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Location, knowledge sourcing and innovation – Evidence from the ICT sector in Austria

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Abstract

The competitiveness of many of today's industries largely depends on the ability to innovate. Innovation is viewed as a result of interactive knowledge processes, demanding from companies to generate, absorb and apply knowledge from internal and external sources. Firms' knowledge sources can be differentiated based on partner types, spatial levels and the mechanisms used for acquiring knowledge from these sources. In addition, knowledge sourcing and innovativeness depend on the firms' location as it impacts potential regional knowledge links as well as the accessibility to interregional ones. The location of a company in a "thick" Regional Innovation System (RIS) should lead to a better performance as compared to a location in a "thin" RIS. Conceptually, the paper aims to develop a better understanding of the relationships and dynamics between internal knowledge and learning through external knowledge sourcing. The derived presumptions are tested by developing and applying a multivariate model that describes the impact of the above-mentioned factors on the innovativeness of firms. The importance of internal knowledge, the variety of knowledge sourcing on regional, national and international levels, the importance of cooperation as a transfer mechanism as well as the location of companies are identified as key determinants of innovativeness in knowledge-based sectors. The paper draws on data from the ICT sector in three regions in Austria. Overall, 110 personal interviews and questionnaires were collected from companies of this sector.

Introduction

Widespread consensus has emerged about the importance of innovation for maintaining and improving the competitiveness of firms as well as the dependence of innovation on knowledge and learning processes. This paper aims at developing a better understanding of i) the relationship between in-house knowledge and the acquisition of knowledge from external sources and ii) the importance of geography both in relation to knowledge sourcing as well as the location of firms. External knowledge sourcing in the context of an “open innovation” model has become increasingly prominent (Smith, 2002; Chesbrough, 2003; Laursen and Salter, 2006). On the other hand, some “absorptive capacity” is required to enable firms to utilise external knowledge sources (Cohen and Levinthal, 1990). Absorptive capacity, however, builds to a large extent on the in-house knowledge of firms. We therefore argue that firms with strong in-house knowledge tend to show a higher innovation performance because they are more able to source knowledge externally and to appropriate it successfully in innovation processes.

In-house knowledge and external knowledge sourcing, therefore, are closely linked and determined by the underlying learning processes and attributes of knowledge. One important attribute is the partly tacit or implicit nature of knowledge complicating its transfer (Polanyi, 1966). Tacit knowledge is learned through interactive processes and repetition. The best way of interactive learning remains face-to-face, thus, placing importance on geographic proximity. However, geographic proximity has to be seen in the context of other forms of proximity, such as those identified by Boschma (2005): cognitive, social, institutional and organisational proximity. Furthermore, codified knowledge can be acquired more easily over large distances than tacit knowledge. As a consequence it has been argued and observed that knowledge is often sourced at various spatial levels reaching from local to global (Bathelt et al., 2004; Tödtling et al., 2006). On the basis of these concepts, propositions about the spatial pattern of knowledge sourcing are derived. In general, both regional and interregional sources are thought to contribute to the innovativeness of firms. However, sources requiring more complex knowledge interactions and learning processes should tend to be located at shorter geographic distance.

Assuming a positive effect of geographic proximity and local links for knowledge interaction leads to the relevance of agglomerations. Major agglomerations usually host universities, research and development organisations, educational organisations, technology transfer centres, a large number of firms and headquarters etc. These organisations constitute important elements in Regional Innovation Systems (RIS), which also comprise the relationships between the organisations, the institutional environment as well as the policy level (Cooke et al., 2003; Tödtling and Trippl, 2005; Asheim and Coenen, 2006). Regions differ in the configuration of their RIS. This paper compares regions with different degrees of agglomeration. Major agglomerations usually show a “thicker” RIS than more

rural areas and firms located in “thick” RIS are assumed to be more innovative. Consistent with the above described, the following three connected research questions will be explored:

- How does in-house knowledge relate to the acquisition of knowledge from external sources in the context of innovation processes of firms?
- What is the impact of geographic distance on the acquisition of knowledge from different knowledge sources and through different transfer mechanisms?
- How important is the location in a “thick” RIS for the innovativeness of companies?

The logic developed in this paper can be applied for various industries. The derived propositions, however, are tested using data from the Information and Communication Technology (ICT) sector in three Austrian regions. The ICT sector operates in a technologically dynamic environment where new knowledge is created constantly and technological innovations quickly replace old solutions. To remain competitive, firms have to acquire knowledge from external sources, engage in learning processes and innovate. Therefore, the issues investigated in this paper are particularly relevant for the ICT sector. The data of 110 firms are assessed using descriptive and multivariate statistical methods.

Internal (in-house) and external knowledge in the innovation process

It has been argued that innovation is the result of increasingly complex, collective and cumulative knowledge-based processes that involve a variety of actors (Lundvall, 1992; Edquist, 1997; Bathelt et al., 2004; OECD, 2005; Tödtling et al., 2006). The increasing complexity of these processes is mainly triggered by the scientific and technological progress, which has led to highly specialised areas of knowledge requiring significant efforts to keep up to date in each of the fields. Innovation may occur through advancement in one specific technological field. The more radical innovations, however, are likely to result from the combination of knowledge from complementary areas. Therefore, the cost of generating and maintaining state of the art bodies of knowledge within firms is rising and it can even be considered impossible for firms to internalise all potentially relevant knowledge. This logic seems to apply to a larger extent to “knowledge-based” industries, which are characterised by a strongly expanding knowledge base, than to industries utilising mainly mature technologies. The perceived importance of knowledge-based industries for today's economy gave raise to comments that we were living in a “knowledge economy” or “learning economy” (OECD, 2002; Smith, 2002; Lundvall, 2004; Cooke et al., 2007). Being a typical “knowledge-based sector”, we will empirically investigate the hypothesis derived from the below arguments for the ICT sector.

In order to allow for a better generalisation and to create a deeper understanding about knowledge and innovation processes across firms and industries, we can use the knowledge base concept, distinguishing in analytical, synthetic and symbolic knowledge bases (Laestadius, 1998; Asheim and Coenen, 2007; Trippl et al., 2009). Analytical knowledge bases characterise industries and firms that

draw to a relatively large extent on codified knowledge, use scientific methods to gain new knowledge and tend to generate more radical innovations. In contrast, tacit knowledge, often developed in interactive processes with clients and customers, dominates synthetic knowledge bases. Knowledge is mainly constructed by “synthesising”, i.e. combining knowledge generated elsewhere and applying it in the context of the firm. This usually leads to more incremental innovations. Symbolic knowledge bases are common in industries where the image or brand associated with a product has a higher importance than the actual value of use such as in cultural industries. Predominantly tacit knowledge and a good understanding of trends and cultural artefacts determine competitiveness. In relation to the ICT sector, we see the necessity to distinguish between firms active in producing hardware and electronic components (ICT manufacturing) and such that develop software and provide customer oriented services (ICT services and software). While the former are mainly characterised by an analytical knowledge base, the latter predominately use a synthetic one. Symbolic knowledge bases are assumed to play a minor role in these subsectors.

The knowledge base concept allows to group industries and firms depending on the dominating types of knowledge, knowledge sources, knowledge interactions and innovation. The concept of “open innovation” implies that an increasing body of knowledge required for innovations is located outside the boundaries of firms (Smith, 2002; Chesbrough, 2003; Laursen and Salter, 2006). The “relevant” knowledge base for innovation, therefore, is determined rather in the system of firms and organisations, interactions between them and prevailing institutions than within the firms. This explains the raise of Innovation System (IS) concepts on regional, sectoral, national and international (cross-border) levels (Lundvall, 1992; Nelson, 1993; Edquist, 1997; Cooke et al., 2004; Tödtling and Trippl, 2005; Asheim and Coenen, 2006).

The capacity of firms to identify and appropriate externally generated knowledge, the “absorptive capacity”, depends on various factors as already elaborated by Cohen and Levinthal (1990): i) the knowledge of each individual working for the firm, ii) the homogeneity / diversity of in-house knowledge, iii) the communication processes within the firm iv) the role of gatekeepers and v) the expectations and ambitions of the firm. The ability to absorb new knowledge depends on what has been learned before; therefore, knowledge processes are cumulative. Also, firms interpret signals from the environment about new knowledge in relation to their current knowledge. Thus, the potential value of new knowledge can be better understood in areas of previous experience, further strengthening the cumulative character and path dependency in the learning process.

In contrast to this insight, a frequently dichotomous view of internal versus external knowledge sourcing has led to the discussion whether one supplements or complements the other. This discussion often ignores important attributes of knowledge and learning processes. In-house knowledge capacitates firms to understand and appropriate information about new but related knowledge from external sources. Hence, the ability and potential for knowledge sourcing increases with the level of

in-house knowledge in related fields. In addition, firms with strong in-house knowledge should have a higher probability to generate innovations with the knowledge sourced externally. Therefore, the proportion of how much knowledge is sourced internally versus externally is of minor importance. Firms with strong in-house knowledge are expected to be more innovative because i) they are more able to source knowledge externally and ii) have a higher expected return of external sourcing. Furthermore, it seems reasonable to assume a self-reinforcing cycle: Solid in-house knowledge enables firms to source external knowledge and enhances the chances to succeed in learning and innovation processes leading to further expanded in-house knowledge.

Geography of knowledge sourcing

The section above substantiated the link between in-house knowledge and the acquisition of knowledge from external sources. In this section, a differentiated understanding of knowledge sourcing will be developed based on the “proximity” concept and the types of the underlying knowledge relationships. Beside geographic proximity, other forms of proximity are presumed to influence the transfer of knowledge and learning processes, namely cognitive and relational proximity. Relational proximity originates from organisational, social or institutional qualities (Boschma, 2005; Cappello and Faggian, 2005). Cognitive proximity describes situations where the actors possess similar knowledge. It facilitates knowledge transfer but might limit the learning potential. With increasing cognitive distance knowledge transfer becomes more complex. Complex knowledge transfer usually requires a stronger degree of interactive learning, for which the involved actors need to be willing and able to invest a significant amount of time and efforts (Polanyi, 1966; Lundvall, 1988). Such complex processes are facilitated through social bonds, organisational links or institutional similarities (relational proximity). Interactive learning is also facilitated through geographic proximity, which reduces the cost of face-to-face meetings and promotes the creation of relational proximity. The above logic implies that the geography of knowledge sourcing should relate to the cognitive and relational proximity of firms with its sources. The larger the cognitive and/or relational distance with specific types of sources, the stronger should be the need for interactive learning and the tendency of firms to tap these sources regionally.

The relationships underlying the knowledge transfers with each source differ in their degree of formality and interactivity (Tödtling et al., 2006). Linking these two dimensions, four basic types of relationships with external knowledge sources can be identified as illustrated in Table 1. Static relations are characterised by limited interactions. If such relations have an underlying formal agreement, they are classified as market relations and include contract research, consulting, licensing and buying of intermediate goods. Informal static relations are labelled as spillovers and include monitoring of competitors, recruitment of specialists, participation in fairs and reading of scientific literature and patent specifications. The more interactive relationships are distinguished in co-

operations (formal networks) and milieu (informal networks). Interactive relationships provide a basis for more complex, dynamic and collective learning processes that also enable the transfer of tacit knowledge. While all types of relationships have a value for knowledge sourcing, it can be argued, therefore, that the interactive ones allow for more substantial learning effects. Geographic proximity is expected to be particularly important for such relationships as it facilitates face-to-face meetings and the creation of relational proximity.

Table 1: Types of relationships to external knowledge sources

	Static (knowledge transfer)	Dynamic (collective learning)
formal / traded relation	<i>market relations</i> contract research consulting licenses buying of intermediate goods	<i>Co-operation / formal networks</i> R&D co-operations shared use of R&D facilities
informal / untraded relation	<i>externalities / spillovers</i> recruitment of specialists monitoring of competitors participation in fairs, conferences reading of scientific literature, patent specifications	<i>milieu / informal networks</i> informal contacts

Source: Tödtling et al. 2006

Knowledge sources can be further classified in such that belong to the value chain (suppliers and customers), knowledge generating organisations (universities, R&D organisations, educational organisations, consultants, business services), competitors and other organisations. ICT firms characterised by a mainly synthetic knowledge base (ICT services and software) are expected to source knowledge mainly from the value chain. Knowledge generating organisations usually have a greater importance for ICT firms that predominantly draw on an analytical knowledge base (ICT manufacturing). While firms can acquire knowledge from the different sources using each type of relationship, a pattern of specific groupings was observed in previous studies (Tödtling et al., 2006; Tripl et al., 2009). With knowledge generating organisations, firms tend to apply more formal types of relationships (contract research, contract with a consultancy or formal cooperations). Monitoring is more common with competitors. With main clients and suppliers, the relationships usually feature interactive elements with an underlying formal input-output relationship. Knowledge transfer with sources of the value chain can be a main component or a by-product of the input-output relationship as well as informal information exchange. As knowledge sourcing from customers and suppliers tends to occur in the context of higher cognitive and relational proximity than from knowledge generating organisations and as the former are frequently located outside the region, we expect a wider geographic spread for knowledge sourcing from the value chain.

Role of regional innovation systems and of agglomeration

In parallel with the development of the understanding that innovations originate not from firms operating in isolation but rather from collective processes, the concept of Innovation Systems (IS) emerged. Initially, this concept addressed the national level, soon, however, it was also applied in regional, sectoral and international (cross-border) contexts (Lundvall, 1992; Nelson, 1993; Edquist, 1997; Cooke et al., 2004; Tödtling and Trippl, 2005; Asheim and Coenen, 2006). More than other concepts, IS account for the interrelationships between the various actors in the system, the underlying institutional setting, the policy dimension as well as the linkages with other IS. In relation to Regional Innovation Systems (RIS), Tödtling and Trippl (2005) identified three types of regions, namely peripheral regions, old industrialised regions and metropolitan regions and three main innovation barriers, organisational thinness, lock-in and fragmentation. These barriers can exist to a different degree in each of the typified regions, however, peripheral regions usually encounter organisational thinness, old-industrial regions sometimes have to overcome a “lock-in” situation, and metropolitan regions are vulnerable to fragmentation.

For this paper and the interpretation of the results of the empirical work, the findings for metropolitan and peripheral regions are discussed because the data covers firms in regions with a differing degree of agglomeration: the national capital Vienna, the two regional capitals Linz and Salzburg, and firms outside these major cities. Larger agglomerations such as Vienna usually feature a higher institutional thickness. More specifically, ICT firms benefit from a high number of potential “demanding” customers in the region, corporate headquarters, multinational enterprises, main administrative bodies and major suppliers. This allows for a higher specialisation, the development of a critical mass of companies in related sectors and intense regional learning processes. Furthermore, major universities, higher educational organisations, research and development organisations as well as technology transfer organisations locate in large agglomerations. In addition, the quality of living attracts qualified workforce to cities. Furthermore, it has been argued that a location in a “thick” RIS even facilitates the access to interregional knowledge sources through better transport connections, the reputation of the location, a higher frequentation of potential international partners and sources, etc. The potential of intensive learning processes emerges through vivid exchange of local and global knowledge (Bathelt et al., 2004).

Empirical investigation based on data for the ICT sector in three Austrian regions

The above-described understanding about the importance of location and the geography of knowledge sourcing for the firms’ innovation processes is tested using data from a survey of ICT firms in three Austrian regions. Relating to the three research questions mentioned in the introduction, the following hypothesis can be deducted from the line of argument developed above:

1. Firms with strong in-house knowledge tend to be more innovative.
2. Firms using a larger variety of knowledge sources tend to be more innovative.
3. Knowledge links to universities and R&D institutes can be found more frequently on a regional level than links to clients and suppliers.
4. Interactive knowledge transfer mechanisms such as cooperations and informal networks are more frequent on a regional level than static knowledge transfer mechanisms such as buying of technology.
5. Firms located in Vienna, which represents Austria's thickest RIS, tend to be more innovative than firms located in Linz, Salzburg or firms outside these cities.

The data was generated through a survey undertaken in the framework of the project "Constructing Regional Advantage" funded by the European Science Fund. In Austria, ICT firms located in Vienna, Upper Austria and Salzburg were investigated (Table 2). The national capital Vienna constitutes the largest agglomeration in the country with about 1.7 mio. inhabitants. The region of Upper Austria counts 1.4 mio. inhabitants, 190.000 of which settle in the regional capital Linz. The region of Salzburg hosts with 529.000 a significantly lower number of citizens. 149.000 people live in the regional capital Salzburg. In terms of income, Vienna leads with a GRP per capita of EUR 43.300, followed by Salzburg with EUR 37.300 and Upper Austria with EUR 31.800. However, we observe higher GRP per capita growth rates in Upper Austria and Salzburg providing some indication for a convergence in income. Vienna constitutes a metropolitan region with major universities, technical colleges, research institutes, higher education facilities and a large industrial base hosting headquarters of national and international groups. However, some studies provide evidence that Vienna used to suffer to some extent from fragmentation, i.e. limited interactions between the sub-systems of the RIS (Tödtling 2002; Fritsch 2004, Trippel, et al. 2009). In Salzburg, being a low-density region compared to Vienna, we find some ICT related research and educational facilities such as a public and private university as well as a non-academic research institute. Some successful niche players in multi-media and geo-informatics locate in Salzburg. Overall, however, the smallness of the regional economy hampers the development of an ICT cluster. In terms of agglomeration and economic size, Upper Austria ranks between Vienna and Salzburg. Upper Austria benefits from relatively advanced R&D facilities, namely the "Softwarepark Hagenberg" and the Johannes Kepler University as well as strong policy support through TMG, Upper Austria's location and innovation agency.

In order to reach a high response rate, sub-sectors of suitable size were chosen except in the region of Salzburg, where all ICT companies were targeted due to the limited overall population of ICT companies. The Aurelia company database was used to identify the ICT firms in the three regions. In Salzburg, the sample consists of 42 companies, covering 34% of the total population. In Vienna, the survey focused on ICT manufacturing. 30 companies were interviewed, which amounts to 33% of the

population. The sample in Upper Austria targeted ICT software development companies. The survey resulted in a sample of 38 firms covering 25% of the population.

Table 2: Basic data of regions and samples

	Vienna	Upper Austria	Salzburg
inhabitants in thousand 2009*	1.687	1.410	529
... Growth since 2001*	8,84%	2,40%	2,72%
area in km ² *	415	11.980	7.156
Density (persons/km ²)	4.068	118	74
Capital	Vienna	Linz	Salzburg
... Inhabitants in thousand**	1.687	190	149
GRP per capita 2007*	43.300	31.800	37.300
... Growth since 2000*	18,31%	28,23%	27,74%
Investigated sub-sector	ICT manufacturing	ICT software development	ICT software development, service and manufacturing
Sample	30	38	42
... % of population	33	25	34
* Statistik Austria			
** Regional governments			

Variables for the quantitative model

The aim of the model is to explain the innovativeness of firms by a number of explanatory variables related to in-house knowledge, the variety of knowledge sourcing on regional, national and international levels, the location of firms as well as control variables. Firstly, we construct the dependent variable measuring innovativeness. The survey investigates different forms of innovation, including product and process innovations as well as innovations in strategy, organisation and marketing. This paper focuses on technological product innovations. The following indicators were assessed in relation to technological product innovations at the company level:

- Introduction of product innovations
- Introduction of product innovations new to the market
- Granted patents

Table 3: Innovation indicators

	Vienna	Salzburg	Upper Austria	Total
Percentage of firms introducing a product innovation	87	79	97	87
Percentage of firms introducing a product innovation – new to the market	73	55	79	68
Percentage of firms that have been granted a patent	60	17	11	26

The data suggests that almost all companies undertake at least incremental innovation activities (87% have generated some form of product innovations). Even a relatively large percentage of firms has

introduced product innovations new to the market (68%). Fewer, however, were granted a patent (26%). The companies in Upper Austria are relatively strong in product innovations, however, comparably few have been granted a patent. In contrast, the firms in Vienna are characterised by a high rate of patenting. Although more of Salzburg's firms have been granted a patent in comparison to Upper Austria, the rate of those generating product innovations is lower (table 3). The dependent variable, therefore, distinguishes between three groups of companies (table 4):

- Low innovativeness: Companies that have not introduced product innovations new to the market nor have been granted a patent (32 observations)
- Medium innovativeness: Companies that have introduced product innovations new to the market or have been granted a patent (52 observations)
- High innovativeness: Companies that have introduced product innovations new to the market and have been granted a patent (26 observations)

Table 4: Product innovations new to the market versus patents

Number of Firms		Patents		total
		no	yes	
Product innovations new to the market	no	32	3	35
	yes	49	26	75
	total	81	29	110

The independent variables represent the importance of in-house knowledge, the variety of knowledge sourcing on regional, national and international levels, the location of firms as well as a number of control variables. The survey was specifically targeted at gathering data about the patterns of knowledge sourcing. For the various knowledge sources, firms were asked to provide detailed information about the type of source (e.g. customer, supplier, university, R&D institute, firm from own sector, firm from other sectors, etc.), the geographic level (regional, national, international) and the transfer mechanisms (e.g. contract research, R&D cooperations, licensing, recruitment of staff, etc.). This very rich dataset was summarised to indicators measuring the variety of sources each firm uses to acquire knowledge on the regional, national and international level, i.e. from how many different types of sources knowledge was acquired on these levels. Concerning the type of relationships, firms were requested to indicate the importance for the acquisition of knowledge (in addition to the specific information provided for each knowledge source) of fairs and exhibitions, market studies, academic publications or journals, buying of licences, software, equipment or machines, R&D cooperations, informal contacts and recruitment of specialists. However, only the variable for R&D cooperations exerts a significant effect on the innovativeness of firms. Therefore, only this variable was kept in the model presented below.

In order to represent in-house knowledge, we decided to include three indicators in the model: the percentage of staff with academic background, the percentage of academic staff with natural science

degree and the percentage of knowledge applied in the firm, which was created in-house. In relation to the location of the firms, postcodes were available to associate the observations with the cities Vienna, Linz and Salzburg as well as the regions with a lower degree of agglomeration. Vienna constitutes the largest agglomeration in Austria with the thickest RIS. Linz and Salzburg are intermediate cities. The RIS is thinnest in the lower density regions. Due to the differences in innovation processes between ICT firms focussing on manufacturing and engineering and such that provide ICT services and programme software, a dummy variable was introduced distinguishing these two basic industrial types. Being aware of the often-proclaimed relationship between firm size and innovativeness, the logarithmised number of employees in 2009 is introduced as a control variable.

Description of model

The dependent variable represents companies in three categories of low, medium and high innovativeness. Therefore, the application of an ordinal regression model constitutes a logical choice. The basic form of an ordinal regression model is as follows (McCullagh, 1980):

$$\text{link}\{\gamma_j(x)\} = \theta_j - \beta x$$

Where γ_j is the cumulative probability for the j th category given a certain value of the covariates x . “Link” represents a monotone increasing function that maps the ordinal scale variable onto $(-\infty, \infty)$. The logit link function is frequently used, offers the advantage of easy interpretation through odds ratios and has the following form:

$$\ln \left(\frac{\gamma_j(x)}{1 - \gamma_j(x)} \right)$$

Other alternative link functions are probit, logit, complementary log-log, negative log-log and cauchit links. De Carlo (2003) emphasises that using different link functions is a way of testing the robustness of the results. The underlying distribution of the dependent variable determines which link function produces the best-fitting models. For heavy-tailed underlying distributions, i.e. outcomes with many extreme values, the cauchit link is most suited:

$$\tan \left(\pi(\gamma_j(x) - 0.5) \right)$$

We will apply both the logit and the cauchit link function and compare the models in order to investigate the robustness of the results and to consider the possibility of a heavy-tailed underlying distribution. The survey includes a number of extreme values, i.e. companies with hardly any innovation activities providing mainly IT support and on the contrary firms scoring in almost all of the relevant innovation indicators. Hence, a heavy-tailed underlying distribution is considered possible.

θ_j constitutes “thresholds” or “cut points” that can be compared with the intercepts of linear regression models and are of little interest in our case (McCullagh, 1980). β stands for a vector of regression parameters describing the effect of the covariates \mathbf{x} on the dependent variable.

As explained above, the dependent variable categorises the companies in such of low, medium and high innovativeness. A closer investigation of the ICT sector reveals important differences between ICT companies focussing on services or manufacturing. As patenting plays a limited role for service oriented ICT companies, only few of the service companies are classified as highly innovative. Hence, ICT manufacturers are spread more evenly over the three innovation categories evidenced by a variance almost double the one of ICT service providers (0.648 versus 0.347).

Table 5: Variance of ICT Services and Software companies versus ICT Manufacturers

	All Observation		ICT Services and Software		ICT Manufacturing	
	Frequency	%	Frequency	%	Frequency	%
low	32	29.1	23	33.8	9	21.4
medium	52	47.3	40	58.8	12	28.6
high	26	23.6	5	7.4	21	50.0
total	110	100.0	68	100.0	42	100.0
Variance	0.529		0.347		0.648	

The basic model shown above is extended to take into account the different variability between ICT manufacturers and ICT service providers. This allows the variances of the underlying distributions to differ across these two groups of firms (i.e. that the manufacturers have a larger variance than service providers). The unequal variance model takes the following form (Norušis, 2010; DeCarlo, 2003):

$$\text{link}\{\gamma_j(x)\} = \frac{\theta_j - \beta x}{\exp(\tau z)}$$

Where z represents the variables giving reason to a different variance (in our case whether the companies are manufacturers or service providers) and τ the respective parameters. The z variables are usually chosen from the group of x variables (Norušis, 2010).

Results of the model

The results of all four models are presented in table 6. In order to assess the quality of the models, the table also shows the calculated r-square values as well as the percentage of correctly predicted observations. Based on these measures, all four models can be considered of good quality. However, allowing for a differing variance for the underlying distributions depending on whether the observed company is focussing on ICT services or manufacturing clearly improves the fit of the models, i.e. the

r-square values increase significantly for model 2 and 4. Furthermore, the percentage of correctly predicted observations rises. As described above, ICT companies that focus on manufacturing have a higher probability of having been granted a patent than such primarily providing services. Accordingly, ICT manufacturing companies are spread more over the three innovation categories and thus the variance for such companies is higher than for mainly service providers. Model 2 and 4 confirm that there is a significant difference in the variance, i.e. for services it is significantly lower. Also, the cauchit link function fits better than the logit one for this dataset. Overall, the r-square values as well as the percentage of correctly predicted observations lead to the conclusion that the models provide a good fit, especially if the different variance of the underlying dependent variable is considered.

Table 6: Results of multivariate model

	Logit						Cauchit					
	Esti- mate	Std. Error	p- value	Esti- mate	Std. Error	p- value	Esti- mate	Std. Error	p- value	Esti- mate	Std. Error	p- value
Threshold (θ)												
Category = 0	1,537	0,951	0,106	0,409	0,553	0,460	-0,192	1,128	0,865	0,092	0,416	0,824
Category = 1	4,532	1,050	0,000	1,736	0,763	0,023	5,278	1,588	0,001	1,561	0,672	0,020
Location (β)												
Regional sources	0,342	0,268	0,202	0,196	0,113	0,083	0,897	0,407	0,028	0,255	0,118	0,030
National sources	-0,247	0,274	0,368	-0,156	0,110	0,156	-0,404	0,371	0,277	-0,195	0,120	0,104
International sources	0,297	0,207	0,151	0,082	0,084	0,329	1,000	0,361	0,006	0,146	0,081	0,073
R&D cooperations	0,472	0,164	0,004	0,206	0,079	0,009	0,528	0,235	0,025	0,120	0,067	0,073
In-house knowledge	0,020	0,008	0,016	0,011	0,004	0,008	0,029	0,011	0,012	0,010	0,004	0,020
Academics	-0,003	0,008	0,709	0,000	0,003	0,988	0,000	0,010	0,994	0,001	0,002	0,531
Science graduates	0,021	0,012	0,065	0,005	0,004	0,207	0,043	0,017	0,010	0,008	0,005	0,129
Lower density	-0,909	0,933	0,330	-0,564	0,724	0,436	-2,670	1,455	0,067	-0,608	0,679	0,371
Salzburg	-1,387	0,905	0,125	-0,797	0,725	0,272	-3,553	1,397	0,011	-0,791	0,692	0,253
Linz	-0,500	0,944	0,596	-0,426	0,718	0,553	-1,706	1,380	0,217	-0,258	0,668	0,699
Firm size	0,255	0,150	0,090	0,071	0,062	0,256	0,161	0,201	0,424	0,082	0,058	0,155
Services	-0,869	0,805	0,280	-0,471	0,620	0,448	-1,692	1,179	0,151	-0,509	0,593	0,391
Scale (τ)												
Services				-1,404	0,319	0,000				-2,425	0,516	0,000
r ² - Cox and Snell	0,399			0,508			0,453			0,541		
r ² - Nagelkerke	0,454			0,577			0,514			0,615		
r ² - McFadden	0,240			0,335			0,284			0,367		
Observations	106			106			106			106		
Correctly predicted	62%			68%			71%			74%		

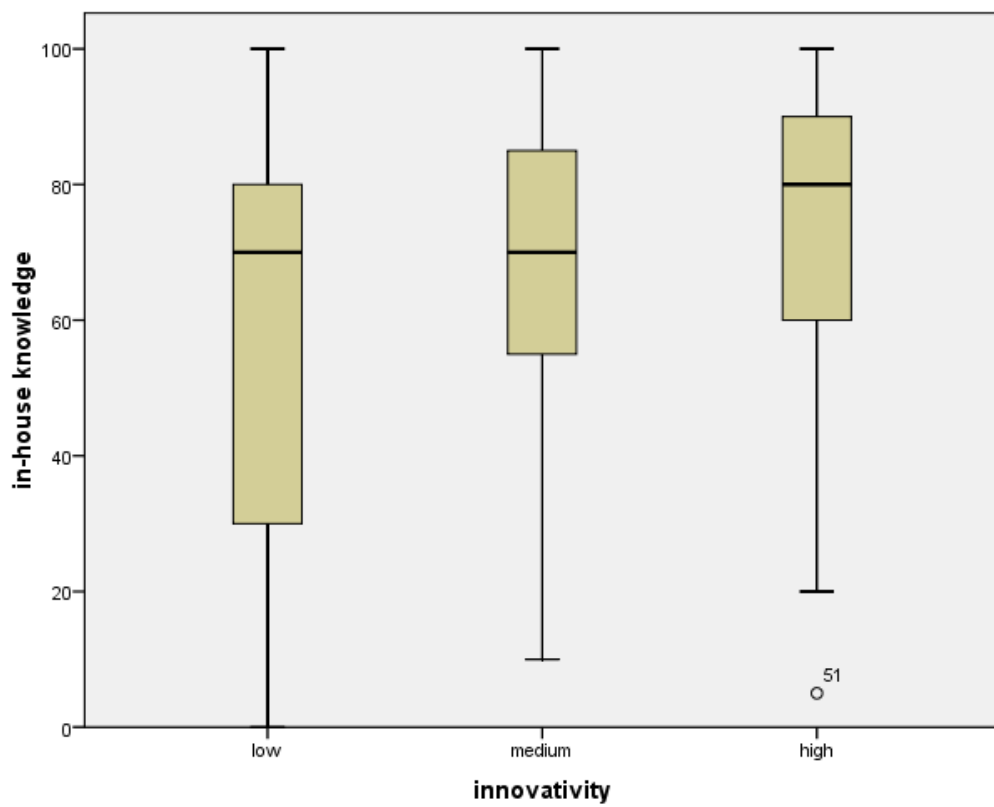
Two of the independent variables show a significant positive effect in all four models: i) in-house knowledge and ii) R&D cooperations. In three of the models the variety of knowledge sourcing on the regional level contributes significantly to the innovativeness of firms. Models 3 and 4 provide

evidence for the importance of international knowledge sourcing (which is positive but not significant in the models 1 and 2). The use of national sources is not significant in any of the four models. In two of the models, we find a significant positive effect for the percentage of academics with natural science degree (positive estimates in all models, significant in model 1 and 3). However, there is no evidence that the percentage of academics based on total employment has an impact on the innovativeness of firms. The results provide an indication that firms in Vienna are more innovative, i.e. all the estimates for a location in the regions of lower density, in Linz or Salzburg are negative and the values are significant in model 3 for the lower density regions and Salzburg. Some evidence was found that size has a beneficial effect on innovations (positive estimates in all models, significant, however, only in model 1).

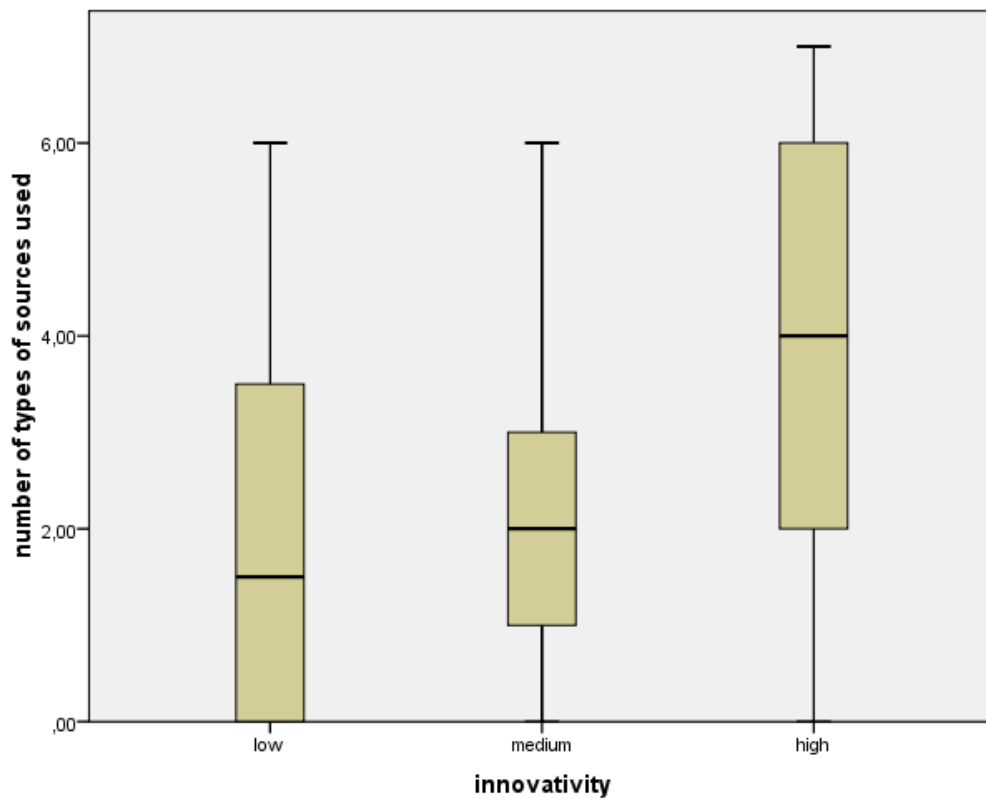
Discussion of the results

The analysis of the empirical data aims at testing the five hypotheses developed in the conceptual section of this paper. We elaborated the idea that innovation activities require both in-house knowledge and the acquisition of knowledge from external sources. While this is widely accepted, we provided arguments that a dichotomous perspective of internal versus external knowledge is misleading. In-house knowledge determines the capacities of firms to acquire knowledge externally as well as the expected return of doing so. Hence, we presume that firms with well-developed in-house knowledge are more innovative. The presented analysis of the data generated from Austrian ICT firms support the above argument: In-house knowledge has a significant positive effect on the innovativeness of firms in all four models (support for hypothesis 1). In addition, the share of academics with natural science degree seems to enhance innovation performance. This implies that in-house knowledge in specific technological fields is supportive for innovations. Firms with a more “analytical knowledge base” usually score higher in this respect. Besides the relevance of in-house knowledge, the results of the multivariate models also provide evidence that external sourcing on regional and international level enhance innovativeness (support for hypothesis 2). The box plots in graph 1 and 2 show furthermore that the innovative firms score higher in both, in-house knowledge and the number of different types of knowledge sources used.

Graph 1: Box-Plot of in-house knowledge versus innovativity



Graph 2: Box-Plot; number of types of sources used versus innovativity



While the data supports the line of argument developed in this paper, we also recognise drawbacks due to the data used. Three indicators measure in-house knowledge, two of which show a significant positive effect on the innovation performance of firms. One of the indicators is rather subjective as the respondents were requested to estimate the share of in-house knowledge against the share of external knowledge applied in innovation processes. The other two indicators relate to the number and share of employed academics in general and in natural sciences. We consider it valuable to develop a more sophisticated instrument to measure in-house knowledge, ideally in the main fields of each sector.

The results allow for interesting interpretations about the geography of knowledge sourcing. Regional and international knowledge sources seem to contribute to the innovativeness of firms while no significant influence is observed for national sources. Positive effects that frequently develop in geographic proximity explain the importance of regional sources. Geographic proximity facilitates face-to-face meetings and thus interactive learning. Furthermore, firms located in one region usually operate in a similar institutional context. Also, the conditions for the development of social proximity are favourable due to potentially existing networks, planned and spontaneous contacts in addition to work relationships as well as the ease of face-to-face meetings. Although more difficult, knowledge transfer also occurs over larger geographic distances and is enhanced through other forms of proximity (Boschma, 2005). International sources allow firms to access knowledge not available regionally, observe changes in the global environment, react to global trends, and reduce the risk of being locked-in outdated production systems, markets and technologies. Knowledge sourcing on a global scale has been observed both in formal (global pipelines) as well as informal forms (Bathelt et al., 2004; Owen-Smith and Powell, 2004; Storper and Venables, 2004; Amin and Cohendet, 2005; Maskell et al., 2006; Cappellin and Wink, 2009). Interestingly, national knowledge sources seem not to contribute to the innovativeness of ICT firms in the three Austrian regions. On the national level, positive effects of co-location vanish. Furthermore, the relative small size of Austria limits the potential of national knowledge sourcing, which probably does not suffice to recognise trends in the wider environment and provides accesses only to a small fraction of the globally produced knowledge. Possibly for these reasons, national knowledge sourcing is not a valuable indicator for explaining the innovativeness of firms in the Austrian case, although some national sources might very well contribute to the innovations of specific firms.

In relation to the geography of knowledge sourcing, we also presumed a relative high importance of the regional level for sourcing from research and development organisations, universities and other knowledge generating organisations compared to sourcing from clients and suppliers (hypothesis 3). Bridging geographic distance for the acquisition of knowledge tends to be easier with clients and suppliers due to existing input-output relationships that reduce relational proximity and due to more similar knowledge bases with these sources. In fact, table 7 illustrates that most knowledge links with

clients and suppliers occur on the international level (47%). By contrast only 9% of the knowledge links with knowledge generating organisations were reported on this level. 65% of all knowledge links with such sources exist on the regional level compared to 27% with clients and suppliers. The distribution of links for other firms is relatively balanced (28% regional, 30% national, 42% international).

Table 7: Knowledge sources per spatial level

Knowledge Source	Measure	Regional	National	International	Total
Value Chain	Number of links	51	50	89	190
	% of knowledge source	26,8%	26,3%	46,8%	100,0%
	% of spatial level	33,3%	47,6%	67,9%	48,8%
Other firms	Number of links	21	22	31	74
	% of knowledge source	28,4%	29,7%	41,9%	100,0%
	% of spatial level	13,7%	21,0%	23,7%	19,0%
Knowledge generating organisations	Number of links	81	33	11	125
	% of knowledge source	64,8%	26,4%	8,8%	100,0%
	% of spatial level	52,9%	31,4%	8,4%	32,1%
Total	Number of links	153	105	131	389
	% of knowledge source	39,3%	27,0%	33,7%	100,0%
	% of spatial level	100,0%	100,0%	100,0%	100,0%

Companies acquire knowledge from the mentioned sources using a variety of mechanisms. Interactive transfer mechanisms, i.e. formal R&D cooperations and informal contacts, are expected to allow for more substantial learning effects than static ones and should, therefore, be more important for the innovativeness of companies. This argument is supported by all four models, as the results are significant for R&D cooperations in all of them. Due to insignificance, the other mechanisms were not retained in the models. Table 8 provides additional information about the geography of transfer mechanisms. It shows that, as expected, the interactive transfer mechanisms occur more frequently on the regional levels (support for hypothesis 4). Companies realise 46% of all R&D cooperations with regional partners, 30% with national and 24% with international ones. We also observe most informal contacts in the region (44%) and a relatively high percentage on the international level (35%). Interestingly, informal contacts are the least frequent on the national level (21%). The acquisition of knowledge through employment/recruitment constitutes mainly a regional phenomenon. Firms in Vienna, however, recruit most frequently on the national level (48% compared to 28% regionally and 24% internationally). The higher importance of the national and international level for the acquisition of knowledge through employment in Vienna is an indicator for the attractiveness of this location. The national level is mentioned the least frequent in relation to informal contacts (21%), contracting (29%), fairs and conferences (20%), observations (13%) as well as overall (25%), which indicates, in line with the results of the models, a relatively low importance of this geographic level for firms in Austria.

Table 8: Transfer mechanisms per spatial level

Mechanism	Measure	Regional	National	International	Total
Employment	Number of mechanisms	54	22	12	88
	% of mechanism	61%	25%	14%	100%
	% of spatial level	14%	9%	3%	26%
R&D-cooperations	Number of mechanisms	86	56	44	186
	% of mechanism	46%	30%	24%	100%
	% of spatial level	22%	22%	13%	57%
Informal contacts	Number of mechanisms	102	50	82	234
	% of mechanism	44%	21%	35%	100%
	% of spatial level	26%	20%	24%	70%
Academic journals	Number of mechanisms	9	7	6	22
	% of mechanism	41%	32%	27%	100%
	% of spatial level	2%	3%	2%	7%
Contracting	Number of mechanisms	61	46	51	158
	% of mechanism	39%	29%	32%	100%
	% of spatial level	16%	18%	15%	49%
Fairs and conferences	Number of mechanisms	29	19	47	95
	% of mechanism	31%	20%	49%	100%
	% of spatial level	7%	8%	14%	29%
Observations	Number of mechanisms	16	8	38	62
	% of mechanism	26%	13%	61%	100%
	% of spatial level	4%	3%	11%	18%
Licensing	Number of mechanisms	24	31	43	98
	% of mechanism	24%	32%	44%	100%
	% of spatial level	6%	12%	12%	31%
Industry journals	Number of mechanisms	9	10	25	44
	% of mechanism	20%	23%	57%	100%
	% of spatial level	2%	4%	7%	14%
Total	Number of mechanisms	390	249	348	987
	% of mechanism	40%	25%	35%	100%
	% of spatial level	100%	100%	100%	100%

The results underline the importance of geography for knowledge sourcing. If geography impacts knowledge sourcing and knowledge sourcing influences innovations of firms, the location of firms will also have an effect on their innovativeness. Firms located in a “thick” RIS potentially benefit from networks with firms and organisations located near-by and easier access to knowledge sources outside the region. Being the largest agglomeration in Austria, Vienna is characterised by a relatively “thick” RIS compared to the regional capitals Linz and Salzburg. Firms located in areas with a lower degree of agglomeration suffer from institutional thinness in their immediate neighbourhoods. Therefore, we expect the effect of location to be significant in our model (hypothesis 5). The results show a tendency for firms located in Linz, Salzburg and outside the cities to be less innovative than those situated in Vienna. However, while the respective estimates are negative in all four models, they show significant

levels only in one model for firms located in Salzburg and outside the cities. Consequently, some but rather limited evidence support the hypothesis that firms located in thick RIS are more innovative. The rather weak effect of location in this case may be explained by the short geographic distances between the investigated regions and by the indicator “regional knowledge sourcing”, which captures positive effects generated through regional networks.

Conclusions

This paper investigated the interrelationship between in-house knowledge and the acquisition of knowledge from external sources as well as the importance of geography both in relation to knowledge sourcing and the location of firms. The analysis provides evidence for the importance of both in-house knowledge and external knowledge sourcing for the innovativeness of firms. In-house knowledge enables and facilitates the acquisition of knowledge from external sources and increases the probability of generating innovations with it. External knowledge sourcing, in turn, strengthens in-house knowledge, thus, creating a self-reinforcing cycle. Consequently, it seems that the dynamic interplay between in-house knowledge and external knowledge sourcing is fundamental for innovations and that a dichotomous perspective of internal versus external knowledge sourcing should be applied with caution.

The empirical investigation also shows that both regional and international knowledge sources are more important in Austria than national ones. Regional and international sources occur more frequently and have a significant positive effect on the innovativeness of ICT firms. Geographic proximity facilitates interactive learning through the ease of face-to-face meetings and by promoting other forms of proximity. The positive effects of geographic proximity and co-location disappear on the national level. On the other hand, being a relatively small country, national knowledge sourcing in Austria is limited, hardly suffices to recognise trends in the wider environment and allows to access only a small fraction of the globally produced knowledge in related fields.

The study also underlines the importance of R&D cooperations for the innovativeness of firms. R&D cooperations implicate interactive learning processes between the involved organisations. Firms in our sample utilise interactive knowledge transfer mechanisms such as R&D cooperations and informal contacts more frequently on the regional level. In contrast, knowledge acquisition from clients and suppliers occurs more frequently on the international level. These results confirm the propositions developed in the theoretical section of this paper.

As geographic proximity influences knowledge sourcing, the characteristics of the RIS, consequently, are expected to influence both knowledge sourcing and the innovation performance of firms. This

paper investigated the impact of firms' location in different types of RIS on innovativeness. As expected, the companies located in Vienna, which represents the thickest RIS in Austria, tend to be more innovative. The observed effects, however, seem to be rather weak. This might be due to the short geographic distances within Austria and the potential representation of "locational" effects through regional knowledge sourcing, which has turned out to strengthen the innovation capacities of firms.

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