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Do Different Types of Innovation Require Specific Kinds of Knowledge Links?

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Do Different Types of Innovation Require Specific Kinds of Knowledge Interactions?

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1) Introduction

Innovations are increasingly seen as the result of an interactive process of knowledge generation and knowledge application. According to the innovation systems model, the business sector, the science sector, and policy actors are involved in this process. What is often neglected in the existing literature is the question as to which extent knowledge links and networking actually support innovation and which types of partners are the most relevant. It is important to keep in mind that different kinds of innovation may require specific types of relations. Radical innovations often draw on new scientific knowledge generated in universities and research organizations. The exchange of this type of knowledge requires intensive personal interactions and thus might favor local and regional levels over others. Incremental innovations on the other hand are often taking place in interaction with customers and suppliers which are often located at higher spatial levels beyond the region.

In the present paper we will analyze the relationship between knowledge links and innovation. More specifically we will look at the different kinds of innovation and the respective knowledge links – characterized by the type and location of innovation partners as well as by the mode of knowledge exchange. In the following section we will deal conceptually with the interactive innovation approach and the types of knowledge links involved. In section 3 a literature survey regarding empirical evidence to the role of knowledge links, in particular of cooperations, for innovation is undertaken. Sections 4 then investigates the research questions empirically for Austria. This analysis is based on a telefon survey of Austrian firms and applies a modified knowledge production function model. Section 5 is focusing specifically on the knowledge links with universities and research organisations and analyzes respective influencing factors.

2) Innovation and knowledge interactions – Conceptual background

The idea that innovation is an interactive process is nowadays broadly accepted. In fact, a number of approaches and concepts such as the following have supported this argument:

- Innovative milieux (Aydalot and Keeble 1988, Camagni 1991, Maillat 1998),
- Innovation systems in different variants: national (NIS: Lundvall 1992, Nelson 1993, Edquist 1997, 2005), sectoral and technological (SIS: Breschi and Malerba 1997, Malerba 2005) and regional innovation systems (RIS: Cooke et al. 2000, 2004, Doloreux 2002, Asheim and Gertler 2005),
- Innovation networks (DeBresson and Amesse 1991, Cooke and Morgan 1998, Powell 1998, Powell and Grodal 2005, Hagedoorn 2002),
- Clusters and knowledge spill-overs (Audretsch and Feldman 1996, Baptista and Swann 1998, Feldman 2000, Keeble and Wilkinson 2000, Malmberg and Maskell 2002).

Although these approaches share the interactive view of innovation (Kline and Rosenberg 1986), they differ with regard to the specific factors which are regarded to be central for innovation:

- The studies on the innovative milieu have stressed the importance of informal relationships and soft factors such as common understanding and behavioral attitudes evolved in a region.
- The innovation systems literature argues that the institutions of a country (NIS) or a region (RIS) in the subsystems of knowledge generation and application have an influence on the innovation activity. Well developed organizations are required for knowledge generation and diffusion (universities, education, technology transfer) as well as firms willing and capable to commercialize this knowledge.
- The network approach looks at specific, well selected relationships in the innovation process among specific actors both in the region and beyond. It stresses motives for engaging in such partnerships such as technological complementarities or access to resources and specific knowledge, and it emphasizes the role of trust and social capital for the development of networks.
- The studies on clusters and knowledge spillovers finally argue that the concentration of firms and supporting organizations in specific industries may give rise to knowledge spillovers and enhanced innovation. Here, the knowledge flow is regarded as an externality whereas the transmission channels often remain unclear. These may be the monitoring and imitation of competitors (Malmberg and Maskell 2002), the

analysis of patents or scientific articles (Jaffe et al. 1993), spin-offs or the mobility of qualified labour (Keeble and Wilkinson 2000).

The relationships among the different actors of the innovation system have to be conceived as socially and territorially embedded (Granovetter 1985, Asheim and Gertler 2005). Innovation systems have initially been identified for the level of countries, where the clearest differences amongst institutions were ascertained (Lundvall 1992, Nelson 1993). Emphasizing the influence of the institutional sphere on the performance of the innovation system determined the nation as the appropriate spatial unit to observe. However, advanced by the tacit knowledge debate, there has recently been a shift in the spatial focus from the national to the regional level. The creation of new knowledge is characterized by the interaction of codified and tacit knowledge (Nonaka and Takeuchi 1995). Personal interactions in a common institutional context facilitate the transfer of tacit knowledge (Dosi 1988, Lundvall 1992). Thus, as tacit knowledge is on the one hand of central importance in the innovation process and on the other hand can only be transferred by personal interactions, which are sensitive to increasing distance (David and Foray 2003), spatial proximity favours innovation relationships. Further, as knowledge spillovers which arise from the non-rival, partially excludable character of knowledge are also facilitated by social interactions, spatial proximity between the actors of the innovation system becomes even more prominent. As a consequence, the focus of the debate partially has shifted from national to regional systems of innovation (Cooke et al. 2000, 2004) as well as to local industry clusters (Baptista and Swann 1998, Keeble and Wilkinson 2000, Malmberg and Maskell 2002).

So far, it is not clear which territorial levels are the most important for innovation systems and networks. There is some evidence that innovation systems expand over different territorial layers leading to a multilevel setting of innovation governance (Cooke et al. 2000, Sternberg 2000, Tödting and Kaufmann 1999). Furthermore, in the process of knowledge creation, geographically distributed knowledge bases will be drawn upon influenced by the involved technology. Standardized technologies are based on the exchange of information subject to standardized codes and they can be transferred easily. The characteristic of the complex technologies – complex and flexible codes – on the other hand require more stringent modes in the exchange of information. Corresponding with the involved technology, different degrees of tacit knowledge and personal interaction are involved in the exchange and creation of knowledge favoring specific territorial levels over others.

In the literature on innovation systems and clusters a large variety of knowledge links is mentioned, but there is little clarity on the involved types of knowledge relations. In a recent paper (Tödtling et al. 2006) we have classified knowledge relations along two dimensions. Relying on Storper (1997) we have differentiated between traded (formal) and untraded (informal) relations, and with Capello (1999) we have distinguished between static and dynamic knowledge interactions. Regarding the first dimension, Storper has argued that it is in particular the untraded, often informal relations which might explain the spatial concentration of innovative industries and activities rather than the traded, more formalised interactions among firms. Regarding the second dimension, static knowledge exchange refers to the transfer of “ready” pieces of information or knowledge from one actor to the other, such as the licensing of a specific technology or the interpretation of a patent description. Dynamic knowledge exchange refers to a situation where interactive learning takes place among actors through cooperation or other joint activities as described by Camagni (1991) and Lawson (2000). In this case the stock of knowledge is increased through the interaction. This classification leads to the following four main types of relations (Figure 1). They constitute “ideal types” which in reality rarely can be observed in pure form.

Figure 1: Types of knowledge interactions in the innovation process

	static (knowledge transfer)	dynamic (collective learning)
formal / traded relation	(1) market relations	(3) cooperation / formal networks
informal / untraded relation	(2) knowledge externalities and spillovers	(4) milieu informal networks

Market relations (1) refer to the buying of “embodied” technology and knowledge in various forms such as the buying of machinery, ICT equipment or software, or the buying of licenses. Since technology or knowledge is traded more or less in a “ready” form, we consider this as a static relation or knowledge transfer. A number of studies have demonstrated that the traded relations are usually at higher spatial levels, reaching clearly beyond the region (Storper, 1997; Sternberg, 2000). Feldman (2000) considers trade links as one of the most important mechanisms of interregional and international technology transfer.

Markets, however, are far from perfect with respect to knowledge generation and exchange. A number of studies have demonstrated through econometric methods that there are considerable *local knowledge externalities or spillovers* (2) in particular from universities and research organisations to firms. Different from market links there is no contract or formal compensation for the acquired knowledge. Audretsch and Feldman (1996), Anselin et al. (1997) and Bottazzi and Peri (2003) have investigated and identified such local knowledge spillovers applying a knowledge production function approach. Jaffe et al (1993) have found considerable proximity effects with respect to patent citations. It is argued that local knowledge spillovers result from various kinds of mechanisms such as knowledge exchange through mobile labour or through informal contacts (Feldman 2000).

Networks and milieus are conceptually different from the above categories. They are based on evolutionary or sociological approaches and the reasoning goes beyond the transaction cost logic. Compared to market links, *networks* (3) are more durable and interactive relations between specific partners in the innovation process. A given technology or piece of knowledge is not only exchanged but collectively further developed and the respective knowledge base increased. This constitutes a dynamic process of collective learning (Lundvall and Johnson 1994; Lundvall and Borrás 1999). Innovation networks may take different forms (De Bresson and Amesse 1991; Powell and Grodal 2005): Some are based on formal agreements or contracts (R&D cooperations, R&D alliances, research consortia) including formal statements on the sharing of tasks, cost, benefits and revenues. These types of networks are often, but not exclusively, including large and international firms, specialised technology companies or major research organisations. Since the search of partners is highly selective and targeted on specific strategic or complementary competences of potential partners, these formal innovation networks are often at an international or even global scale. They are most frequent in knowledge-based industries such as ICT and biotechnology (Powell 1998; Hagedoorn 2002, McKelvey et al. 2003).

Innovation networks may also include more *informal links* among companies and organisations, such as those in industrial districts (Asheim 1996) and in high-tech regions (Saxenian 1994). Such relations are particularly based on trust, a shared understanding of problems and objectives, and the acceptance of common rules and behavioural norms. In the literature this is referred to as social capital (Putnam 1993; Wolfe 2002) or a shared culture leading to a specific *innovative milieu* (4) (Camagni 1991; Maillat 1998; Ratti et al., 1997). The rapid exchange of ideas and knowledge are the key to an innovative milieu, but as in the case of networks, there is a dynamic aspect of a collective enhancement of the local knowledge base through continuous innovation interactions, i.e. collective learning

(Lawson 2000). An innovative milieu is tied to a specific locality or region since it is based on personal relations and face to face interaction, common rules and a shared understanding. These often result from interactions in a specific local/regional production system or cluster. However, a shared understanding is not confined to a local milieu, but may also be established through organisational or institutional proximity (Boschma 2005) or through virtual exchange and discussion groups. Amin and Cohendet (2004) refer in this context to “communities of practice” which, for example, can be established through the Internet on a global scale (Kaufmann et al., 2003).

3) Knowledge links and innovation: Findings from the literature

Innovations, thus, are occurring within a complex web of formal and informal as well of static and dynamic relationships. Looking at empirical evidence we find studies on knowledge spillovers of universities and research organisations as e.g. by Jaffe et al. 1993, Audretsch and Feldman 1996, Baptista and Swann 1998, Bottazzi and Peri 2003. These approaches often use a knowledge production function approach, estimating indirectly potential effects of research activities on innovation performance of regional firms. The concrete links between universities / research organisations and firms are usually not explicitly investigated. The milieu approach on the other hand is often based on qualitative research methods (Ratti et al. 1997, Maillat 1998) where it is hard to measure knowledge linkages and their effects in a comparative and more representative way.

In the following, we focus therefore mainly on the role of – mostly formal – networks for innovation, since they are more easy to identify. Which evidence do we have so far regarding the relationship between networking and innovation? Although there is already a substantial empirical literature on the relationship between networks and innovation, the direction of the causal relationship is not clear as Fritsch (2001) has pointed out. Some authors suggest that the division of labour in the innovation process leads to or requires more networking. Innovative companies need complementary knowledge (both codified and tacit) which cannot be readily acquired on spot markets but rather through more durable relationships such as cooperations. Other authors argue for the reverse direction of this relationships, i.e. that cooperation (networks) stimulates innovation. This suggests that there is no clear causal relationship between networking and innovation, but that it is a strongly interrelated process, occurring in time and space.

Also regarding the character and details of this relationship we find different views in the literature. In some studies it has been pointed out that in particular *regional* cooperation and

networks favour innovation, due to higher levels of trust and a better exchange of tacit knowledge (literature on industrial districts and innovative milieux). These are often characterised as informal types of relationships ("buzz") where in particular the tacit component of knowledge is easily exchanged. More recently it has been argued that innovations in firms are stimulated both by "local buzz" and "global pipelines" (Bathelt et al. 2004) and that it is important for innovative firms to engage in international and *global* networks in the innovation process (R&D collaborations, etc.).

Fritsch (2001), summarizing some of the relevant literature, finds that "... our understanding of the importance of cooperation and spatial proximity for the division of innovative labour and the efficiency and quality of regional innovation systems is still rather vague. Little is known e.g. about the role of certain types of actors (e.g. academic institutions) or types of relationships for regional innovation systems. In particular, it is unclear how far interregional differences in cooperative behaviour exists and if there is a causal relationship between the propensity to cooperate on R&D and the output of innovation activities". Fritsch (2001) investigates empirically the propensity to engage in cooperations and finds out that this is positively influenced by firm size and R&D intensity. The strongest positive influence of size and R&D intensity were found for cooperations with public research institutions. In addition, location and sector were significant influencing variables for the propensity to cooperate. He also investigates the importance of spatial proximity for cooperative relationships and finds that proximity is most important for cooperation with public research institutions.

The propensity to cooperate has also been investigated by Angel (2002) for the chemical, electronics and instruments industries in the US. The author focuses on technology development partnerships with other companies (suppliers, customers, other firms) and finds that large firms and those in major urban areas are more likely to enter into technology partnerships. Firms located in technologically specialised agglomerations did not demonstrate a higher propensity of entering such technology development partnerships.

Fritsch and Franke (2004) investigate as to which extent innovation output (patenting activity, number of patents) are influenced by R&D expenses, spillovers (measured by R&D in other firms in the same industry, in business related services or in public research), cooperations and by location. By looking at patents the authors focus on more advanced innovations beyond incremental change. They have applied a Logit model for the dichotomous dependent variable "registration of a patent in the last 3 years" and a negative-binomial (negbin) regression for the dependent variable "number of innovations registered for patenting". Responses of 1800 firms from the regions of Baden, Hannover and Sachsen were analysed.

The results show a significant positive influence of R&D expenditure as well as significant positive effects of regional spillovers, in particular of R&D in other firms in the same industry, and of R&D in business related services. The effects of cooperations turned out to be less clear: Only the existence of cooperations with service firms and with public research institutions had a significant positive impact, whereas the number of cooperations with customers, suppliers and with other firms have had no significant effect on patenting.

Based on a larger data set (4300 responses), Fritsch (2004) investigates R&D cooperation behaviour and effects for eleven European regions. He finds a considerable variation between the investigated regions regarding the engagement of firms in R&D cooperations with customers, suppliers, service firms, other firms and research institutes as well as regarding the R&D efficiency (number of patents with respect to R&D expenditure and R&D employment). However, in a further analysis he finds no evidence of a positive relationship between R&D cooperation and innovative output except for a positive effect of cooperations with R&D institutes on patenting.

Arndt and Sternberg (2000) analyse the relationship between innovation and the performance of companies (measured by the growth of employment and turnover, the share of turnover with innovative products and the export ratio). They find that cooperative firms are more successful in all of these categories. The strongest relationship, however, refers to the share of innovative products and the export rate. In a second, more descriptive analysis they also differentiate between regional and extra-regional cooperations as well as types of innovation. It is demonstrated that incremental innovations are not related to cooperations, whereas firms with high shares of new products are more often engaged in both intra- and extra-regional cooperations. More radical innovations (completely new developments) were higher in the case of firms with mainly interregional cooperation.

Based on the REGIS survey Kaufmann and Tödtling (2001) have investigated types and location of innovation partners of 517 firms in seven regions of Europe and analysed their effects on innovation activity distinguishing between more advanced and incremental innovations. Only three types of innovation partners have had a significantly positive influence on the introduction of products which are new to the market - suppliers, consultants, and universities. Referring to firm characteristics, the authors found that size and industry were not significantly distinguishing between incremental and more advanced innovators whereas the region was important. The investigated firms in Baden-Württemberg clearly surpassed the firms of the other regions. External relations had some influence on the

innovativeness of firms, but they were not decisive for enabling firms to introduce more advanced innovations. The analysis has led to the following conclusions:

- Universities stimulated or enabled firms to introduce more advanced innovations whereas contract research organizations had no positive effects in this respect. “Pure” science seemed to be more effective in stimulating advanced innovations than applied research focusing on commercialization.
- The generally most frequent innovation partners - the customers - had neither a positive nor significant influence on the frequency of advanced innovations. However, other partners from the business system - suppliers and consultants - did have a positive influence. They seemed to transfer important technology and know-how to innovating firms, enabling them to introduce more advanced innovations.
- On the contrary, institutions particularly designed to act as intermediaries between science and industry like technology transfer organizations did not seem to be effective in stimulating advanced innovations.

4) Innovation and Knowledge Interactions: Evidence for Austria

In this section the relationship between knowledge links and the innovation output will be analyzed empirically for Austria. The knowledge links are regarded as a potential input in bringing forward innovations as an output. Kaufmann and Tödting (2001) have shown that existing relationships with the science sector improve the capability of firms to introduce more advanced innovations. Here, we will extend on this work by further differentiating the relationships by the type of the knowledge interaction and the innovation output.

Methodology and data base

The following results are based on a telefon-survey of 400 Austrian innovative firms conducted in 2001 on the course of the RINET-project (Kaufmann et al. 2003). The sample of 400 Austrian was deduced from a Marketing database of Austrian firms and included 320 firms from manufacturing and 80 from services. From the service sector only computer and related technologies, engineering activities and related technical consultancy, as well as technical testing and analysis were selected whereas the manufacturing sector was considered in total but was stratified regarding firm size and sector.

Table 1: Investigated sample

<p>A) 320 firms in manufacturing (NACE 15 – 37) with more than 10 employees</p> <ul style="list-style-type: none">• disproportional shares by firm size class: 10 to 49 employees: 76 Interviews (23,7 %) 50 to 249 employees: 147 Interviews (46 %) more than 250 employees: 97 Interviews (30,3 %)• disproportional shares for high-tech sectors: 96 interviews (30 %) from following sectors: NACE 24 chemicals and chemical products NACE 32 ICT NACE 33 medical instruments, optical instruments NACE 34 transport equipment, vehicles <p>B) 80 service firms with more than 5 employees from the following sectors:</p> <p>NACE 72 data and software, computer services NACE 74.2 architecture and engineering NACE 74.3 technical, physical and chemical analysis and testing</p>

Regarding sectors we classified the firms into three categories: high-technology firms, firms belonging to mature manufacturing sectors and the service sector. The high-tech class in this case comprises chemicals (pharmaceuticals), ICT, medical, precision and optical instruments, the mature sector the remaining manufacturing sectors, and the service sector the activities indicated in table 1.

As far as the location of firms is concerned, we distinguished between the Vienna urban region (the capital of Austria and its surrounding municipalities), the other Austrian urban centres (e.g., the capitals of Austrian provinces) and all other peripheral or rural locations.

Model

The model can be regarded as a modified knowledge production function. The innovation output is described by two categories: products new to the firm (adoption of innovations and incremental change) and products new to the market (advanced innovations). The inputs in the knowledge production are the existence of an in-house R&D department, R&D expenditures, the employment of researchers, the holding of a patent and external knowledge links. These are differentiated by type of relation – information exchange (spillover, milieu), contract research (market), and cooperation (network) as well as by innovation partners - customers, suppliers, providers of business services, universities, technology transfer organizations, financial services and innovation support organizations.

Employment and turnover are considered as general characteristics of the firm. Furthermore, the sectors have been aggregated as indicated above: the high-technology sector, the mature manufacturing sector and the knowledge intensive service sector. Regarding the location of the firm, the Vienna urban region, the other Austrian urban centers and all other peripheral or rural locations have been distinguished.

We have applied a binary logistic regression with a stepwise LR forward procedure including variables which are significant at the 15% level. The R² should not be compared with the regression R² as in the logistic regression the values are usually much lower. The LR-test examines whether all slope parameters in the model are equal to zero. Hereby, a p-value greater than 0.05 indicates that all slope parameters are not significantly different from zero at the 5% level. The Hosmer-Lemeshow test is an indication of the goodness-of-fit of the model. Hereby, a p-value lower than 0.05 indicates that the model does not fit at a 5% significance level. The correct classification table states what percentage of the predicted outcomes has been classified correctly. In bold figures we have marked the coefficients that are significant at the 5% level. Thereby, a positive coefficient influences the probability of the response positively.

Interpretation of the results

The “new to the firm model” does fit arguably well. Hereby, the existence of an in-house R&D department and cooperation with business service firms improve the capability of the firm to introduce innovations that are new to the firm. Belonging to the service sector does negatively influence the probability at a 10% significance level.

The “new to the market model” shows a better fit. Again, the existence of an in-house R&D department is significant. Furthermore, the holding of a patent and the cooperation with universities/research institutes does improve the capability of introducing new market innovations. Obviously, the more advanced innovations require to a higher degree R&D and scientific inputs from universities and research organizations than less novel products.

Table 2 Modified Knowledge Production Function Model

<i>Dependent Variable:</i>	Products new to the firm		Products new to the market	
	<i>Coefficient</i>	<i>Significance</i>	<i>Coefficient</i>	<i>Significance</i>
Firm Characteristics				
High-tech sector	0,3005	0,5178	0,4773	0,3385
Service sector	-0,6638	0,0592	-0,5116	0,1394
ln (Employment)	-0,0485	0,6461	-0,0858	0,4374
Location Characteristics				
Urban Region of Vienna	0,5073	0,1286	0,3564	0,2930
Rural Areas of Austria	0,4352	0,1738	0,0227	0,9439
Innovation Characteristics				
R&D department	0,7110	0,0184	0,8751	0,0039
Researchers	0,0688	0,8388	-0,2660	0,4476
Patents	0,2477	0,4240	0,8421	0,0083
Innovation Partners				
<i>Contract Partnership</i>				
Business Service Firms	-	-	0,5547	0,122
<i>Cooperation</i>				
Business Service Firms	1,0644	0,0017	-	-
Universities and Research Org.	-	-	1,0433	0,0049
Constant	0,5423	0,2547	0,4538	0,3470
Test Statistics				
LR-test	28,3670	0,0004	48,153	0,0000
Hosmer-Lemeshow Goodness-of-Fit	6,3751	0,6053	8,1655	0,4175
Nagelkerke R2		0,115		0,184
Correct Classification		77,35%		76,96%
N		362		369

For both types of innovations the location of the firm has no influence on the introduction of new products. Similar results have been found for other small countries such as the Netherlands (Oerlemans et al. 2000). We can interpret this as an already high integration of the spatial system of such countries, where most regions are relatively well connected and the urban fields cover most parts of the country. Also, no significant influence could be observed for the less intensive forms of knowledge interactions, information exchange and (mostly short term) contracts. This result might be due to the fact that these less intensive and more milieu type of relations have rather indirect effects on the innovative behaviour of firms and cannot be directly related to particular innovations.

In summary, the capability of introducing advanced innovations is enhanced through the existence of an in-house R&D department. In addition, firms are increasing their chance to introduce new products to the market by relying on existing patents and cooperating with universities/research institutes. Interestingly, researchers do not increase the probability for advanced innovations. However, the input of researches is partly captured in the use of patents indicating, that the technical competence of the R&D department builds on the knowledge comprised in the firm's own patents.

5) Knowledge interaction with universities

As we have seen in the previous section and in Kaufmann and Tödting (2001), the relations of firms with universities and research organizations have some relevance for bringing forward more advanced innovations and also for knowledge spillovers (Audretsch and Feldman 1996, Bottazzi and Peri 2003). For this reason, we will have a closer look at the factors influencing the interaction of firms with universities and research organizations. In the following we are, thus, investigating as to which extent the knowledge interactions between industry and science are influenced by firm characteristics (size and sector), location characteristics (urban, rural) and by innovation characteristics of the firm (R&D, researchers, previous relations to universities).

Model

The dependent variable in the model is the relation of firms to universities and research organizations differentiated by type of knowledge interaction - information exchange (representing knowledge spillovers and the milieu), contract research (market), and cooperation (network).

Explaining variables comprise the R&D intensity of the firm, indicated by the existence of an in-house R&D department, the employment of researchers and the R&D expenditures. These indicators describe the R&D competence of the firm which is considered as an important precondition to engage into interactions with science. In addition, the occurrence of an unsuccessful research project in the past has been included as an indicator of previous learning experiences with such projects. Employment has been included as a size indicator of the firm, since previous studies have shown that larger companies are, for various reasons, more able and likely to engage in relations with science.

As in the first model, the sectors have been grouped into high-technology and mature manufacturing sectors and the knowledge intensive service sector. The location of the firm distinguished between the Vienna urban region, the other Austrian urban centers and all other peripheral or rural locations.

In all three cases the model fit is quite well. It is interesting to observe that the influencing factors are rather similar for all three types of relations. Researchers seem to constitute the key channel for engaging into knowledge interactions with universities and research organizations. Obviously the researchers are those who have the competence to engage in such relations and they are those able to understand the concepts used in science and to speak “the same language”. Then, as expected, bigger firms engage more often in science-industry networks than smaller firms. This may be due to financial capabilities as well as to the fact that larger firms are less confined to applied and incremental innovation activities only as it is often the case for small firms. SMEs, thus, have clearly more barriers for interactions with science as was demonstrated also in other studies (Kaufmann and Tödttling 2001, Asheim et al. 2003, Fritsch and Schwirten 1998).

Interestingly, the fact that the company has had unsuccessful research project(s) in the past increases the probability of networking with universities or research organizations. We may interpret this as a higher readiness of firms with an experience of failure in the past to look for outside help and competence for new innovation projects in order to reduce the risk of such projects.

Table 3 Knowledge Interaction Model

<i>Dependant Variable:</i>	<i>Interaction with Universities and Research Institutes through</i>					
	<i>Information Exchange</i>		<i>Contract Research</i>		<i>Joint Research</i>	
	<i>Coefficient</i>	<i>Sign.</i>	<i>Coefficient</i>	<i>Sign.</i>	<i>Coefficient</i>	<i>Sign.</i>
Firm Characteristics						
High-tech Sector	0,1216	0,7242	0,4650	0,2036	0,2705	0,4452
ln (Employment)	0,2150	0,0086	0,2488	0,0046	0,1724	0,0347
Location Characteristics						
Urban Region of Vienna	-0,0644	0,8162	0,1041	0,7331	-0,1026	0,7162
Urban Regions of Austria	0,1524	0,5786	0,2273	0,4559	-0,1432	0,6155
Innovation Characteristics						
R&D Department	0,1752	0,4817	0,1849	0,5023	0,0169	0,9484
Researchers	1,2236	0,0000	1,3725	0,0000	1,1420	0,0000
Aborted Research Project	0,7760	0,0006	1,0205	0,0000	0,8201	0,0004
Constant	-2,1681	0,0000	-3,1618	0,0000	-2,2003	0,0000
Test Statistics						
LR-test	69,0670	0,0000	82,4860	0,0000	55,103	0,0000
Hosmer-Lemeshow Goodness-of-Fit	8,4202	0,3935	7,7295	0,4603	4,268	0,8322
Nagelkerke R2		0,216		0,269		0,182
Correct Classification		69,70%		74,29%		69,72%
N		396		389		393

The fact that the firm belongs to the high tech sector does not influence the probability to engage into relations with science. This is at the first sight surprising, since we might expect that high tech firms rely to a higher extent on scientific knowledge and on partners from universities and research organizations (Keeble and Wilkinson 2000). Obviously, the more relevant variable is the employment of researchers which captures such a potential sectoral effect.

As in the previous model, location has no influence on science-industry relations. Urban location, thus, does not lead to a higher probability of such relations. In the light of much cluster literature this is unexpected, since most universities and research organizations are in fact located in cities, many of them in Vienna. Spatial proximity, thus, does not seem to be highly important for science-industry interactions. Firms interested in and capable of engaging in such relations seem to be doing so irrespective of their location.

Summing up, our results indicate that the size of the firm, the employment of researchers and the experience of failure with previous R&D and innovation projects are factors stimulating and helping to cross the border between the entrepreneurial and the scientific systems.

6) Conclusions

Our findings show that different types of innovations do require different kinds of knowledge inputs and also different knowledge links. More advanced innovations (products new to the market) rely to a higher extent on internal R&D and patenting and they are stimulated and supported by cooperation with universities and research organizations. Obviously they rely more on scientific inputs than the adoption of innovations or incremental changes.

The introduction of products which are new to the firm is also positively influenced by R&D activities, but to a smaller extent. As Cohen and Levintal (1990) have shown, also the adoption of innovations and incremental change need some “absorptive capacity” of firms. Regarding external relations, it is cooperation with service firms rather than with universities which helps to undertake such a kind of innovation.

It is interesting to find that for both types of innovations the less binding forms of knowledge interactions – the information exchange and the short term contracts – have no influence on innovative activity. This may be partly due to the fact that these less intensive relations are more difficult to capture in a standardized questionnaire. Partly these relations might have more indirect effects on the innovative behavior of firms by improving the general milieu for knowledge interactions and innovation.

The sectoral affiliation of firms as well as their location do not show up as significant factors for the innovative behaviour. Regarding the sector, the results thus indicate that innovation is not particularly related or confined to high tech industries but occurs in all investigated sectors. This is particularly relevant for Austria which was economically relatively successful in the past, despite a weak high tech sector. Therefore, there does not seem to be a particular need for a kind of innovation policy which targets specific high tech industries only.

Regarding location, our findings seem to show no particular disadvantage of rural areas or smaller cities for innovation and knowledge interactions. This might be due to the fact that Austria is a small country with a well developed transportation and communication system

which covers most regions of the country. If there are locational disadvantages for innovation in particular regions, it seems to be possible to overcome them by, for example, the recruitment of personnel, the engagement in innovation networks and the use of modern ICT (Kaufmann et al. 2003).

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