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Knowledge Sourcing and Innovation in Austrian ICT companies – Does Geography matter?

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Abstract

The competitiveness of many of today's industries largely depends on the ability to innovate. Innovation is nowadays regarded as a result of an open and interactive knowledge process, demanding from companies to generate, absorb and apply knowledge relying both on internal and external sources. Companies often maintain links to various knowledge sources from local to international levels using particular channels for acquiring such knowledge. Also the location of companies is thought to have an influence on the pattern of knowledge links and on the innovation performance of companies. The location of a company in a "thick" Regional Innovation System (RIS) should lead to a better innovation performance as compared to a location in a "thin" RIS. The paper aims to develop a better understanding of the relationship between the location of the company (type of RIS), their (geographical) pattern and the mechanisms of knowledge sourcing, and their innovation performance. The derived assumptions are tested by applying a multivariate model that investigates the impact of the above-mentioned factors on the innovativeness of firms. Besides internal knowledge, the variety of knowledge sources used on regional, national and international levels, in particular the engagement in R&D cooperation, and the location of companies are identified as key determinants of innovativeness in a knowledge-based sector such as ICT. The paper draws on data from the ICT sector in three regions Austria. Overall, 110 personal interviews and questionnaires were collected from companies in three Austrian regions of this sector.

1) Introduction

There is widespread consensus nowadays about the importance of innovation for enhancing the competitiveness of firms, as well as on the interactive nature of the innovation process. Partly due to a rapid scientific and technological progress and an increasing complexity of innovation we find an involvement of many actors in the process. Relevant knowledge is often located outside the firm as e.g. concepts such as „open innovation", innovation networks and innovation systems have suggested. As a consequence, firms have to acquire knowledge from other firms and organisations and combine it with their internal knowledge (Fritsch 2001, Chesbrough 2003, Powell and Grodahl 2005, Laursen and Salter 2006). This paper aims at developing a better understanding of the pattern and mechanisms of knowledge sourcing, the relation to innovation performance and the relevance of geography in this context. Geography is playing a role with regard to two related aspects: as location of companies in particular types of regional innovation systems, and as preferred spatial levels of knowledge sourcing.

Companies usually acquire relevant knowledge from different types of sources such as customers, suppliers and research organisations. These are distributed at various spatial levels - from local to global - depending on the knowledge base of the companies and the location of relevant knowledge sources and innovation partners. We want to investigate if some types of knowledge sources as well as mechanisms of knowledge exchange are more often used at particular geographical levels than others and if this has an influence on innovation performance. We argue that despite strong forces and trends towards globalisation of knowledge flows (Kaufmann et al. 2003, Morgan 2004, Amin and Cohendet 2005) there is still some role for geographic proximity and for the region in the knowledge- and innovation process (Sternberg 2000, Fritsch 2001, Tödtling et al. 2006, Malecki 2009). This results from the partly tacit or implicit nature of knowledge complicating its transfer (Polanyi 1966). Tacit knowledge is transferred through interactive processes and 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. Codified knowledge can more easily be acquired trough "pipelines", i.e. formal relations, over large distances than tacit knowledge. As a consequence 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 extra-regional sources are thought to contribute to the innovativeness of firms (Arnd and Sternberg 2000). However, sources requiring more complex knowledge interactions and learning processes should tend to be located at shorter geographic distance, i.e. at local or regional levels (Fritsch 2001, Fritsch and Franke 2004).

Assuming a positive effect of geographical proximity and local links for knowledge interaction leads to the relevance of agglomerations and of regional innovation systems. 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, Asheim and Coenen 2006). Regions differ in the configuration of their RIS as was argued by Tödtling and Trippl (2005). Major agglomerations usually show a "thicker" RIS than more rural areas Consistent with the above described the following three connected research questions will be explored:

- How do companies source external knowledge? In particular what kinds of knowledge sources are they having and which mechanisms of knowledge exchange are they using? At which geographical levels can these be found?
- Does the pattern of innovation and knowledge sourcing vary between types of RIS?
- How does location (type of RIS) and the pattern of knowledge sourcing relate to the innovativeness of companies? How important is the location in a "thick" RIS for the innovativeness of companies?

These questions will be investigated for three types of regions / RIS in Austria using data collected from the Information and Communication Technology (ICT) sector. 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 pattern and role of external knowledge sourcing investigated in this paper is particularly relevant for the ICT sector. The data of 110 firms are assessed using descriptive and multivariate statistical methods.

2) Conceptual Background

External knowledge sourcing in the innovation process in the ICT sector

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 complex nature of these processes mainly results from 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 or through the combination of knowledge from different 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 characterised by a strongly expanding knowledge base, than to industries utilising more 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, Cooke et al. 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. They benefit in particular from contacts to universities and research organisations, e.g. through R&D collaborations, and the mobility of staff. 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 characterised to a higher extent by an analytical knowledge base, the later predominately use a synthetic one. In addition, some ICT sub-sectors are thought to rely partly on a symbolic knowledge base like gaming and media related ICT products, or applications for mobile devises.

The role of geographical proximity and of particular geographical levels varies between types of knowledge sources: Knowledge exchange with universities and research organisation needs to overcome a relatively large cognitive and relational distance. As a consequence such relations can often be found at the regional level where easy face to face interactions can facilitate knowledge transfer (Fritsch 2001, Keeble and Wilkinson 2000). This may be different in high-tech sectors such as Biotechnology. Firms in such sectors undertake significant research and development efforts and thus share a similar (analytical) knowledge base with universities and research organisations. Accordingly, long-distance knowledge transfer is more feasible and occurs relatively frequently (e.g. Moodysson et al., 2007) Knowledge exchange with customers and suppliers is characterised by cognitive and relational proximity and shaped by existing and distant customer / supplier networks. As a consequence they can often be found at an international level (Tödtling et al. 2006).

Companies, however, also require internal capacity to identify and absorb externally generated knowledge. Such an “absorptive capacity”, as already elaborated by Cohen and Levinthal (1990) depends on several factors such as the knowledge of each individual working for the firm, the homogeneity / diversity of in-house knowledge, the communication processes within the firm, and the role of gatekeepers. 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 fields of previous experience, further strengthening the cumulative character and path dependency in the learning process. Hence, in-house knowledge enables firms to understand and appropriate information about new but related knowledge from external sources. In addition, firms with strong in-house knowledge should have a higher ability to use and apply knowledge sourced externally and to generate innovations. As a consequence, internal and external knowledge have to be regarded as complements rather than as substitutes in the innovation process.

Mechanisms of knowledge exchange

Companies can use different kinds of mechanisms for acquiring knowledge from external sources. These differ in their degree of formality and interactivity (Tödtling et al. 2006). Linking these two dimensions, four basic ideal types of relationships with external knowledge sources can be identified as illustrated in Table 1. Static relations have a short term nature and limited interactions, and are characterised by the transfer of a particular kind of information or knowledge. 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 mechanisms are characterised by an ongoing relationship and the enhancement of the knowledge base involved. They can be 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 that the interactive ones allow for more substantial learning effects. Geographic proximity and the ease of face to face contacts at the local and regional level seem to support the functioning of innovation cooperation, although there is also evidence (Hagedoorn (2002), McKelvey et al. (2003) and Cappellin and Wink (2009) that formal R&D cooperations are certainly not tied to the region. Geographic proximity is expected to be important also for certain informal and untraded relationships such as milieu effects and spillovers, as these are often based on a common cultural background, trust, and face-to-face interactions. For such knowledge links to occur at the regional level requires, however, a certain density and “institutional thickness” of the respective RIS.

Table 1: Types of relationships / mechanisms for acquiring knowledge

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

Source: Tödtling et al. 2006

As already stated above, ICT firms that are characterised by a mainly synthetic knowledge base (ICT services and small software firms) are expected to source knowledge to a high extent from the value chain. With main clients and suppliers, knowledge exchange is often an informal by-product of the underlying formal input-output relationship. As knowledge sourcing from customers and suppliers tends to occur in the context of high cognitive and relational proximity and as these are frequently located outside the region, we expect a wide geographic spread for these types of relationships. The same applies to the monitoring of competitors which are also often located outside the region. This understanding partly opposes the view of the traditional Industrial District model where interactions with partners along the value chain are thought to be mainly regional. For ICT firms that draw more on an analytical knowledge base (such as ICT manufacturing or large software firms) knowledge generating organisations such as universities and research organisations are expected to have a higher importance. Geographical proximity might help to overcome the cognitive distance acting often as barrier for university-industry interaction (Kaufmann and Tödtling 2001). The region, as a consequence, has a higher importance as an interaction space. With knowledge generating organisations, firms tend to apply more formal types of relationships (such as contract research, consultancy contracts, formal R&D cooperations) besides relying on informal links such as the relation of graduates to former professors, or internships of PhD Students etc. (Tödtling et al., 2006; Trippl et al., 2009).

Role of regional innovation systems and of agglomeration

Also the location of companies in particular types of regions and innovation systems matters for knowledge sourcing and innovation performance. Innovation system concepts share the view of innovation as an interactive collective process emphasizing in particular the institutional context for innovation. 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). RIS account for the density of firms and organisations, interrelationships between the various actors in the region, the underlying institutional setting, the policy dimension as well as the linkages with other IS. Tödtling and Trippl (2005) identified three types of Regional Innovation Systems (RIS), namely peripheral, (old) industrialised and metropolitan RIS. These represent different innovation environments for companies:

- In metropolitan RIS **c**ompanies have more and diverse opportunities for knowledge sourcing and good preconditions for innovation.
- In industrial RIS **c**ompanies often have advantages of specialised clusters. Under certain conditions (in old industrial areas), however, they may face problem of “lock in”, resulting in a too strong fix on old technological trajectories.
- In peripheral RIS **c**ompanies face problem of organisational “thinness”, i.e. there are few knowledge sources on the regional level.

Our empirical analysis covers all three types of RIS: Vienna is representing a metropolitan RIS, Upper Austria an industrialised RIS, whereas Salzburg represents the case of an organisational “thin” RIS. 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).

Upper Austria represents an industrial RIS, where the dominant industries are in low and medium technology industries such as steel production, vehicles, plastic goods, and others. There are also ICT activities in particular in the Software Park Hagenberg and in a Mechatronics cluster, among others.

Although there are clearly less knowledge organisations in the region compared to Vienna, there seems to be a good level of networking in part due to an active cluster policy within the region. Salzburg represents the case of a “thin” RIS with few knowledge organisations, and a smaller number of companies.

3) Background and methodology of empirical study on 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 literature and the line of argument developed above:

1. Firms using a larger variety of knowledge sources tend to be more innovative.
2. Knowledge links to universities and R&D institutes can be found more frequently on a regional level than links to clients and suppliers.
3. 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.
4. Firms located in Vienna (“thick” RIS) tend to have more regional knowledge links and they tend to be more innovative than firms located in other areas. In particular for the “thin” RIS of Salzburg we expect companies to have knowledge links more often at an international level in comparison.

The data were gathered 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, Trippl 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 agency for business location and innovation. Traditionally, Upper Austria has a strong industrial base and policy support has strengthened sectoral specialization and regional networking activities. In this respect, TMG established cluster support organizations already in the early 90ies several.

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. Most of the surveyed companies are SMEs with less than 250 employees except seven companies in Vienna, two in Upper Austria and one in Salzburg.

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/km2)	4.068	118	74
Capital	Vienna	Linz	Salzburg
... Inhabitants in thousand**	1.687	190	149
GRP per capia 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			

4) Innovation activities and patterns of knowledge sourcing

Viennese ICT manufacturing firms engaged in a broad spectrum of innovation activities: they show a relatively high inclination towards radical innovation as reflected by a high percentage of firms claiming to develop products that are new to the market, a high number of firms that have engaged in R&D and have been granted patents. Moreover, about 50% of the firms have changed and modernized their organisational structures and their market concepts, suggesting that innovation is not only understood as a technological issue (table 3). Upper Austrian firms score highest in the categories product innovation and those that are new to the market. This fact is not surprising taking the strong orientation of the software development firms in Upper Austria on customized production into account. Overall it can be summarized that Salzburg based firms score lower in all categories listed in table 3 when being compared to the firms in Vienna and Upper Austria. This data supports hypothesis 4 that firms located in Vienna representing Austria's thickest RIS tend to be more innovative than firms located in the "thin" RIS of Salzburg. However, further analysis will be undertaken below in order to consider the influence of multiple factors on the innovativeness of firms.

Table 3: Innovation indicators

	Vienna	**Salzburg**	**Upper Austria**
Percentage of firms introducing the following innovations (last three years)			
Product Innovation	87	79	97
Product Innovation - new to market	73	55	79
Process Innovation	80	52	61
New/significantly changed strategy	53	26	58
New/significantly changed organisational structures	47	19	40
New/significantly changed market concept	50	19	37
Patents (last three years)			
Percentage of firms that have been granted a patent	60	17	11
Percentage of firms that have been granted a co-patent	13	0	2,6
Average number of patents	24,6	0,4	,1
Median number of patents	1	0	0
R&D department/employees			
Share of firms with an R&D department	60	29	32
Share of R&D employees of total employees	27%	9%	25%
Median number of R&D employees	4,5	1	3

In terms of knowledge sourcing, firms from Salzburg rely to a larger extent on international sources (43%) than firms from Vienna (33%) and Upper Austria (28%: Table 7 in the Annex). The differences are significant (table 9) for sources that belong to the value chain, i.e. clients and suppliers and such that can be categorised as knowledge generating institutions (universities, R&D organisations, educational organisations, consultants, business services). The reason for firms from Salzburg to rely more on international sources is not surprising as it is the region with the thinnest RIS. In addition it is neighbouring Germany and the region of Munich which is strong in ICT. Nevertheless, even in

Salzburg the regional level is used most frequently for sourcing knowledge from knowledge generating institutions. We find that Upper Austrian firms surprisingly have the strongest regional focus in terms of acquiring knowledge from such sources (79%) compared to firms in Vienna (54%) and Salzburg (56%). This finding might be due to the intensive cluster- and networking support in Upper Austria by the regional agency TMG as well as the activities of the software park Hagenberg. In contrast to this finding, knowledge sourcing from the value chain occurs to a lesser extent on the regional level (for firms in Vienna 41%, Upper Austria 27% and Salzburg 16%). The higher figure in Vienna can be explained by the fact that Vienna offers by far the largest regional market, i.e. the greatest number of clients and suppliers that potentially are a valuable knowledge source. As seen from these figures, knowledge links to universities and R&D institutes can be found more frequently on a regional level than links to clients and suppliers as suggested in Hypothesis 2.

For each knowledge source, the interviewed firms were requested to indicate through which channels they acquired knowledge as shown in table 8. In all regions, the three most frequently used channels are informal contacts, R&D cooperations and contract research. Informal contacts with international sources are common for firms regardless of their location in either of the investigated regions. These are e.g. professional informal contacts at fairs, conferences, workshops etc. On a regional level, firms from Upper Austria and Vienna also utilise informal contacts frequently. The data, therefore, supports the thesis that informal contacts are relevant for accessing knowledge within the region and beyond. While the importance of the region for this kind of knowledge sourcing has been acknowledged since Marshall (1920), the relevance of the international level was reported relatively recently. Informal contacts on the international level result from the attendance of fairs, conferences, project meetings, previous employment, student networks, etc. (Storper and Venables 2004, Amin and Cohendet 2004, Maskell et al. 2006). Contrary to firms from Upper Austria and Vienna, those from Salzburg hardly use regional informal contacts. This might be due to the institutional thinness and the lack of an innovative milieu.

R&D cooperations are the second most frequent channel for knowledge sourcing in all three regions. We observe a geographic decay of the frequency of R&D cooperations in Vienna and Upper Austria. Firms from Salzburg, however, access knowledge through R&D cooperations most frequently on the international level, which is yet another expression of the lack of relevant institutions on the regional level. In contrast to firms located in Upper Austria and in Vienna, for which informal contacts are the most frequent channel, firms from Salzburg acquire knowledge most frequently through contract research. Adding up the market-based channels (contract research and purchasing of licenses, machinery, software), we find that Salzburg based firms utilise such channels relatively often (35,2%) in comparison to firms from Upper Austria (25,7%) and Vienna (23,7%). These market-based channels often have to do with the buying of existing knowledge and usually feature a lower degree of interactive knowledge transfer. Interactive knowledge transfer, however, is considered to be the prime source for acquiring tacit knowledge and thus upgrading the knowledge base of the firm. Utilising market relations more frequently, firms from Salzburg, therefore, should find it more difficult to upgrade their in-house knowledge through knowledge sourcing. Compared to market-based channels, attending conferences and fairs are considered to be informal channels, yet still characterised by a low degree of interactive learning. However, often they constitute entry points for engaging in more durable relations and networks. As expected, the relative importance of the international level is significantly higher for firms in Salzburg than for firms in Upper Austria or in Vienna due to the low number of relevant actors within the region. Table 4 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 3). 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.

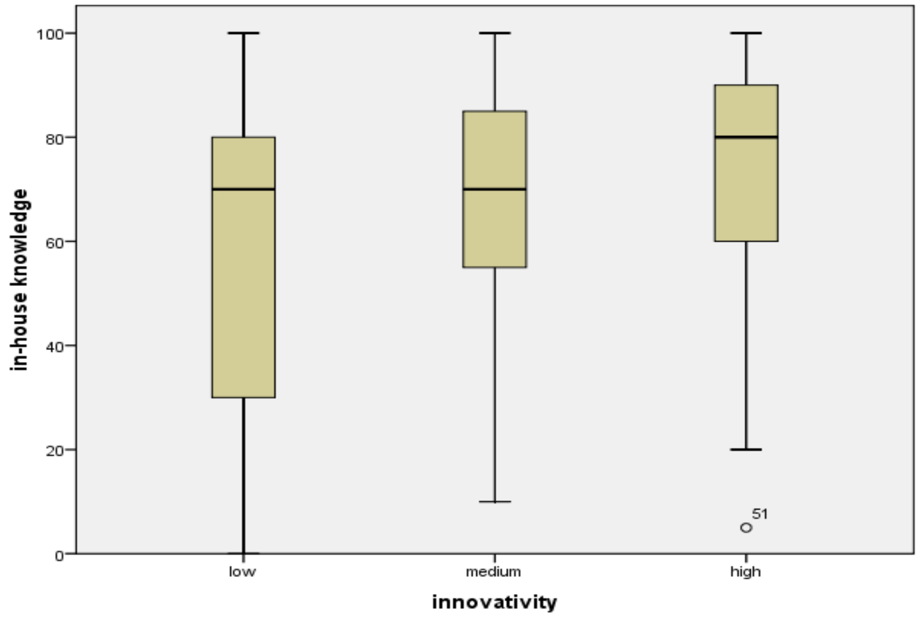
Table 4: Transfer mechanisms by spatial level

Mechanism	Measure	Regional	National	International	Total
Recruitment of personnel	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%
Monitoring	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%

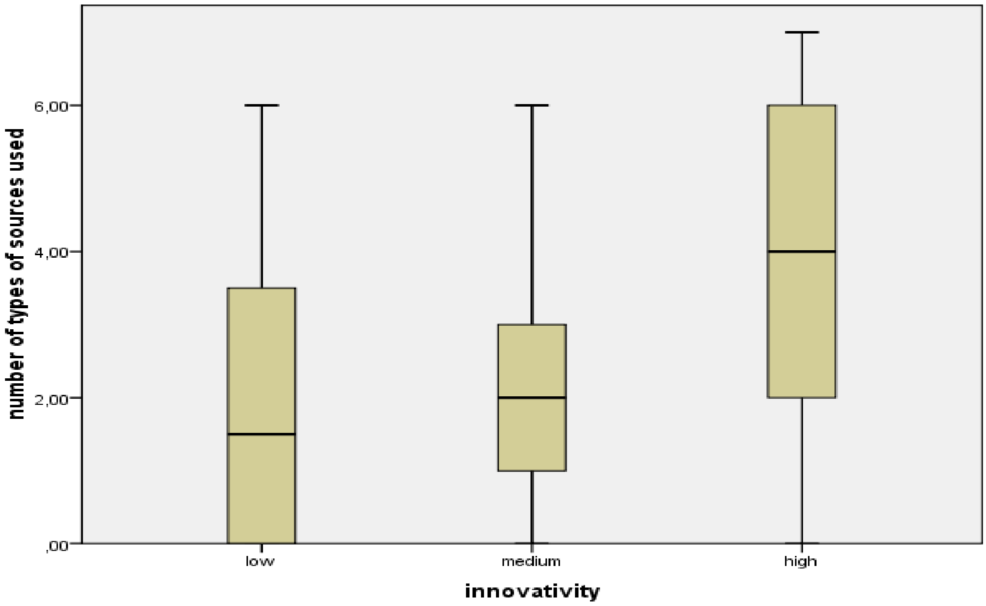
Multivariate analysis of the investigated variables

While the section above has largely described the pattern of innovation and knowledge sourcing, in this section a multivariate model is presented, which aims at explaining the innovativeness of firms by key variables relating to knowledge sourcing, in-house knowledge, location and a set of control variables. A first view on the relation between the internal and external knowledge of firms, and the innovativeness of firms is shown in the following box plots in graph 1 and 2. We can see that innovative firms (see variable description below) score high in both the importance of in-house knowledge in the innovation process and the variety of external knowledge sources used. This clearly points to a complementary role of external and internal knowledge in the companies' innovation process.

Graph 1: Share of in-house knowledge versus innovativeness of companies



Graph 2: Variety of external knowledge sources versus innovativeness of companies



The multivariate analysis shows more details of the investigated interrelationships. We have applied an ordinal regression model (McCullagh 1980) which is described in more detail in Grillitsch and Tödtling (2010). The model takes into account the differing variability depending on whether the specific firm belongs to ICT hardware and engineering or ICT software or service providers by introducing a scale variable (Norušis 2010, DeCarlo 2003). Furthermore, two models were calculated with the same variables but using once the logit and once the cauchit link functions. 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.

The dependent variable distinguishes three groups of companies (table 5):

- 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 5: Product innovations new to the market versus patents

Number of Firms		Patents		
		no	yes	total
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 such as company size, whether the firm is part of a group or network, year of establishment, etc. The survey was specifically targeted to gather 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 have included 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. 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.

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.

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 tends to exert a negative effect, which, however 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).

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%

5) Discussion of the results

The results of the multivariate models have provided clear evidence that the use of external knowledge sources enhances the innovativeness of companies, thus, supporting hypothesis 1. In particular, external R&D cooperations had significant positive effects in all four models. This underlines the importance of more durable interactive relationships with particular knowledge providers for innovation. Regarding spatial levels, the variety of external sources (types) on regional and international levels seems to matter as well (significant positive effects in three and two respectively of the models).

The results allow for interesting interpretations about the geography of knowledge sourcing. The variety of knowledge sources at regional and international levels seems to contribute to the innovativeness of firms while no significant influence is observed for national sources. Positive effects of the regional level seem to be due partly to geographic proximity facilitating face-to-face meetings and 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.

Our findings, furthermore, provide evidence that external knowledge does not substitute internal knowledge. In-house knowledge has a significant positive effect on the innovativeness of firms in all four models. 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. Our results indicate that in-house knowledge determines the capacities of firms to acquire knowledge externally and to apply this knowledge in the advancement of innovations.

Besides the pattern of knowledge sourcing the location of firms was expected to have an effect on their innovativeness. Firms located in a “thick” RIS should benefit from the density of firms and research organisations, a highly qualified labour force 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. In particular, firms located outside the agglomerations suffer from institutional thinness in their immediate neighbourhoods (hypothesis 4). 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, we find some but rather limited evidence in support of hypothesis 4 that firms located in thick RIS are more innovative. The rather weak effect of location in our findings may be explained partly by the indicator "regional knowledge sourcing", which already captures positive effects of regional networks.

6) Conclusions

This paper has investigated the pattern and mechanisms of knowledge sourcing as well as the role and importance of geography in relation to knowledge sourcing and the innovation performance of firms in the ICT sector. The empirical study of 110 companies in three Austrian regions has demonstrated that both regional and international knowledge sources are frequently used by companies, whereas national sources have been used to a lesser extent. Furthermore, the variety of knowledge sources used at regional and international levels has shown a significant positive effect on the innovativeness of companies. In particular, knowledge from R&D institutes and universities is sourced more often within the region compared to knowledge from clients and suppliers. Geographic proximity, thus, seems to matter particularly for the transfer of more complex technological knowledge since it facilitates interactive learning through the ease of face-to-face meetings and by promoting other forms of proximity such as social and cultural proximity. The geographic distance to international knowledge providers, which are often suppliers and customers along the value chain, seems to be overcome through relational and cognitive proximity. These results confirm the propositions developed in the theoretical section of this paper. Knowledge sourcing at the national level, however, seems to have little benefits for innovation performance. This might to some extent be due to the small size of the country limiting the potential of relevant knowledge sources. The national level hardly suffices to identify key market- and technology-trends in the industry, and it allows to accesses only a small fraction of the relevant knowledge in related fields..

The study of the Austrian ICT sector also underlines the importance in particular of R&D cooperations for the innovativeness of firms. R&D cooperations implicate ongoing and interactive learning processes between the involved firms and organisations. Firms in our sample utilise interactive knowledge transfer mechanisms such as R&D cooperations and informal contacts frequently – but not exclusively - at the regional level. The study also finds evidence for the argument that firms with both strong in-house knowledge and a certain variety in external knowledge sources tend to be more innovative. In-house knowledge seems to enable and facilitate the acquisition of knowledge from external sources and it seems to increase the ability to use this knowledge for advancing innovations.

Finally, our analysis has demonstrated that the characteristics of regional innovation systems are influencing the pattern of knowledge sourcing and the innovation performance of firms. We found that companies in Vienna, representing the" thickest" RIS in Austria, rely more on knowledge sources from the region, in particular universities and suppliers, whereas those in Salzburg, a "thin" RIS, are receiving innovation relevant knowledge clearly more from international sources along the value chain, i.e. customers and suppliers. As regards the impact of the firms' location on innovativeness we found - as expected - that companies located in Vienna tend to be more innovative. The observed effects, however, seem to be rather weak. This might be due to the potential representation of "location" effects through regional knowledge sourcing, which has turned out to strengthen the innovation capacities of firms as stated above.

Geography, thus, has both direct and indirect effects on the innovation performance of firms: Whereas the direct effect of the companies' location on innovativeness has turned out to be rather weak in our study, the indirect effect via the pattern of knowledge sourcing seems to be stronger. This implies that companies can improve their innovation performance by drawing on knowledge sources from the region and beyond, and by "fine-tuning" knowledge links effectively to their internal knowledge base and to the respective type of RIS. In order to effectively use and apply external knowledge, companies, however, have to develop also their internal knowledge and innovation capabilities.

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Table 7: Technological knowledge: Geography of knowledge links (% of total)

	Vienna (N=177=100%)				Salzburg (N=60=100%)				Upper Austria (N=181=100%)			
	Regional	National	International	Total	Regional	National	International	Total	Regional	National	International	Total
Suppliers	12,4	2,8	10,7	26	8,3	11,7	13,3	33,3	6,1	14,9	13,8	34,8
Customers	5,1	0,6	11,9	17,5	1,7	5	16,7	23,3	1,7	3,9	3,3	8,8
Firms of the same sector	1,7	3,4	4	9	3,3	1,7	6,7	11,7	2,8	2,8	6,1	11,6
Firms of diff. sectors	3,4	2,8	2,8	9	1,7	1,7	0	3,3	2,2	2,2	2,2	6,6
Universities and technical colleges	13,6	9,6	2,8	26	8,3	5	1,7	15	22,1	3,9	2,2	28,2
Research institutes	4	2,8	0,6	7,3	1,7	0	0	1,7	2,2	0,6	0	2,8
Others sources	1,1	3,4	0,6	5,1	6,7	0	5	11,7	5	1,1	1,1	7,2
Total	41,2	25,4	33,3	100	31,7	25	43,3	100	42	29,3	28,7	100
Number of links	73	45	59	177	19	15	26	60	76	53	52	181

Table 8: Technological knowledge: Importance of knowledge transfer channels (% of total)

	Vienna				Salzburg				Upper Austria			
	Contacts to partners in …				Contacts to partners in …				Contacts to partners in …			
	Regional	National	International	Total	Regional	National	International	Total	Regional	National	International	Total
Number of channels	155	85	140	380	31	24	50	105	204	140	158	502
Contract research	7,1	3,9	5,3	16,3	8,6	4,8	10,5	23,8	5	5,2	4	14,1
Licences, machinery, software	2,9	1,3	3,2	7,4	3,8	3,8	3,8	11,4	1,8	4,4	5,4	11,6
R&D cooperation	10,5	7,4	4,2	22,1	6,7	5,7	8,6	21,0	7,8	4,4	3,8	15,9
Informal contacts	13,2	4,5	10,0	27,6	2,9	6,7	6,7	16,2	9,8	5,2	7,4	22,3
Employment of specialist	2,1	3,7	1,8	7,6	1,9	0,0	0,0	1,9	8,8	1,6	1	11,4
Monitoring of competitors	0,5	0,3	4,5	5,3	1,9	0,0	5,7	7,6	2,4	1,4	3	6,8
Conferences, fairs	3,9	0,5	6,3	10,8	1,9	1,9	7,6	11,4	2,4	3	3	8,4
Academic journals, magazines	0,5	0,8	1,6	2,9	1,9	0,0	4,8	6,7	2,8	2,8	4	9,6
Total	40,8	22,4	36,8	100	29,5	22,9	47,6	100	40,6	27,9	31,5	100

Table 9: Chi-Square test for significance of knowledge sourcing patterns

Value Chain									
	Actual Values				Expected Values				Chi-Square Test p-value
	Regional	National	International	Total	Regional	National	International	Total	
Vienna	64	23	68	155	48	46	62	155	
Salzburg	11	22	36	69	21	20	27	69	
Upper Austria	47	73	54	174	53	52	69	174	
Total	122	118	158	398	122	118	158	398	**0,000**
Other companies									
	Actual Values				Expected Values				Chi-Square Test p-value
	Regional	National	International	Total	Regional	National	International	Total	
Vienna	17	20	41	78	18	19	41	78	
Salzburg	6	6	13	25	6	6	13	25	
Upper Austria	15	14	33	62	14	15	33	62	
Total	38	40	87	165	38	40	87	165	0,993
Knowledge generating institutions									
	Actual Values				Expected Values				Chi-Square Test p-value
	Regional	National	International	Total	Regional	National	International	Total	
Vienna	36	22	9	67	44	15	8	67	
Salzburg	10	5	3	18	12	4	2	18	
Upper Austria	53	8	6	67	44	15	8	67	
Total	99	35	18	152	99	35	18	152	**0,025**