innovation activities, with having patents applied for (but not with R&D intensity) and the firm being affiliated to science-oriented sectors.

Comprehensive empirical investigations on strategies with respect to KTT activities with universities are still relatively rare. The lack of more comprehensive survey data is one important reason for it. Nevertheless, there are some indications that the way university knowledge is absorbed matters for the innovation performance of a firm. Becker (2003) showed that university knowledge as an external knowledge source has not any stimulating effect on product innovations; in contrast, joint R&D projects with universities do have a stimulating effect.

Based on survey data, our analysis aims at studying firms' strategies for KTT with public research organisations and their determinants. Moreover, the impact of different KTT strategies on firms' performance is also investigated in this paper. The survey data enabled us to distinguish between19 different forms for KTT activities (e.g. firm representatives attending scientific conferences, joint use of technological infrastructure, co-operative research). KTT strategies are defined as a combination of different forms for KTT.

More concretely, we found three dominant ways to make use of public research activities. For a first group of firms none of the 19 possible forms of KTT activities is very important on the average. We will call this strategy A, i.e. firms are in "loose" contact with public research organisation. For a further group of KTT active firms only KTT forms are important on the average that are related to informal, educational and consulting activities. In this case KTT does not immediately focus on the R&D activities of a firm. We will call this strategy B, i.e. firms are engaged in "non-core" contacts with public research organisations. A third and last group of KTT active firms emphasises on the average KTT forms (e.g. joint laboratories, sabbaticals, R&D co-operations) that are directly related to the R&D activities of the firm. We will call this strategy C, i.e. firms are undertaking "core" contacts with public research organisations. Furthermore, it was found that the different strategies correlate with certain firm characteristics, such as firm size, experiences with KTT activities or firm specific hindrances of KTT activities. Firms are diversifying their contacts across different types of scientific institutions. And most importantly, the impact of KTT on firms' innovation performance is related to the chosen strategy.

In sum, we found that firms are taking different paths to make use of public research activities and that strategies are differing in their impact on several firm performance measures, such as patent activities and innovativeness. Thus, there are good and better ways for KTT. Firms can learn from the experiences of each other and policy maker can improve their understanding for KTT.

The new elements of this analysis are: Firstly, the study builds on a differentiated measurement of a wide spectrum of KTT covering 19 single forms of KTT activities. Secondly, based on a cluster analysis of data for 669 KTT active firms' three dominant strategies to conduct KTT could be found. Thirdly, the determinants are identified and the impact of different KTT strategies on firm performance is quantified. Fourthly, the whole analysis is based on a representative survey on Swiss firms, comprising a wide coverage of industries (manufacturing, service, construction) and firm size classes (firms with at least 5 employees). This is the first study on this topic for Switzerland.

In section 2 we present the general findings on firms' strategy and its implication for KTT strategies. Section 3 deals with the data and the empirical methods used in this study. In section 4 we analyse different KTT strategies in greater detail. In section 5 we provide the reader with determinants for KTT strategies and the main hypotheses. In section 6 we present our estimation results and in section 7 we provide the reader with a summary and our main conclusions.

2. Conceptual framework for firms' KTT strategies: determinants and impact on firm performance

A specific theoretical framework for KTT strategies of private firms is still lacking. Most of what we know derives from empirical investigations, which leave us with a patchwork of single important items that contribute to our understanding of firms' behaviour and strategies when it comes to KTT (see also Veugelers and Cassiman 2005). Thus, findings on firms' strategies in general may be useful to guide our investigation on KTT strategies.

Porter (1980) focuses in his five-force model on the external competitive environment in order to explain firms' options for behaviour and strategic orientation in the relevant markets. Shapiro (1989) applies a game-theoretic approach to model firms' behaviour in a competitive environment. This approach deals with strategic moves that have to be considerable in order to influence competitors' behaviour. According to this approach a firm is actively involved in shaping the market environment, e.g. through considerable "sunk-costs" investments in order to gain competitive advantages. These two approaches are of limited usefulness for understanding firms' KTT strategies. Both approaches give a great emphasis to external factors, namely the market environment as the main determinant for strategic behaviour. In contrast, the propensity to KTT activities seems to be determined primarily by internal firm-specific factors like size (see e.g. Mohnen and Hoareau 2003, Fontana et al. 2004), human capital endowment and absorptive capacity respectively (see e.g. Arvanitis et al 2005b, Schmidt 2005).

The "resource-based view" of firms' behaviour is more adequate as a source of conceptual inspiration in order to understand KTT strategies (see Penrose 1995, Wernerfelt 1984, Barney 1991, and Barney et al. 2001). From a resource-based point of view firms are heterogeneous as to their resource endowments and capabilities. The resource endowment determines to a great extent firms' behaviour or marks its spectrum of behaviour. It is firm-specific, thus relatively difficult to transfer or to modify. Teece et al. 1997 quote several reasons for the persistence of firm behaviour due to the specificity of resource endowment: firms lack the organisational capacity to develop new competences, some assets are not tradable (e.g. tacit knowledge), and needed inputs have to be bought at relatively high prices that reduce possible rents. In this context, the "sticky" character of the resource endowment on the average makes the study of firm strategies a challenge for economic research. Useful strategies enable firms to change or modify the resource endowment and thus improve firms' performance (see Wernerfelt 1984, Kor and Mahoney 2004).

Obviously, KTT is an important means to modify the resource endowment of firms. This is confirmed by firm assessments of the main motives to undertake KTT activities with universities. Firms are motivated for KTT, firstly in order to get better access to human capital (see Geisler and Rubinstein 1989, Schartinger et al. 2001, Onida and Malerba 1989, Arvanitis et al. 2005b). A second strong motivation for KTT activities is a better access to new knowledge and technology for improving the firm's knowledge base (see Lee 2000, Santoro and Chakrabarti 2002, Schmoch 2003, Arvanitis et al. 2005b). Thirdly, firms get involved in KTT activities with universities in order to built-up new fields of research (see Onida and Malerba 1989, Lee 2000, Schibany and Schartinger 2001).

However, which information or knowledge is perceived as important and useful depends very often on the already available knowledge inside a firm. Cohen and Levinthal (1989) called the ability to utilise new external knowledge the absorptive capacity of a firm. They emphasised a firm's own R&D efforts for developing a strong absorptive capacity. In fact, we see that in many studies the absorptive capacity is an important determinant for KTT activities. Arvanitis et al. (2005b) found a significant positive effect on the propensity for KTT in Switzerland of the absorptive capacity as measured by the skill-level of employees or the existence and intensity of R&D activities. Laursen and Salter (2004) investigated for the UK the types of firms that use universities as a source of innovation. They found also that variables related to the absorptive capacity of a firm such as R&D intensity and long-term R&D, show a positive impact on KTT activities.

Theoretical literature on R&D co-operations focuses primarily on the effect of imperfect appropriability of the results of innovation activities on the incentives to innovate (see e.g. Spence 1984; D'Aspremont and Jacquemin 1988). Thus, appropriability is a further important factor related to a firm's resource endowment (see Foss and Foss 2005). There is a twofold incentive problem. On the one hand, the existence of imperfect appropriability increases the incentives to co-operate, because of profits resulting from internalising external losses caused by imperfect appropriability (see e.g. De Bondt 1997). On the other hand, imperfect appropriability also increases the incentives to utilise spillovers resulting from R&D investments of the co-operation partner and encourages free-riding on R&D efforts of the co-operating firms by outsiders (see e.g. Shapiro and Willig 1990; Greenlee and Cassiman 1999). However, when co-operation partners are not direct competitors (e.g. suppliers of complementary goods), or when one partner is a science institution, imperfect appropriability of the benefits of generated knowledge is not an important issue (see Veugelers and Cassiman 2005). On the contrary, the possibility of acquiring new knowledge through incoming spillovers enhances considerably the propensity to get involved in KTT activities with universities and other public research institutions. Schmid (2005) found that firms are more likely also to be engaged in R&D co-operations with universities, if incoming spillovers measured by firms' evaluation on the importance of external information sources were high. Thus, the extent of spillovers from universities is an important determinant of a strategy aiming at an enlargement of a firm's resource endowment.

In addition, firms' KTT strategy may be also determined by limiting factors, which are perceived as obstacles for KTT. Although they are related to firms' resource endowments and capabilities, they are also reflecting external circumstances beyond the control of a firm, e.g. deficiencies of the science institution or difficulties to find contact persons (see Arvanitis et al. 2005a). Specific categories of obstacles for KTT, comprising firm-related obstacles as well as environment-related impediments, were empirically investigated e.g. by Mayer (2000), Schartinger et al. (2000), Onida and Malerba (1989) and Geisler (1997).

In addition to the main determinants of various KTT strategies we also intend to investigate the impact of KTT strategies both on firm innovativeness and firm economic performance. The growing importance of KTT for the innovation performance of a firm has already been emphasised in empirical studies (see e.g. Mansfield 1991, 1998, Feldman 1994, Beise and Stahl 1999, Arvanitis et al. 2005c). We can learn from a resource-based point of view that adequate KTT strategies that take into consideration the existing knowledge profile of a firm and indicate windows for improvements contribute to both an enlargement and an enrichment of the knowledge base, thus leading to positive effects on firms' performance. This way the resource-based view provides us with some heuristics to conceptualise the impact of KTT strategies on firms' performance.

Firstly, especially in the field of innovation, it is necessary to modify the knowledge base in order to remain innovative and to gain competitive advantages. Innovations are characterised through new insights or at least through a newer combination of existing knowledge. Thus, external knowledge sources gain in importance and as stated by Freeman (1992), especially in the case of rather radical innovation, universities knowledge is likely to play a significant role. Furthermore, useful knowledge is likely to be scarce, 'tacit' and not easy tradable (see Teece et al. 1997). Thus, it is not sufficient to know which kind of resources or capabilities are lacking. In addition one has to find ways to transfer them or build them in the firm.

Secondly, the strategic challenge to improve the innovation performance of a firm lies essentially in gaining excess to external knowledge or to build a knowledge network in "co-evolution" with the knowledge base within the firm. As a consequence we have to consider, in addition to several firm characteristics, the knowledge base and resource endowment of a firm in order to investigate the impact of various KTT strategies on the innovation or economic performance of a firm.

Following this heuristic we use a production function as an analytical framework. The main input we are interested to investigate is the strategic factor as measured by our "strategy variables". We are controlling for the resource endowment with respect to human capital, knowledge capital and physical capital. Furthermore, firm size and sector affiliation are taken into consideration. This way, we can identify the effects of the strategic factor (a) on the firm innovativeness and (b) on firm economic performance in addition to the effects of the available knowledge base.

Furthermore, we intend to analyse the impact of KTT strategy at two different performance levels, first the level of innovation performance as measured e.g. by the sales share of innovative products, second the level of economic performance as measured e.g. by labour productivity. It is assumed that the effects of KTT strategies are stronger on the innovation level and weaker – if at all discernible – at the firm level. This assumption is supported by the study of Mansfield and Wagner (1975). They showed that the success at the technical level is necessary but not sufficient for economic success. In our case KTT may positively impact the innovation performance of a firm but could have no visible impact on firms' economic performance, since other factors, e.g. organisational efficiency, marketing and market competition, may be more important than KTT for a high economic performance.

3. Data

The data used in this study were collected in the course of a survey among Swiss enterprises using a questionnaire which included questions on the incidence of KTT activities among firms, forms, channels, motives and impediments of the KTT activities of Swiss firms as well as on some basic firm characteristics (innovation and R&D activities, investment, sales, exports, employment and employees' vocational education). The survey was based on a (with respect to firm size) disproportionately stratified random sample of firms with at least 5 employees covering all relevant industries of the manufacturing sector, the construction sector and selected service industries (excluding industries with an expected very low propensity of KTT activities such hotels/catering, retail trade, real estate/leasing, personal services) as well as firm size classes (on the whole 25 industries and within each industry three industry-specific firm size classes with full coverage of the upper class of large firms).

Answers were received from 2582 firms, i.e. 45.4% of the firms in the underlying sample. The response rates do not vary much across industries and size classes with a few exceptions (over-representation of wood processing, energy industry and machinery, under-representation of clothing/leather industry). The non-response analysis (based on a follow-up survey of a sample of the non-respondents) did not indicate any serious selectivity bias with respect to the incidence of KTT activities with science institutions. A careful examination of the data of these 2582 firms led to the exclusion of 154 cases with contradictory or non-plausible answers; there remained 2428 valid answers. 669 of these firms were involved in KTT activities with Swiss universities and build the database for this study (see table A1 in the appendix for the composition of the final dataset). Further, we used the multiple imputations technique by Rubin (1987) to substitute for missing values in the variables due to item non-response (see Donzé 2001 for a detailed report on the procedure used). The estimations were based on the mean of five imputed values for every missing value of a certain variable.

4. Firms' KTT strategies

Our starting point is that the KTT strategies can be conceived as combinations of the 19 forms of KTT activities listed in Table 1. We asked Swiss firms to appraise the importance of these 19 different forms for KTT on a five-point Likert scale (1: not important; 5: very important). The questionnaire contained forms related to research activities carried out in co-operation with universities as well as "softer" forms for KTT, like informal contacts (attending scientific conferences, reading and citing scientific publications), further education and staff mobility (industrial sabbatical, joint PhDs, joint lecturing, employing graduates for R&D activities), use of technical infrastructure or consulting services (see Table 1). We applied cluster analysis, an explorative technique, in order to identify different KTT strategies.

Our cluster analysis follows the non-hierarchically procedure as described in Manly (1986). This procedure involves partitioning the sample, allowing observations to move in and out of groups at different stages of the analysis. At the beginning, more or less arbitrary group centres ("cluster seeds") were chosen and individual observations were allocated to the nearest one. An observation was later moved to another group, if it proved to be closer to that group's centre than to the centre of the initial group. This process, during which close groups were merged and distant ones split, was continued until stability was achieved with a predetermined number of clusters. At the end of this process every firm is assigned to only one cluster. The analysis yielded three clusters. They are characterised by an as small as possible within-cluster variance and by an as large as possible between-cluster variance. We applied the 'FASTCLUS' procedure of the SAS Software to carry out this type of cluster analysis.

Every cluster defines one specific strategy. Every firm assigned to this cluster is characterised by the cluster strategy. Thus, it is assumed that a firm pursues only one KTT strategy. Table 1 shows which combinations of the single 19 forms of KTT activities build the base of each of the three identified strategies. Table 2 shows which type of firms can be found in the respective clusters.

Strategy A "loose contacts": Firms in this category are engaged in KTT activities; however they assessed on the average none of the 19 forms for KTT as very important (see Table 1). Especially smaller firms with rather frequent R&D activities can be found in this strategy-cluster. They are primarily focusing on KTT activities with national universities, they have relatively few contacts to universities and they think that mediating or funding institutions like transfer-offices are of minor importance. A relatively great share of firms in this cluster is working in the traditional service sector, the construction sector or in the less technology-intensive manufacturing industries. Although the education-level of the employees in these firms is relatively high, the share of academics is relatively low. Deficiencies related to their own firm are the greatest obstacles in order to further intensify their KTT activities.

Strategy B "non-core contacts": Firms in this cluster applied "softer" KTT forms (and evaluated them as important on the average), which are not immediately dedicated to "core" R&D activities, i.e. informal contacts, attending conferences, reading and referring to publications, joint diploma theses, students' participation in firm R&D, common courses, joint PhD, teaching of firm researchers at the university, attending university training courses, expertise and consulting (see Table 1). This strategy is to a great extent applied by very large and also very small companies with no or occasional R&D activities. They are also focused more on KTT activities with national universities. They have various KTT contacts. Mediating or funding institutions like transfer-offices or the national innovation promotion agency CTI) are of minor importance. Most of these firms are affiliated to modern service sectors (e.g. telecommunication, banks, and insurances). The education-level of the staff is rather high, while the share of academics is slightly higher compared to cluster A. They are relatively frequently hindered to further intensify their KTT contacts through deficiencies on part of the universities.

Strategy C "core contacts": Firms in this cluster applying KTT forms immediately dedicated to their R&D activities (and evaluating them as important on the average), i.e. common laboratory, use of university technical infrastructure, employing graduates in R&D, contact of graduates with university, university researchers' participation in firm R&D, R&D joint projects, long-term research contracts, and research consortiums (see Table 1). This strategy is rather frequently applied by larger firms. They are very R&D-intensive and they are also focused on KTT activities with foreign universities. They strongly diversify their KTT contacts between different universities. Mediating or funding institutions are very important. The share of high-tech firms is relatively high. The education level is very good and the share of academics is relatively high in most of the firms in this cluster, compared to firms following other KTT strategies. Risk-related factors as well as scarce financial resources are the main categories of obstacles of further intensifying KTT activities.

5. Hypotheses and model specification

5.1 Determinants of KTT strategies

Following a resource-based view of the firm, we include in our model of the determinants of KTT strategies variables measuring the absorptive capacity of a firm (frequency of R&D activities, skill-level), the extent of incoming spillovers (number of KTT contacts with different universities, international KTT activities, use of mediating institutions), and several factors impeding KTT activities. The dependent variables are dummy variables for the three strategies A, B and C (STRA, STRB, STRC; see Table 3).

Consistent with the research results of other studies (see Laursen and Salter 2004, Fritsch 2002); we expect a positive impact of variables indicating the absorptive capacity on the KTT activities of a firm in general. When it comes to the specific strategies, it is expected that firms with a greater absorptive capacity will apply strategies that require more intensive forms of KTT contact than firms with lower absorptive capacities. Thus, we assume that frequency of R&D activities FUEA and the proxy for skill-level ACAD should have a positive sign for firms following more intensive KTT strategies (see Table 4).

H1: The absorptive capacity of a firm has a significant impact on the choice of KTT strategies. We expect a positive effect for strategy C vis-à-vis strategies A and B.

Assuming that KTT activities with universities in the broader sense, i.e. not only R&D co-operations, produce spillovers that are easier accessible by competent competitors than spillovers based on R&D co-operations with e.g. suppliers, points at the relatively importance of "incoming spillovers" for choosing a KTT strategy. In order to approximate the extent of incoming spillovers of a firm we applied three measures. The variable NETSIZE indicates the number of contacts with different universities (see Table 4). We assume that a greater net of scientific contacts enables a firm to detect quicker promising research results and gain first-mover advantages on product markets. The same is true for the variable KTTA that indicates the existence of international KTT activities. The variable MED points at the importance of mediating institutions like transfer offices or KTT funding organisations. It is likely that a high value for MED indicates a firm's effort to use spillovers generated by public research activities. We assume that each of the three variables NETSIZE, KTTA, MED representing the extent of incoming spillovers of a firm, i.e. show a significant positive impact on KTT strategies that require more intensive forms of contact as compared to strategies focusing on less intensive contacts with universities (e.g. reading and citing articles).

H2: Incoming spillovers are decisive for choosing a specific KTT strategy. We expect a positive effect for strategies C and B vis-à-vis strategy A.

We asked the participants of our survey to point at the importance of 26 obstacles of KTT activities. They could evaluate each obstacle on a five-point Likert scale (1: 'not important'; 5: 'very important'). A principal component factor analysis of the variables for these 26 single obstacles yielded a pattern of five factors (see Table A.2 in the appendix). The problems reflected by these obstacles are partly due to deficiencies of the resource base of the firm (e.g. lack of finance, lack of information with respect to KTT, lack of specialized personnel for KTT etc.). The RISK-factor comprises obstacles related to organisational/institutional aspects, uncertainty aspects and property rights problems (see Table 4). The DEFUNI factor comprises obstacles related to deficiencies of the science institutions with respect to KTT activities and a perceived mismatch of research interests. The DEFINFO-factor comprises problems related to lack of information, namely difficulties to get information, difficulties to find a contact person, and lack of resources for interface activities. The DEFCAP-factor points at obstacles related to the necessity of considerable follow-up work in order to implement public R&D results and to financial shortcomings on the sides of firms and universities. Finally, the

DEFFIRM-factor contains the following single obstacles: firms are lacking skilled staff, lack of interest in scientific projects and lack of technical equipment. While RISK, DEFINFO, DEFCAP, DEFFIRM are groups of obstacles related to the resource base of a firm, DEFUNI refers to obstacles caused by external factors, in this case the potential partners of public institutions. We expect that obstacles on the whole would exert a negative influence on KTT. However, more intensive KTT contacts should come along with decreasing importance of the different categories of obstacles. Thus, “core contact strategy” and/or “non-core contact strategy” should be less hindered by obstacles than firms following a “loose contact strategy”.

H3: Firms’ perception of important obstacles has a negative effect on the propensity to KTT activities. This is valid for categories of obstacles that are related to the resource base of a firm as well as to obstacles due to external factors. We expect a stronger effect of obstacles for strategy A vis-à-vis strategy B and strategy C.

We further control for firm size and sector affiliation. We built seven firm size dummies (G1 to G7), where G1 is the reference. We also built affiliation dummies for the high-tech manufacturing sector (HTCH), the low-tech manufacturing sector (LTCH), the construction sector (CONSTR), the sector of modern services (MSER) and the sector of traditional services (TSER) (see Table 4). We assume that there are size-related factors that show a positive correlation with more intense KTT strategies. Also it is likely that sector specific factors related to HTCH and MSER are positively correlated with more intensive KTT forms.

5.2 KTT strategies and firms’ performance

Assuming a profit maximising behaviour of firms, the various strategies are pursued in order to improve the firm performance at different levels. Since KTT activities are mainly conducted to strengthen firms’ R&D activities or to launch new innovative products, we expect that successful KTT strategies would be reflected primarily in a higher innovation performance. Furthermore, successful KTT strategies could also leave some traces on the overall firm performance. A strategy impact at this level should be lower compared to the respective effect on innovation performance, if it is at all discernible (see also chapter 2).

In order to determine the impact of the different strategies on performance measures we specify an innovation and a productivity equation (see Table 5 for the dependent variables). The innovation performance is measured by the variable PAT that indicates whether a firm has patent applications in the period 2002-2004 or not. Furthermore, we approximate the innovativeness of a firm with the variable NPROD that indicates the sales share of new products on total sales (log). The overall firm performance is measured by the variable LPROD (log of labour productivity).

Following the specification of Arvanitis et al. (2005c) we identify the resource endowment of the firm as most decisive for its innovation performance and its overall firm performance as well (see Table 6). In addition to three dummy variables for the different KTT strategies

(STRA, STRB, STRC), we used as independent variables proxies for the intensity of human capital (LQUAL; logarithm of the share of employees with tertiary-level education), the intensity of physical capital (LCI: gross investment per employee), the affiliation of the firm to a foreign company (FOREIGN; foreign firm yes/no), R&D activities of a firm (FUE; yes/no) and control variables for firm size (seven dummy variables) and for industry affiliation (5 sector dummy variables). According to standard empirical evidence from earlier studies we expected positive effects for LQUAL, LCI and the firm size. The effect of the variable FOREIGN as well as the impact of STRA, STRB, and STRC on the performance variables is not a priori clear. As to the different strategies we propose the following hypotheses, assuming that a more intensive transfer contact with public research organisations more effectively modifies the knowledge base of a firm and thus has a positive impact on its innovation and economic performance:

H4: Strategy C "core contacts" has a greater impact on innovation performance of firms than strategy A or strategy B. Furthermore, strategy B "non-core contacts" is more successful in order to improve the innovation performance of a firm than strategy A "loose contacts".

H5: Strategy C "core contacts" has a greater impact on the economic performance than strategy A and strategy B. Furthermore, strategy B "non-core contacts" is more successful in order to improve the economic performance than strategy A "loose contacts".

6. Estimation results

6.1 What determines firms' KTT strategies?

We used the same set of determinants (see table 4) for all three strategies. We estimated a multinomial logit model for the three strategies A, B and C. This method showed to be efficient according to two tests for the "independency of irrelevant alternatives" (HAUSMAN-test and SUEST (seemingly unrelated estimation)-test carried out with the STATA Software, version 9). More concretely, we applied this procedure to investigate the relevance of variables for absorptive capacity, incoming spillovers, firm-specific obstacles of KTT activities and further firm characteristics for choosing a KTT strategy. The results are presented in Table 7. Strategy A "loose contacts" (STRA) serves as the base category. Thus, we compare Strategy B and C respectively with strategy A. Based on these estimates we tested hypotheses 1 to 3.

The variables FUEA and ACAD are representing the absorptive capacity of a firm. Quite interestingly, significant differences in absorptive capacity are detectable between firms following strategy A (variable STRA) and strategy B (variable STRB) respectively. As indicated by the significant negative sign of the variable FUEA, firms following strategy

STRB conduct R&D activities less frequently than firms conducting STRA. The significant negative sign of FUEA in the estimation for STRB indicates that a greater absorptive capacity does not go along with more intensive types of KTT strategies. Anyway, *hypothesis 1* cannot be falsified, since the absorptive capacity of a firm have a significant impact on the strategy choice and at least between STRC and STRB we see the expected significant positive correlation.[1]

The results clearly show that firms with the ability to internalise potential "incoming spillovers", as indicated by the variables NETSIZE, KTTA and MED, follow STRB or especially STRC rather than STRA. This indicates that the importance of extent of incoming spillovers and the intensity of KTT are significant positively correlated. While only NETSIZE is significant positive as to STRB, all three variables (NETSIZE, KTTA, MED) have a significant positive impact on STRC compared to STRA. Thus, we cannot falsify *hypothesis 2*. Incoming spillovers are decisive for the choice of a KTT strategy. Moreover, the more comprehensive are the contacts between firms and public research organisations, the more important are such spillovers.

The pattern of the effects of obstacles of KTT activities differs only slightly between firms following STRA compared to STRB. Firms following STRB are less confronted with deficiencies on part of their own firm such as lack of qualified staff, lack of technical equipment and lack of interest in scientific projects (DEFFIRM) than this is the case for firms conducting STRA. The obstacle profile differs more between STRA and STRC. The more KTT-experienced firms in strategy cluster STRC emphasise stronger the RISK-factor (organisational/institutional and property rights aspects) and the DEFCAP-factor (follow-up work, financial shortcomings) than firms engaged in STRA. In contrast, we found that deficiencies on part of the universities are less important for firms following STRC than for those pursuing STRA, as it is indicated by the statistically significant negative sign of DEFUNI. Thus, the detected mismatch between firms' research interests and capabilities and the research interests and capabilities of public research institutions seems to diminish, if the intensity of transfer contact increases. This hints at some learning effects with respect to abilities and thus related advantages of transfer activities with public research institutions.

In sum, we cannot reject *hypothesis 3* that firms' perception of important obstacles impacts their KTT strategy. Moreover, it can be stated that more intensive KTT contacts go along with a shift in the obstacle profile of a firm. Firms with few and less intensive contacts are very aware of their own deficiencies and they seem to have a fixed idea about the deficiencies of universities. In contrast, firms with more KTT experiences emphasise risk-related factors and financial restrictions. Both interpretations, obstacles are determining KTT strategy and the KTT strategy characterises the obstacle profile are basically valid. Based on a cross-sectional

[1] This calculation is not shown in the Table 7. However, we calculated our estimations also by choosing STRB as a base category and in this case FUEA showed the significantly positive sign in STRC (compared to STRB).

data set, this causality cannot be econometrically further investigated. However, following the resource-based view it is appropriate to assume that obstacles are at least to some extent founded in firms' resource-base. Thus, it is more likely that primarily obstacles mark the limitations for KTT strategies.

Choosing strategy B vis-à-vis strategy A does not depend on firm size. Firms in the modern service sector seem to have a preference for strategy B compared to strategy A. Large firms with more than 500 employees show a stronger preference for strategy C compared to strategy A, but no sector effect could be detected in this case.

6.2 The impact of KTT strategies on firms' performance

In order to measure the impact of the different KTT strategies on several firm performance measures, we applied a probit estimation procedure to estimate their impact on patent activities. As to the impact of KTT strategies on the share of new products on total sales and the productivity measure, we applied an OLS regression with heteroscedasticity-robust standard errors (White procedure). According to the Rivers-Vuong-test for endogeneity (see Rivers and Vuong 1988) the variable FUE did not show any significant bias[2].

We differentiate between two different performance levels, i.e. innovation performance of a firm and its economic performance. These levels are measured through three different (dependent) variables. PAT (patent applications yes/no) and NPROD (logarithm of the share of new products on total sales) measure the innovation performance of a firm and LPROD (logarithm of value added per employee) measures the economic performance of a firm.

Table 8, Table 9, and Table 10present the results of our estimations. Firstly, we comment shortly on the effects of independent variables other than the strategy variables. These variables (equal for all estimations) do have a different impact on the innovation performance and on the firm performance, respectively. PAT focuses on the immediate innovation output. It is significantly positively correlated with the R&D activities of a firm and its human capital. Furthermore we find a positive size effect and no sector effects. NPROD indicates the market success of innovative products. It is significantly positively correlated with the R&D activity of a firm and firm size. It is not significantly correlated with the variables for human capital, capital investments, foreign-ownership, firms' size and sector affiliation. In contrast, all variables are significantly positively correlated with the firm performance (LPROD) with the exemption of sector affiliation (manufacturing).

Secondly, also the KTT strategy variables (STRA, STRB, and STRC) have a different effect on the innovation performance measures and on the firm performance measure, respectively. We chose STRA (strategy A) as the reference. PAT is significantly positive correlated with STRC (strategy C) compared to STRA (strategy A). NPROD is significantly positive

[2] The Rivers-Vuong-test could only be performed as to our estimations for NPROD and LPROD, since basically all of the available instruments (export activities, firm size and sector affiliation) are significantly correlated with PAT. As to NPROD and LPROD this is to some extent the case for firm size and sector affiliation.

correlated to STRC compared to STRA, while no strategy effect can be detected with respect to average labour productivity (LPROD).
In sum, we see that strategy matters in order to identify an impact of KTT on the innovation performance of a firm. STRC clearly shows advantages over STRA and STRB.
These results give some hints for possible activity fields of KTT policy aiming at supporting firms that want to change their strategic approach from STRA to STRC and thus increase the impact of KTT on the innovation performance of the firm.

7. Summary and Conclusions

Firms are increasingly engaged in knowledge and technology transfer (KTT) activities with universities or public research institutions in order to improve the innovation and economic performance of the firm. To achieve this goal they are applying different strategies and in relation with the chosen strategy their KTT activities are more or less successful.

A survey on KTT activities of Swiss firms carried out in 2005 provided us with a comprehensive data set. Based on data for 669 KTT active firms, three dominant KTT strategies were identified by using cluster analysis and were characterised in the context of a "resource based" view of the firm. Strategy A (STRA "loose contacts") is pursued by firms that evaluated on the average none of the 19 forms as very important. Strategy B (STRB "non-core contacts") is followed by firms that mainly apply "softer" KTT forms that are not immediately dedicated to the R&D activities of the firm. Finally, strategy C (STRC "core contacts") is found for firms that emphasise forms of KTT activities that are immediately dedicated to their R&D activities (e.g. contract-R&D).

In a second step we investigated the determinants of KTT strategies. Applying several econometric procedures it was shown that the absorptive capacity of a firm has a significant impact on the choice of KTT strategies: firms following STRA or STRC do have greater absorptive capacities than firms applying STRB. Furthermore, our indicators for "incoming spillovers" also showed significant differences between the three strategies. Firms conducting STRC emphasise broad KTT networks and appreciate the service of KTT-supporting institutions. This kind of softer spillover mechanisms is of greater importance for firms in cluster STRC compared to firms in strategy cluster STRA. Firms in strategy cluster STRB also emphasise broad KTT networks compared to firms conducting STRA. This way they increase the probability to "internalise" knowledge spillovers resulting from university research or research collaboration between universities and the firm. The obstacle profile of firms in various strategy clusters differs as well. Firms that are pursuing STRB are less hindered through deficiencies within their own firm than firms following STRA. More pronounced are differences between strategy cluster STRA and STRC. The more KTT-experienced firms in strategy cluster STRC detect deficiencies on part of universities to a much lower extent than firms in STRA. On the contrary, KTT activities of firms in cluster STRC are clearly stronger hindered by risk related obstacles and financial restrictions.

In a further step we analysed the impact of the different strategies on firms' innovation and economic performance. We found that KTT strategy matters for the innovation performance of a firm. STRA is in both innovation equations significantly inferior to STRC after controlling for certain firm characteristics and its resource endowment. The results for STRB are not clear-cut. Neither of the two strategies B and C shows a significant impact on the overall firm performance-level compared to strategy A. Further, we found that the human capital of a firm as well as their R&D activities, investment behaviour, foreign ownership as well as a number of control variables (firm size and sector dummies) are positive correlated with the labour productivity of a firm.

In sum, the study shows that from a firm's point of view it is worth reconsidering the type of KTT strategy to be applied in order to transfer efficiently publicly available knowledge. Of course, there are good and better ways to do so. Basically more intensive KTT relations that are focused on "core" R&D activities of a firm are more promising than rather "loose" contacts, if the involved firm has high absorptive capacities and is in a position to "internalise" possible spillovers resulting from the KTT engagement, e.g. through a broad KTT network or through the services offered by transfer-supporting institutions. These conditions are more likely to be found in larger firms.

From a policy point of view the study provides some insights in order to promote KTT and the "valorisation" of public knowledge. Firstly, an enlargement of the network of a firm through contacts to more than one science institutions (variable NETSIZE) increases the likelihood that the firm applies the most successful strategy C. The same can be expected also for contacts with foreign science institutions (variable KTTA) and the utilisation of the services of KTT-supporting institutions. Thus, policy measures that support firm efforts in this direction help them also to apply more successful KTT strategies. Secondly, based on the obstacle profile of a strategy cluster, policy makers can derive some interesting conclusions for designing policy measures to promote KTT. Availability of additional funds matters for firms conducting strategy C, but not for KTT activities at a low-level (loose and non-core contacts). In the latter case firms are mainly hindered to intensify their KTT activities through the experience of a mismatch between the R&D orientation (research interest) of the scientific institutions and the research interests of the firm, or the lack of a vision for the commercialisation of available results of public research. Furthermore, they detect some deficiencies within their firm, e.g. lack of qualified staff, lack of technical equipment and lack of interest in scientific projects that makes it difficult to get involved in KTT activities. Thirdly, strategy C which is the most successful one in terms of innovation and economic performance is applied more often by large firms (with more than 500 employees) than by smaller firms. Since firm growth is limited at least in the short run, the strategic choice, e.g.

the choice of strategy C, is limited as well for small firms. Thus, the potential impact of policy measures is restricted, since smaller firms can not provide enough internal resources to change to a more effective strategy even if the general framework conditions of the economy are favourable for such a change.

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Table 1: Results of the cluster-analysis

Forms	Means of scores (5 point Likert-scale)				% of Firms assessing form as very important (4 or 5 on a five-point Likert-scale)			
	STRA	STRB	STRC	Total	STRA	STRB	STRC	Total
Informal								
Informal contacts	2.74	3.28	3.64	3.07	24.32	41.03	56.86	35.13
Attending conferences	2.53	3.44	3.44	2.99	14.71	50.43	53.92	33.18
Reading, referring to publications	2.61	3.35	3.44	3.00	19.22	50.85	48.04	34.68
Infrastructure								
Common laboratory	1.36	1.33	2.43	1.51	2.40	2.56	27.45	6.28
Use of university technical infrastructure	2.05	1.73	3.57	2.17	13.21	7.26	56.86	17.79
Education								
Employing graduates in R&D	2.34	2.44	4.02	2.63	23.42	27.35	76.47	32.88
Contact of graduates with university	1.83	1.91	3.41	2.10	10.81	11.11	50.00	16.89
Students' participation in firm R&D	1.96	2.38	3.67	2.37	9.91	15.81	60.78	19.73
Diploma theses	1.99	2.96	3.65	2.58	12.31	31.62	61.76	26.61
PhD	1.35	1.79	2.82	1.73	3.90	7.26	30.39	9.12
University researchers' participation in firm R&D	1.56	1.76	2.97	1.84	5.41	6.41	34.31	10.16
Common courses	1.22	1.90	2.34	1.63	0.30	7.69	15.69	5.23
Teaching of firm researchers at the university	1.26	2.13	2.46	1.74	1.50	15.38	21.57	9.42
Attending university training courses	2.24	3.45	3.41	2.84	7.51	49.57	54.90	29.45
Research								
R&D joint projects	2.03	1.81	3.97	2.25	14.71	8.12	72.55	21.23
Long-term research contracts	1.37	1.32	3.05	1.61	3.60	1.28	36.27	7.77
Research consortium	1.35	1.28	3.01	1.58	2.40	0.43	31.37	6.13
Consulting								
Expertise	1.66	2.39	2.92	2.11	3.90	16.67	35.29	13.15
Consulting	1.86	2.46	3.08	2.26	7.21	17.95	38.24	15.70

Table 2: Descriptive characterisation of KTT strategies (percentage of KTT active firms)

Variable		Strategy A	Strategy B	Strategy C	Total
Frequency of R&D activities	no activities	29.73	40.17	6.86	29.90
	occasionally	13.51	16.67	11.76	14.35
	permanently	56.76	43.17	81.37	55.76
Average share of employees with tertiary-level education		8.46	12.70	14.45	10.86
Average share of higher educated employees (incl. tertiary-level education)		26.02	31.15	32.47	28.80
Number of contacts to science institutions	0	10.51	9.40	6.86	9.57
	1	25.83	14.53	7.84	19.13
	2	22.52	22.22	9.80	20.48
	3	18.92	19.23	17.65	18.83
	4	10.81	14.10	12.75	12.26
	5	5.11	8.12	14.71	7.62
	> 5	6.30	12.39	30.38	12.11
Contacts to foreign science institutions	yes	32.43	34.19	74.51	39.46
Mediating institutions	0 (not important)	84.68	83.76	31.37	76.23
	1	11.11	8.97	32.35	13.60
	2	2.70	5.13	20.59	6.28
	3	1.50	1.71	7.84	2.54
	4	0.00	0.43	5.88	1.05
	5 (very important)	0.00	0.00	1.96	0.30
Obstacles of KTT activities⊗(1)					
RISK		-0.1073	-0.0680	0.5062	
DEFUNI		0.0110	0.0548	-0.1617	
DEFINFO		-0.0193	-0.0052	0.0750	
DEFCAP		-0.0587	-0.1004	0.4221	
DEFFIRM		0.1164	-0.1036	-0.1424	
Firm size:					
5-19 employees		13.51	11.11	7.84	11.81
20-49 employees		16.82	17.52	5.88	15.40
50-99 employees		20.42	18.38	12.75	18.54
100-199 employees		18.92	19.66	17.65	18.98
200-499 employees		22.22	16.67	30.39	21.52
500-999 employees		5.11	8.55	14.71	7.77
1000 and more employees		3.00	8.12	10.78	5.98
High-tech manufacturing		41.44	29.06	67.65	41.11
Low-tech manufacturing		27.63	26.07	16.67	25.41
Construction		6.31	3.42	2.94	4.78
Modern services		15.32	31.20	11.76	20.33
Traditional services		9.31	10.26	0.98	8.37

(1): See table 4 for the construction of the obstacle variables.

Table 3: Determinants of KTT Strategies – Dependent variable

Dependent Variable	Description
STRAT	KTT strategies taking the values 1, 2 or 3: 1 … indicates strategy A: "loose contacts" 2 … indicates strategy B: "non-core contacts" 3 … indicates strategy C: "core-contacts"

Table 4: Determinants of KTT Strategies – Independent variables

Independent Variables	Description	Expected sign
Absorptive capacity		
FUEA	Frequency of R&D activities taking the values 0 for 'no activities', 1 for 'occasionally' and 2 for 'permanently'.	+
ACAD	Share of employees with a tertiary education on total employees (full-time equivalents).	+
Appropriability mechanisms		
NETSIZE	Number of contacts to universities (to the same type and/or different types of universities).	+
KTTA	Knowledge and technology transfer with foreign universities (yes/no).	+
MED	Sum of the scores for the individual evaluation of the importance of the following mediating institutions on a five-point Likert scale (1; unimportant, 5; very important): Transfer offices, KTI/CTI (Innovation Promotion Agency), SNF/SNFS (Swiss National Science Foundation), EU Framework Programmes, Other European Programmes.	+
Obstacles		
(Scores of a principal component factor analysis of the importance of 26 obstacles to KTT, as assessed by firms on a five-point scale)		
RISK	Resource-intensive administrative and approval procedures, legal restrictions; lack of project administration support on the part of the academic institution; lack of support for commercialisation of research findings on the part of the academic institution; property rights problems; project management problems on part of the academic institution; different views on urgency; lack of confidence; risk of putting reputation at stake; secrecy with respect to firms' know-how is not guaranteed; insufficient efficiency of university staff compared to firms' staff; technological dependency from external institutions; Uncertainty about outcomes of co-operations; lack of entrepreneurial spirit	-
DEFUNI	Lack of scientific staff for transfer activities; R&D orientation of science institutions is uninteresting for firms; possible R&D results cannot be commercialised; firms' R&D questions are not interesting for science institutions	-
DEFFIRM	Lack of qualified staff; Lack of technical equipment; Lack of interest in scientific projects	-
DEFCAP	Need of comprehensive additional follow-up work in order to implement public R&D results; Lack of firm financial resources for transfer activities; Lack of financial resources of science institutions for co-operation on an equal basis with firms.	-
DEFINFO	Difficulties to get information about R&D activities in science institutions; Difficulties to find contact persons; Lack of resources for "interface" (e.g. transfer office)	-
Control variables		
G1 to G7	Seven size dummy variables based on number of employees (full-time equivalent); G1 (<20), G2 (20 - <50), G3 (50 - <100), G4 (100 - <200), G5 (200 - <500), G6 (500 - <1000), G7 (1000+). Reference size dummy = G1	+
HTCH, LTCH, CONSTR, MSER, TSER	Five sector dummy variables based on the sector affiliation of the firm; HTCH (high-tech firms; chemicals, plastics/rubber, machinery electrical machinery, electronic/instruments, vehicles), LTCH (low-tech firms; food/beverage, textile, clothing/leather, wood processing, paper, printing, glass/stone/clay, metal, metal working, watches, other manufacturing, energy/water); CONSTR (construction sector), MSER (modern services; banking/insurance, computer services, business services, telecommunication) TSER (traditional services; wholesale, transport). Reference sector = CONSTR	+

Table 5: Performance equation – dependent variables

Dependent Variables	Description
PAT	Firm files patent applications (yes/no)
NPROD	Logarithm of the share of new products on total sales (log)
LPROD	Logarithm of value added per employee (full-time equivalents); value added = sales minus intermediate input

Table 6: Performance equation – independent variables

Independent Variables	Description	Expected sign*
Resource endowment		
FUE	Firm undertakes R&D activities (yes/no)	+
LCI	Logarithm of gross investment per employee (full-time equivalents)	+
LACAD	Logarithm of the share of employees with tertiary-level education	+
Strategy variables		
STRA	Result of a cluster analysis of various KTT forms (see Table 1): Firms in this cluster are engaged in KTT (knowledge and technology transfer) activities, however on the average none of the 19 KTT forms have been assessed as very important	+
STRB	Result of a cluster analysis of various KTT forms (see Table 1): Firms in this cluster are engaged in KTT activities. “Softer” KTT forms on the average are very important (4 or 5 on a five-point Likert scale) for them, i.e. informal contacts, attending conferences, reading and referring to publications, joint diploma theses, students’ participation in firm R&D, common courses, joint PhD, teaching of firm researchers at the university, attending university training courses, expertise and consulting.	+
STRC	Result of a cluster analysis of various KTT forms (see Table 1): KTT forms immediately dedicated to R&D activities on the average are very important (4 or 5 on a five-point Likert scale) for firms in this cluster, i.e. common laboratory, use of university technical infrastructure, employing graduates in R&D, contact of graduates with university, university researchers’ participation in firm R&D, R&D joint projects, long-term research contracts, and research consortium.	+
Control variables		
G1 to G7	Seven size dummy variables based on number of employees (full-time equivalent); G1 (<20), G2 (20 - <50), G3 (50 - <100), G4 (100 - <200), G5 (200 - <500), G6 (500 - <1000), G7 (1000+). Reference in estimation = G1	+
FOREIGN	Firm is affiliated to a foreign company (yes/no)	n.a.
IND, CONSTR, DL	Three sector dummy variables based on the sector affiliation of the firm; IND (manufacturing sector), CONSTR (construction sector), DL (service sector). Reference in estimation = CONSTR.	+

(*): the expected sign refers to all dependent variables.

Table 7: Results - determinants of KTT Strategy

Multinomial logistic regression				Number of obs	=	669
				Wald chi2(40)	=	223.94
				Prob > chi2	=	0.0000
				Pseudo R2	=	0.2020

Log pseudolikelihood = -534.62645

	Coef.	Robust Std. Err.	z	P>z	[95% Conf. Interval]	
STRB						
FUEA	-.4594886	.1239372	-3.71	0.000	-.702401	-.2165761
ACAD	.0094201	.0066592	1.41	0.157	-.0036318	.0224719
NETSIZE	.1621118	.0487203	3.33	0.001	.0666219	.2576017
KTTA	.15081	.2056732	0.73	0.463	-.252302	.553922
MED	.1193378	.1633408	0.73	0.465	-.2008044	.4394799
RISK	.1163969	.0979711	1.19	0.235	-.075623	.3084168
DEFUNI	.0330927	.0889574	0.37	0.710	-.1412606	.2074461
DEFINFO	.038135	.0926976	0.41	0.681	-.1435489	.219819
DEFCAP	.0298046	.0998143	0.30	0.765	-.1658279	.2254371
DEFFIRM	-.1741847	.1012638	-1.72	0.085	-.3726581	.0242886
G2	.2372614	.3476393	0.68	0.495	-.444099	.9186218
G3	.3201562	.3473793	0.92	0.357	-.3606947	1.001007
G4	.5662641	.3511094	1.61	0.107	-.1218977	1.254426
G5	.0576296	.3597107	0.16	0.873	-.6473904	.7626495
G6	.7330281	.4541971	1.61	0.107	-.1571819	1.623238
G7	.8964778	.5104347	1.76	0.079	-.1039558	1.896911
HTCH	.3793464	.4711984	0.81	0.421	-.5441855	1.302878
LTCH	.5886038	.4633587	1.27	0.204	-.3195625	1.49677
MSER	1.091687	.4841939	2.25	0.024	.1426845	2.04069
TSER	.6971843	.5105448	1.37	0.172	-.303465	1.697834
CONST.	-1.356328	.502397	-2.70	0.007	-2.341008	-.3716477
STRC						
FUEA	-.0232423	.2329292	-0.10	0.921	-.4797752	.4332906
ACAD	.0139124	.0104034	1.34	0.181	-.0064779	.0343027
NETSIZE	.2155513	.0568261	3.79	0.000	.1041742	.3269285
KTTA	1.007615	.3171011	3.18	0.001	.3861083	1.629122
MED	1.039452	.1585272	6.56	0.000	.7287441	1.350159
RISK	.3555062	.1547077	2.30	0.022	.0522846	.6587277
DEFUNI	-.2947921	.1606846	-1.83	0.067	-.6097282	.020144
DEFINFO	.1555176	.1439815	1.08	0.280	-.1266809	.4377161
DEFCAP	.4310909	.14361	3.00	0.003	.1496206	.7125613
DEFFIRM	-.1434178	.1527574	-0.94	0.348	-.4428168	.1559813
G2	-.1941183	.8509036	-0.23	0.820	-1.861859	1.473622
G3	.4043461	.656014	0.62	0.538	-.8814178	1.69011
G4	.4826289	.649692	0.74	0.458	-.7907439	1.756002
G5	.8517726	.5976918	1.43	0.154	-.3196819	2.023227
G6	1.39772	.7127832	1.96	0.050	.0006909	2.79475
G7	1.578466	.7816272	2.02	0.043	.0465051	3.110427
HTCH	.2417865	.7346752	0.33	0.742	-1.19815	1.681723
LTCH	.0134527	.7458464	0.02	0.986	-1.448379	1.475285
MSER	-.2357509	.8033683	-0.29	0.769	-1.810324	1.338822
TSER	-1.101142	.9912065	-1.11	0.267	-3.043871	.8415871
CONST.	-4.046461	.8666342	-4.67	0.000	-5.745033	-2.347889

STRA is the base outcome; heteroscedasticity-robust standard errors (White procedure).

Table 8: Innovation performance – impact of KTT strategy on patenting

Probit regression

Number of obs. = 665
Wald chi2(14) = 133.44
Prob > chi2 = 0.0000
Pseudo R2 = 0.2424

Log pseudolikelihood = -278.57527

PAT	Coef.	Robust Std. Err.	z	P>z	[95% Conf.	Interval]
LACAD	1748606	.0674796	2.59	0.010	.042603	.3071182
LCI	-.0133473	.0462647	-0.29	0.773	-.1040245	.0773298
FUE	.9571877	.1610195	5.94	0.000	.6415953	1.27278
STRB	-.1988233	.1308756	-1.52	0.129	-.4553348	.0576881
STRC	.31795	.1626221	1.96	0.051	-.0007835	.6366835
FOREIGN	.1900486	.1401519	1.36	0.175	-.0846441	.4647413
G2	.5929765	.2876205	2.06	0.039	.0292507	1.156702
G3	.7751062	.2635399	2.94	0.003	.2585775	1.291635
G4	1.136547	.2587846	4.39	0.000	.6293384	1.643755
G5	1.191693	.2579349	4.62	0.000	.6861497	1.697236
G6	1.299484	.2900022	4.48	0.000	.7310905	1.867878
G7	1.151846	.3028871	3.80	0.000	.5581978	1.745493
IND	.5370311	.3234917	1.66	0.097	-.097001	1.171063
DL	-.2555169	.3501539	-0.73	0.466	-.9418059	.4307721
CONS	-2.523306	.4679535	-5.39	0.000	-3.440479	-1.606134

Heteroscedasticity-robust standard errors (White procedure).

Table 9: Innovation performance – impact of KTT strategy on share of new products

Linear regression

Number of obs = 661
F(14, 536) = 9.43
Prob > F = 0.0000
R-squared = 0.1620
Root MSE = 1.2367

NPROD	Coef.	Robust Std. Err.	t	P>t	[95% Conf.	Interval]
LACAD	-.0333561	.0530006	-0.63	0.529	-.1374303	.0707181
LCI	.0393252	.0431201	0.91	0.362	-.0453472	.1239977
FUE	.8241294	.1278244	6.45	0.000	.573128	1.075131
STRB	.1024404	.1096792	0.93	0.351	-.1129305	.3178113
STRC	.3053823	.1452939	2.10	0.036	.020077	.5906877
FOREIGN	-.0367106	.1199428	-0.31	0.760	-.2722355	.1988142
G2	.3443828	.1975539	1.74	0.082	-.0435426	.7323081
G3	.1068978	.1822231	0.59	0.558	-.2509233	.4647188
G4	.4412987	.1874677	2.35	0.019	.0731791	.8094183
G5	.4597041	.1808583	2.54	0.011	.104563	.8148453
G6	.4316539	.2114298	2.04	0.042	.0164812	.8468265
G7	.3076231	.2279731	1.35	0.178	-.1400347	.7552809
IND	.4379749	.2719291	1.61	0.108	-.0959968	.9719465
DL	.1157187	.2777339	0.42	0.677	-.4296516	.6610889
CONS	.3435097	.3355607	1.02	0.306	-.3154117	1.002431

Heteroscedasticity-robust standard errors (White procedure).

Table 10: Firm performance – impact of KTT strategy on labour productivity

Linear regression

Number of obs. =	665
F(14, 537) =	8.03
Prob > F =	0.0000
R-squared =	0.1651
Root MSE =	.49608

LPROD	Coef.	Robust Std. Err.	t	P>t	[95% Conf.	Interval]
LACAD	.0461402	.0214133	2.15	0.032	.0040926	.0881877
LCI	.1160853	.0200903	5.78	0.000	.0766356	.1555349
FUE	.0808564	.0491058	1.65	0.100	-.0155688	.1772816
STRB	.0109733	.0452187	0.24	0.808	-.077819	.0997656
STRC	.0443884	.0617041	0.72	0.472	-.076775	.1655517
FOREIGN	.1930926	.0492836	3.92	0.000	.0963183	.2898668
G2	.1926524	.0684548	2.81	0.005	.0582332	.3270717
G3	.1972069	.0605763	3.26	0.001	.0782581	.3161557
G4	.1705868	.0660635	2.58	0.010	.0408631	.3003104
G5	.1924943	.0615839	3.13	0.002	.0715668	.3134217
G6	.2840942	.0859767	3.30	0.001	.1152685	.4529198
G7	.3783157	.1675513	2.26	0.024	.0493085	.7073228
IND	.0710291	.0793367	0.90	0.371	-.084758	.2268163
DL	.2062648	.0863622	2.39	0.017	.0366822	.3758474
CONS	10.88405	.1215077	89.58	0.000	10.64546	11.12265

Heteroscedasticity-robust standard errors (White procedure).

Appendix

Table A.1: Composition of the data set – number of observations in total and allocated to industries and firm size

Industries	N	Size (full-time equivalents) <20	20-49	50-99	100-199	200-499	500-999	1000+
Food/beverage	34	5	3	4	8	7	5	2
Textile	9	1	1	2	2	2	1	0
Clothing/leather	0	0	0	0	0	0	0	0
Wood processing	9	4	2	1	2	0	0	0
Paper	9	0	1	1	3	4	0	0
Publishing	17	0	2	8	2	4	0	1
Chemicals	37	4	5	6	9	7	4	2
Plastics/rubber	13	2	1	2	5	2	0	1
Other non metallic mineral products	13	2	0	5	1	4	0	1
Metal	9	0	1	1	3	4	0	0
Metalworking	37	3	7	9	12	4	2	0
Machinery	116	7	13	27	27	27	10	5
Electrical machinery	33	1	2	4	7	13	5	1
Electronic/instruments	67	15	7	11	12	13	6	3
Watches	6	0	0	2	0	3	0	1
Vehicles	9	0	0	2	2	3	0	2
Other manufacturing	12	0	1	3	3	4	1	0
Energy/water	15	2	2	0	2	5	1	3
Construction	32	2	7	7	4	9	2	1
Wholesale	35	4	17	4	3	5	2	0
Transport	21	2	1	2	6	6	1	3
Banking/insurance	35	4	5	3	2	4	8	9
Computer services	28	2	4	4	8	8	2	0
Business services	67	19	19	16	4	5	2	2
Telecommunication	6	0	2	0	0	1	0	3
Total	**669**	**79**	**103**	**124**	**127**	**144**	**52**	**40**

Table A.2: Factor analysis of obstacles for KTT activities

(based on assessments of the respondents on a 5-point Likert scale)

Rotated Factor Pattern

	Factor1 (RISK)	Factor2 (DEFUNI)	Factor3 (DEFINFO)	Factor4 (DEFCAP)	Factor5 (DEFFIRM)
Lack of confidence	0.76798				
Risk of putting reputation at stake	0.75226				
Property rights problems	0.73101				
Lack of project administration support on the part of the academic institution	0.72257				
Project management problems on part of the academic institution	0.71811				
Lack of support for commercialisation of research findings on the part of the academic institution	0.70513				
Different views on urgency	0.68830				
Resource-intensive administrative and approval procedures, legal restrictions	0.68313				
Technological dependency from external institutions	0.58033				
Uncertainty about outcomes of co-operations	0.57297				
Secrecy with respect to firms' know-how is not guaranteed	0.57015				
Efficiency of university staff compared to firms' staff	0.56385				
Lack of entrepreneurial spirit	0.53115				
R&D orientation of science institutions is uninteresting for firms		0.72950			
Possible R&D results cannot be commercialised		0.68254			
Firms' R&D questions are not interesting for science institutions		0.61794			
Lack of scientific staff for transfer activities		0.40684			
Difficulties to get information about R&D activities in science institutions			0.84150		
Difficulties to find contact persons			0.83772		
Lack of resources for "interface" (e.g. transfer office)			0.74890		
Lack of firm financial resources for transfer activities				0.74141	
Lack of financial resources of science institutions for co-operation on an equal basis with firms				0.66823	
Need of comprehensive additional follow-up work in order to implement public R&D results				0.56064	
Lack of qualified staff					0.83109
Lack of technical equipment					0.79187
Lack of interest in scientific projects					0.56564
Number of observations					669
Kaiser's overall measure of sampling adequacy (MSA)					0.927
Variance accounted for by the first 5 factors					0.617
Root mean square off-diagonal residuals (RMSE)					0.051
Variance accounted for by each factor	9.806	2.342	1.556	1.256	1.080
Final communality estimate (total)					16.038

Table A.3: Correlations between determinants of the KTT strategies

	FUEA	ACAD	NETSIZE	KTTA	MED	RISK	DEFUNI	DEFINFO	DEFCAP	DEFFIRM	G2	G3	G4	G5	G6	G7	HTCH	LTCH	MSER	TSER
FUEA	1.0000																			
	669																			
ACAD	0.0729	1.0000																		
	0.0595																			
	669	669																		
NETSIZE	0.1808	0.1465	1.0000																	
	0.0000	0.0001																		
	669	669	669																	
KTTA	0.3357	0.0777	0.2322	1.0000																
	0.0000	0.0446	0.0000																	
	669	669	669	669																
MED	0.1749	0.1309	0.1830	0.1928	1.0000															
	0.0000	0.0007	0.0000	0.0000																
	669	669	669	669	669															
RISK	0.2543	-0.0023	0.1838	0.1728	0.1941	1.0000														
	0.0000	0.9529	0.0000	0.0000	0.0000															
	669	669	669	669	669	669														
DEFUNI	-0.0194	-0.0177	0.0335	-0.0175	-0.0526	0.0000	1.0000													
	0.6166	0.6469	0.3865	0.6519	0.1740	1.0000														
	669	669	669	669	669	669	669													
DEFINFO	0.0105	-0.0358	-0.0045	-0.0288	0.0469	0.0000	0.0000	1.0000												
	0.7867	0.3547	0.9073	0.4565	0.2260	1.0000	1.0000													
	669	669	669	669	669	669	669	669												
DEFCAP	0.1779	0.0274	0.0629	0.1475	0.1049	0.0000	0.0000	0.0000	1.0000											
	0.0000	0.4789	0.1043	0.0001	0.0066	1.0000	1.0000	1.0000												
	669	669	669	669	669	669	669	669	669											
DEFFIRM	-0.1494	-0.1529	-0.1709	-0.0996	-0.0073	0.0000	0.0000	0.0000	0.0000	1.0000										
	0.0001	0.0001	0.0000	0.0099	0.8508	1.0000	1.0000	1.0000	1.0000											
	669	669	669	669	669	669	669	669	669	669										
G2	-0.1752	0.0181	-0.0983	-0.0987	-0.0872	-0.1011	-0.0457	-0.0484	-0.0032	-0.0232	1.0000									
	0.0000	0.6394	0.0110	0.0107	0.0241	0.0089	0.2373	0.2116	0.9344	0.5490										
	669	669	669	669	669	669	669	669	669	669	669									
G3	0.0130	0.0100	-0.0694	-0.0624	-0.0640	-0.0176	0.0323	0.0283	0.0330	0.0588	-0.2035	1.0000								
	0.7366	0.7968	0.0729	0.1067	0.0984	0.6489	0.4045	0.4647	0.3940	0.1285	0.0000									
	669	669	669	669	669	669	669	669	669	669	669	669								
G4	0.1109	-0.0807	-0.0600	0.0615	0.0131	0.0103	-0.0177	-0.0491	0.0622	-0.0478	-0.2065	-0.2309	1.0000							
	0.0041	0.0370	0.1212	0.1121	0.7349	0.7909	0.6480	0.2046	0.1078	0.2174	0.0000	0.0000								
	669	669	669	669	669	669	669	669	669	669	669	669	669							
G5	0.0895	-0.0564	0.0929	0.0087	0.0442	0.0520	-0.0069	0.0239	-0.0278	-0.0040	-0.2234	-0.2498	-0.2535	1.0000						
	0.0207	0.1450	0.0163	0.8214	0.2540	0.1794	0.8594	0.5370	0.4727	0.9186	0.0000	0.0000	0.0000							
	669	669	669	669	669	669	669	669	669	669	669	669	669	669						
G6	0.0602	-0.0377	0.1668	0.0969	0.0365	0.0704	-0.0197	0.0357	-0.0423	-0.0134	-0.1238	-0.1385	-0.1405	-0.1520	1.0000					
	0.1196	0.3297	0.0000	0.0122	0.3458	0.0689	0.6112	0.3562	0.2745	0.7288	0.0013	0.0003	0.0003	0.0001						
	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669					
G7	0.0261	0.0809	0.2010	0.1060	0.0543	0.0045	0.1361	-0.0517	-0.0479	-0.1013	-0.1076	-0.1203	-0.1221	-0.1321	-0.0732	1.0000				
	0.5000	0.0364	0.0000	0.0061	0.1608	0.9085	0.0004	0.1818	0.2161	0.0087	0.0053	0.0018	0.0016	0.0006	0.0584					
	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669				
HTCH	0.4106	-0.0689	0.0555	0.3138	0.1504	0.2485	-0.0116	0.0242	0.1620	-0.0268	-0.1207	0.0080	0.0759	0.0429	0.0411	-0.0313	1.0000			
	0.0000	0.0750	0.1512	0.0000	0.0001	0.0000	0.7640	0.5319	0.0000	0.4893	0.0018	0.8356	0.0498	0.2676	0.2881	0.4190				
	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669			
LTCH	-0.0768	-0.1858	-0.0455	-0.1200	-0.0659	-0.0636	-0.0191	-0.0329	-0.0083	0.0617	-0.0587	0.0397	0.0501	0.0368	-0.0412	-0.0313	-0.4876	1.0000		
	0.0472	0.0000	0.2398	0.0019	0.0885	0.1002	0.6216	0.3949	0.8299	0.1108	0.1291	0.3055	0.1952	0.3416	0.2871	0.4183	0.0000			
	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669		
MSER	-0.1442	0.4278	0.0778	-0.0811	-0.0340	-0.1194	0.0137	0.0269	-0.0873	-0.1146	0.0933	-0.0211	-0.1119	-0.1019	0.0198	0.0919	-0.4220	-0.2948	1.0000	
	0.0002	0.0000	0.0443	0.0360	0.3801	0.0020	0.7238	0.4880	0.0240	0.0030	0.0158	0.5858	0.0037	0.0084	0.6088	0.0174	0.0000	0.0000		
	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	
TSER	-0.2640	-0.1263	-0.0996	-0.1667	-0.0908	-0.1148	-0.0119	-0.0375	-0.1090	0.0891	0.1402	-0.0608	-0.0224	-0.0138	-0.0273	-0.0079	-0.2525	-0.1764	-0.1527	1.0000
	0.0000	0.0011	0.0099	0.0000	0.0188	0.0029	0.7587	0.3334	0.0048	0.0212	0.0003	0.1160	0.5623	0.7209	0.4813	0.8378	0.0000	0.0000	0.0001	
	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669	669

Table A.4: Correlations between variables in the performance equations

	LACAD	LCI	FUE	STRB	STRC	FOREIGN	G2	G3	G4	G5	G6	G7	IND	DL
LACAD	1.0000													
	669													
LCI	0.0261	1.0000												
	0.5002													
	669	669												
FUE	0.1665	0.0941	1.0000											
	0.0000	0.0150												
	669	669	669											
STRB	0.0683	-0.0275	-0.1699	1.0000										
	0.0776	0.4779	0.0000											
	669	669	669	669										
STRC	0.1135	0.0563	0.2112	-0.3111	1.0000									
	0.0033	0.1459	0.0000	0.0000										
	669	669	669	669	669									
FOREIGN	0.0811	-0.0282	0.0917	-0.0716	0.1334	1.0000								
	0.0366	0.4674	0.0180	0.0650	0.0006									
	665	665	665	665	665	665								
G2	0.0097	-0.1225	-0.1408	0.0432	-0.1118	-0.0549	1.0000							
	0.8031	0.0015	0.0003	0.2646	0.0038	0.1574								
	669	669	669	669	669	665	669							
G3	0.0127	-0.1058	0.0396	-0.0030	-0.0632	0.0154	-0.2035	1.0000						
	0.7430	0.0061	0.3064	0.9382	0.1024	0.6920	0.0000							
	669	669	669	669	669	665	669	669						
G4	-0.0688	0.0109	0.1051	0.0126	-0.0145	0.0651	-0.2065	-0.2309	1.0000					
	0.0752	0.7792	0.0065	0.7446	0.7090	0.0933	0.0000	0.0000						
	669	669	669	669	669	665	669	669	669					
G5	-0.0328	0.0850	0.0527	-0.0867	0.0915	-0.0017	-0.2234	-0.2498	-0.2535	1.0000				
	0.3975	0.0279	0.1731	0.0249	0.0179	0.9648	0.0000	0.0000	0.0000					
	669	669	669	669	669	665	669	669	669	669				
G6	-0.0216	0.0890	0.0292	0.0212	0.1098	0.0797	-0.1238	-0.1385	-0.1405	-0.1520	1.0000			
	0.5773	0.0214	0.4503	0.5840	0.0045	0.0398	0.0013	0.0003	0.0003	0.0001				
	669	669	669	669	669	665	669	669	669	669	669			
G7	0.0880	0.1191	0.0116	0.0662	0.0860	-0.0625	-0.1076	-0.1203	-0.1221	-0.1321	-0.0732	1.0000		
	0.0229	0.0020	0.7649	0.0870	0.0262	0.1075	0.0053	0.0018	0.0016	0.0006	0.0584			
	669	669	669	669	669	665	669	669	669	669	669	669		
IND	-0.1629	0.0895	0.3518	-0.1770	0.1599	0.0580	-0.1800	0.0450	0.1254	0.0787	0.0049	-0.0615	1.0000	
	0.0000	0.0206	0.0000	0.0000	0.0000	0.1351	0.0000	0.2453	0.0012	0.0418	0.9001	0.1118		
	669	669	669	669	669	665	669	669	669	669	669	669	669	
DL	0.2384	-0.0394	-0.2908	0.2068	-0.1496	-0.0493	0.1688	-0.0560	-0.1133	-0.0991	0.0009	0.0769	-0.8942	1.0000
	0.0000	0.3086	0.0000	0.0000	0.0001	0.2045	0.0000	0.1478	0.0033	0.0103	0.9806	0.0467	0.0000	
	669	669	669	669	669	665	669	669	669	669	669	669	669	669