Innovation and Knowledge Sourcing in the Vienna ICT Manufacturing Sector *
Zaisťovanie zdrojov inovácií a vedomostí v spracovateľskom sektore informačných a komunikačných technológií vo Viedni

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Abstract

The aim of this paper is to investigate the nature and geography of innovation and knowledge sourcing activities in the ICT manufacturing sector in the region of Vienna. Vienna is often regarded as a prime example of a fragmented metropolitan regional innovation system. Fragmented regional innovation systems are characterised by a strong endowment with knowledge infrastructure elements and other innovation relevant institutions, but they suffer from a lack of local networking and knowledge circulation. In this paper we examine for Vienna whether this key deficiency of the regional innovation system, i.e. fragmentation, is also a crucial feature of knowledge based sectors such as the ICT manufacturing industry which exhibit an analytical knowledge base. Drawing on 18 face-to-face interviews with firms and an analysis of 207 knowledge links and 264 knowledge transfer channels we will show that local collective learning processes are vital for innovative companies in the Vienna ICT manufacturing sector, whilst at the same time they rely heavily on international knowledge sources. The significance of the local level as interaction space for knowledge exchange found in the ICT manufacturing sector indicates that at least for this knowledge based industry, Vienna's innovation system is of a less fragmented nature than previous studies have suggested. Knowledge based sectors are characterised by a high level of localised knowledge circulation which underpins radical innovation.

Key words: ICT sector, manufacturing, fragmented regional innovation systems,

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fragmentation

Abstrakt

Cieľom tohto článku je preskúmať povahu a rozmiestnenie inovácií a aktivít zdrojov informácií v IKT sektore spracovateľského priemyslu v regióne Viedeň. Viedeň je často považovaná za najlepší príklad fragmentovaného metropolitného regionálneho inovačného systému. Fragmentované regionálne inovačné systémy sú charakterizované ako silne dotačné s prvkami znalostnej infraštruktúry a ostatnými inovačnými inštitúciami, ale trpia nedostatkom miestnych sietí a prenosu poznatkov. V tomto článku preskúmame Viedeň, či táto kľúčová neefektívnosť regionálneho inovačného systému, t.j. fragmentácia, je tiež rozhodujúcim prvkom odvetvia založeného na vedomostiach ako napríklad IKT sektor, ktorý je založený na analytických poznatkoch. Načrtnutím na 18tich osobných rozhovoroch s firmami a analýze 207 vedomostných liniek a 264 transferových kanálov ukážeme, že kolektívne procesy učenia sú životne dôležité pre inovatívne spoločnosti viedenského IKT sektora, zatiaľ čo sa v rovnakom čase spolieha na medzinárodné zdroje poznatkov. Význam miestnej úrovne ako priestoru pre interakciu výmeny poznatkov nájdený v IKT sektore naznačuje, že aspoň pre tento sektor založený na vedomostiach, viedenský inovačný systém nie je tak fragmentovaný ako naznačovali predchádzajúce štúdie. Sektory založené na vedomostiach sú charakterizované vysokou úrovňou lokalizovaného obehu znalosti, ktorý je základom pre radikálne inovácie.

Kľúčové slová: *IKT sektor, spracovateľský priemysel, fragmentované regionálne inovačné systémy, fragmentácia*

Introduction

The key aim of this paper is to examine the nature and spatial dimension of innovation and knowledge sourcing activities in the ICT manufacturing sector in the region of Vienna. Vienna is often regarded as a prime example of a fragmented metropolitan regional innovation system (Tödtling and Trippl 2005). Fragmented regional innovation systems are characterised by a strong endowment with knowledge infrastructure elements and other innovation-relevant institutions, but they suffer from a lack of local networking and knowledge circulation. In this paper we investigate for Vienna whether this general pattern, or more precisely, this key deficiency of the regional innovation system, i.e. fragmentation, is also a crucial feature of knowledge based sectors such as the ICT manufacturing industry. More specifically, we will deal with the following research questions:

- What is the nature of innovation activities in the ICT manufacturing sector in the region of Vienna and which types of innovation are most relevant?

- Which knowledge sources play a key role during the innovation process and what is their spatial pattern? Do they provide rather similar or complementary knowledge? What are the main differences between market knowledge and technological knowledge with respect to these dimensions?

- How relevant are different mechanisms of technological knowledge transfer at various spatial scales and which mechanisms are used to get access to different sources of technological knowledge?

The remainder of the paper is organised as follows. Section 2 provides the conceptual background and briefly reviews the relevant literature. Section 3 covers the empirical part of the paper. We present the main results of face-to-face interviews with representatives of 18 ICT manufacturing firms in the region of Vienna. Finally, in Section 4 we summarise the key findings and draw some conclusions.

Theoretical concepts and literature review

There is a widespread consensus among scholars that innovation is becoming an increasingly complex phenomenon, differing strongly between sectors (Pavitt 1984; Storper 1997; Malerba 2005) and depending heavily on a variety of knowledge interactions between different actors at various spatial scales (Smith 2000).

Knowledge generation and innovation in the ICT sector: the role of an analytical knowledge base

Recently, the concept of "knowledge bases" has been introduced to give due emphasis on sectoral innovation differences (Laestadius 1998; Asheim and Gertler 2005; Tödtling et al 2006). The key argument brought forward by the protagonists of this concept is that innovation processes in industries are strongly shaped by their specific knowledge base. In this context, a distinction is drawn between 'analytical', 'synthetic' and 'symbolic' types of knowledge base. These imply different combinations of tacit and codified knowledge, different knowledge sources and knowledge interactions, as well as types of innovation. According to the proponents of the knowledge base concept the ICT sector exhibits an analytical knowledge base. In the following the key features of this type of knowledge base will be described in detail (for a discussion of the main characteristics of synthetic and symbolic knowledge bases,see, for instance, Asheim and Gertler 2005).

Table 1: Key features of an analytical knowledge base

Analytical knowledge base
Knowledge based sectors (e.g., biotechnology, ICT)
- dominance of codified knowledge, complementary role of tacit knowledge
- appliance of scientific principles and methods - Systematic basic and applied research; formal organisation of the knowledge generating process (e.g. in R&D departments), documentation of results
- High importance of scientific inputs of universities and other research organisations - "Learning by exploring", university-industry partnerships
- Radical innovation

Source: Own

Table 1 gives an overview on the crucial features of an analytical knowledge base, which is typical for knowledge based sectors such as biotechnology, ICT or nanotechnology. In industries drawing on an analytical knowledge base scientific knowledge and access to the sources producing this type of knowledge is crucial. Knowledge generation is more often based on cognitive and rational processes, analytical techniques or formal models. Basic and applied research as well as systematic development of technologies is among the core activities of firms. Companies, therefore, typically have their own R&D departments, but they also rely on the research results of universities and other research organisations to bring forward innovations. University-industry links and networks to science, as well as academic spin-offs are in most cases a common feature of industries which exhibit an analytical knowledge base. Knowledge inputs and outputs are often codified, but tacit knowledge is needed in order to interpret, understand and work with codified knowledge in an appropriate way (Nonaka et al. 2000, Johnson and Lundvall 2001). There are several reasons for the importance of codification. Firstly, knowledge generation is based on reviews of existing studies and the application of scientific principles and methods. Secondly, knowledge processes are rather formally organised (e.g. in R&D departments) and outcomes tend to be documented in scientific papers, reports, electronic files or patent descriptions. These activities require specific capabilities such as analytical skills, abstraction, theory building and testing, and documentation. The workforce, therefore, needs university training or research experience to a great extent. Scientific discoveries and technological inventions are the aims of R&D activities which may lead to patents and licensing activities. New products or processes in such industries tend to be of a more radical type than in the other knowledge bases. They may give rise to technology-based start-ups and spin-off companies, which are frequently supported by universities and other incubators.

To summarise, for the ICT sector we can expect to find a high propensity towards knowledge exchange with universities and other research organisations in order to introduce radically new products. Whilst the concept of knowledge bases has considerably enhanced our understanding of the nature of innovation and the main knowledge sources in different industries, until now little has been said about the geography of knowledge interactions and no distinction has been drawn between market knowledge and technological knowledge within this concept[1].

1 For a differentiation between market and technological knowledge in innovation networks, see Boschma and Ter Wal (2007)

Nature and geography of knowledge linkages

In another stream of literature, however, the relevance of knowledge interactions for successful innovation processes has been intensely discussed in the past years (see, for instance, Keeble 2000), drawing special attention to the nature and geography of knowledge linkages (Gertler and Wolfe 2005; Tödtling et al. 2006; Tödtling and Trippl 2007). In the last decade, a considerable body of literature has emerged, arguing that localized flows of know-how and expertise are of key significance for the innovation capacity and competitive strength of clusters and regions (see, for instance, Porter 2000; Malmberg and Maskell 2002). There seems to be a growing consensus among many scholars, however, that not only local knowledge circulation fuels innovations but that interactions with international knowledge providers also play a central role (Bunnel and Coe 2001; Amin and Cohendet 2004; Lagendijk and Oinas 2005), enabling firms to gain access to expertise not generated and available within the limited context of the region.

More specifically, it is often argued that the interplay between local and global knowledge flows is vital during the innovation process (Gertler and Levitte 2005; Cooke et al. 2007). Already Camagni (1991) in his theoretical work on innovative milieus pointed to the complementary character and interrelatedness of local knowledge exchange, mainly informal in nature, and formal global networks. More recently, Bathelt et al. (2004) proposed the concept of "local buzz and global pipelines" to highlight that innovation in clusters rests on both myriad informal linkages at the local level and more formal knowledge interactions with distant sources and partners.

Tödtling et al. (2006) have suggested a more differentiated typology of knowledge interactions that rests on two dimensions (Figure 1). The first dimension distinguishes between traded and untraded interdependencies in the innovation process (Storper 1997). In traded and formal relations there are monetary or other forms of compensation for particular knowledge flows, whereas in non-traded and informal relations there is no specific immediate compensation. The second dimension refers to the static versus dynamic aspects of knowledge exchange (Capello 1999). Static knowledge exchange here refers to the transfer of 'ready' pieces of information or knowledge from one actor to the other. Dynamic knowledge exchange refers to a situation, where there is interactive learning among actors through, e.g., co-operation or other joint activities (Lundvall 1992, Camagni 1991). In this case the collective stock of knowledge is increased through the interaction. Based on these two distinctions we can identify four types of knowledge links, including market relations, co-operations or formal networks, externalities / spillovers, and milieu / informal networks.

	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, confer-ences - reading of scientific literature, patent specifications	*milieu / informal networks* - informal contacts

Figure 1: Types of linkages to external knowledge sources and partners
Source: Tödtling et al. 2006

In Figure 1 important examples for these different types of knowledge interactions are shown. Regarding the spatial dimension of these knowledge linkages, it can be hypothesized that market relations and formal networks might be mainly found at the global level, whilst spillover and milieu effects might be mainly local in nature.

In the following we will examine whether the specific pattern of innovation (i.e. a high importance of radical innovation and knowledge interactions with universities

as it is suggested by the work on knowledge bases) and of the spatial dimension of knowledge exchange (i.e. a combination of local informal links and global formal networks as it is proposed by the literature on local buzz and global pipelines) can also be found in the Vienna ICT manufacturing sector. Vienna is usually regarded to be a case in point for a fragmented metropolitan innovation system (for a typology of different types of regional innovation systems and for a detailed description of their main characteristics, see Tödtling and Trippl 2005). This type of regional innovation system is often characterised by the presence of excellent knowledge infrastructure elements (such as universities, educational institutions, knowledge transfer agencies, etc.) and other innovation-relevant institutions. However, the problem of fragmentation, i.e. the lack of networks and interactive learning seems to represent an important innovation barrier in such regions. The two RIS subsystems of knowledge generation and application tend to operate separately, as university-firm links are often at a low level. Also, innovation networking among local companies may be weak.
The key question to be dealt with in the following is whether this general feature of Vienna's innovation system (i.e. the lack of local knowledge circulation, which reflects the fragmented structure of the system) can also be found in knowledge based sectors exhibiting an analytical knowledge base such as the ICT manufacturing sector.

Innovation and knowledge links in the Vienna ICT manufacturing sector

Fragmented metropolitan regional innovation system of Vienna

Vienna has been regarded to be a prime example of a fragmented metropolitan regional innovation system (Tödtling 2002; Tödtling and Trippl 2005). As many other metropolitan regions Vienna has an excellent knowledge infrastructure, reflecting its undisputed role as scientific and educational centre of Austria. Furthermore, many specialised institutions supporting innovation activities of firms and promoting the commercialisation of academic knowledge have been established in the past years. Whilst the region is well endowed with innovation relevant institutions, the interaction between the different elements of the regional innovation system seems to be rather weak (Tödtling 2002; Fritsch 2004). The innovation system, thus, suffers from fragmentation, brought about by low degrees of localised knowledge flows and innovative networking.

Looking specifically at the ICT sector reveals that Vienna is very well endowed with innovation relevant institutions, exhibiting specialised structures in this field. First, in Vienna there is a strong presence of knowledge generating organisations. Academic key actors in the field of ICT include the Technical University of Vienna (faculty of electrical engineering and information technology), the University of Vienna (faculty of computer sciences), and the Medical University of Vienna (Section of Medical Computer Vision, and excellence centre telemedicine). Among the non-academic research institutes we find the Austrian Research Institute for Artificial Intelligence (OFAI) of the Austrian Society for Cybernetic Studies (OSGK) and Seibersdorf Research (medical informatics). Furthermore, there are several co-operative research institutes located in the region of Vienna, including four CD Labs and four competence centres. The universities mentioned above are also the key institutions of higher education in the field of ICT. In the last years several technical colleges have been founded leading to a further differentiation of the regional innovation system. We find ten degree programmes in the fields of software and informatics and seven in the areas of electronics, communication systems, and automation seven degree. To summarise, the region's ICT research capacity and its capabilities to provide highly qualified workers and talent and to transfer knowledge are rather strong. Other relevant organisations include an academic spin-off centre with a special focus on ICT, several technology liaison offices, and two ICT technology centres. An analysis of the subsystem of knowledge application and exploitation shows that Vienna is the core centre of commercialising ICT knowledge in Austria. In 2001 about 6000 ICT plants were located in Vienna, representing more than 30 % of all Austrian ICT plants[2]. These plants hold about 80.000 employees (25 % of

2 These data are from the firm census from the year 2001, the most recent ones which are available at 4 digit level.

the Austrian total), indicating a very strong concentration of different ICT activities in Vienna. Finally, looking at the regional policy dimension we can observe cluster policies for ICT, funding initiatives for innovation projects of single ICT firms ("Calls") and measures to strengthen the region's scientific ICT capacity. A recent study, however, has shown that institutional networking between the various policy actors and supporting organisations is still in its infancy (Trippl et al. 2007a).

In the following we will explore empirically whether fragmentation, i.e. the lack of local knowledge circulation, of innovation networking among firms and between firms and universities, is a key feature of the Vienna ICT manufacturing sector.

Innovation and knowledge links in the Vienna ICT manufacturing sector

Methodology

The empirical analysis is based on 18 face-to-face interviews with firms from the ICT manufacturing sector in Vienna, conducted in the context of the CRA project[3] in April and May 2008. The ICT manufacturing industries consist of the following subsectors: NACE 30 manufacture of office machinery and computers, 321 manufacture of electronic valves and tubes and other electronic components, 322 manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy, 323 manufacture of television and radio receivers, sound or video recording or reproducing apparatus and associated goods, 332 manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment, and 333 manufacture of industrial process control equipment. For our empirical investigation, we decided to exclude very small enterprises with less than four employees. According to the

3 The project "Constructing Regional Advantage" (CRA) is an international research project co-funded by the European Science Foundation and coordinated by Prof. Asheim of Lund University. The other project partners are: Dokuz Eylul University - Department of Economics ,Turkey, University of Utrecht - Faculty of Geosciences/ Department of Economic Geography, Netherlands, Charles University - Faculty of Science, Czech Republic,
University of Agder - Faculty of Economics and Social Science, Norway, University of Tampere -(Department of Regional Studies), Finland, University of Economics and Business Administration -(Institute for the Environment and Regional Development), Austria.

AURELIA database, a reliable source on business information in Austria, there are 35 companies, engaged in the manufacture of ICT products located in Vienna. We tried to interview all of them; 18 very willing to participate in our study, representing 51% of the population. The interviewed firms disclosed 207 knowledge links and 264 knowledge transfer channels. This rich data set allows for a comprehensive analysis of the geography and the mechanisms of knowledge exchange in the subsector.

The interviews were based on a standardized questionnaire, jointly developed within the CRA project, which consisted of three major parts: One dealt with general company features, innovation activities and innovative performance, another one with the company's contacts for gathering and exchanging market and technological knowledge and finally, the third part was dedicated to the evaluation of sector specific policy initiatives supporting innovation. In this paper, we will discuss the results of the first two parts of the questionnaire. For the data analysis we applied methods of descriptive statistics.

Results and Discussion

Table 2 shows that more than 50% of the firms had less than 22,5 employees in the year 2008. The arithmetic mean in terms of employment is much higher as it is distorted by one very big company, Siemens, which employs 7590 people in Vienna. In line with other manufacturing industries in Vienna, employment shrank in the last couple of years. Nevertheless, there is a large share of young enterprises: 50% of the companies were founded between 1998 and 2005.

Table 2: Age and size of Vienna ICT manufacturing firms

	Employees 2008	Employees 2005	Year of Foundation
Mean	526,8	540,7	1978,1
Median	22,5	32,5	1998,0
Minimum	3,0	2,0	1879,0
Maximum	7590,0	7919,0	2005,0

Source: Own

Table 3 shows that technical colleges, which are rather young organisations in Austria (the first technical colleges were founded in 1994), are the most important organisations from which Vienna ICT manufacturing firms hire skilled personnel, followed by firms of the same sector and universities. About 44% of the companies employ people with an academic degree, predominantly engineers.

Table 3: Recruitment

Sources	very important, important
Universities	55,6
Technical Colleges	72,2
Firms of the same sector	61,1
Firms of different sectors	16,7

Source: Own

Among the 18 firms interviewed, the biggest number was made up by companies which produce instruments, appliances and apparatus for measuring and checking. Companies of the NACE sectors 332 and 333 represented about 39% of the firms in the survey. The second biggest subsector in the survey was NACE 30 (manufacture of office machinery and computers), with a share of 22,2% of all the firms questioned.

Table 4: Sectoral Composition

NACE_Code	Frequency	Percent
30	4	22,2
321	1	5,6
322	3	16,7
323	3	16,7
332	6	33,3
333	1	5,6
Total	18	100,0

Source: Own

Looking at the activities the firms perform in the Vienna region, it shows that development and the production of customized products are the most important ones. Over 80 percent of the companies are engaged in these activities. However, the share of companies that produce standardized products in Vienna is surprisingly high (61,1%) for a European metropolitan region. As expected, design and marketing activities also play an important role for the remainder of the Vienna ICT-producing companies.

Table 5: Activities of Vienna ICT-manufacturing companies

Activities	Percent
Customized production	83,3
Standardized production	61,1
Development	88,9
Design	61,1
Marketing	61,1

Source: Own

If we look at the innovation activities in particular (table 6), we can see that all firms claim to have conducted product innovations in the period from 2005 to 2006. More than 80 percent of the companies claim to have developed and commercialized products that were new to the market. While a similarly high share of firms, conducted process innovations the shares of firms, which changed their strategy, their organisational structures and their market concept are considerably lower. Earlier studies on the Vienna ICT sector as whole and on the Vienna software sector (Trippl et al. 2007a, Trippl et al. 2007b) have shown considerably lower propensities towards product innovation. The high inclination of Vienna ICT manufacturing firms toward radical innovations also shows in the turnover statistics: more than 40% of the firms' turnover figures result from the sale of new products, about 27% from the sale slightly changed ones. Less than a third of the average turnover comes from selling older, unchanged products. The importance of radical innovation is also confirmed by the relatively high share of firms (66,7%), which have been granted a patent in the period from 2005 to 2008. Co- patenting, however, is of negligible importance in the case of the Viennese ICT producing industries. Again, the average number of patents is severely distorted by the only big player in Vienna, the Siemens corporation. The median shows, that half of the firms have been granted less than two patents between 2005 and 2008. In the period of investigation Siemens alone has been granted about 600 patents. The dominance of Siemens also shines through when we look at R&D employment.

Table 6: Innovation activities

Percentage of firms engaged in the following activities (2005-2006)	
Product Innovation	100,0
Product Innovation- new to market	83,3
Process Innovation	88,8
New/ significantly changed strategy	55,5
New/ significantly changed organisational structures	50,0
New/ significantly changed market concept	61,1
Average share of turnover with:	
New products	41,7
Slightly changed products	26,9
Unchanged products	31,4
Patents (2005-2008)	
Percentage of firms that have been granted a patent	66,7
Percentage of firms that have been granted a co-patent	5,6
Average number of patents	37,4
Median number of patents	1,5
R&D Employees	
Share of firms with an R&D department	44,4
Average number of R&D employees	185,5
Median number of R&D employees	7,5

Source: Own

As noted earlier, when analysing the company's knowledge links we asked the companies to differentiate between contacts important for the exchange of market-related knowledge and contacts important for technological knowledge, expecting differences regarding the sources and channels for the exchange of market and technological of knowledge. Table 7 shows the importance of different knowledge sources for gathering and exchanging technological knowledge and market knowledge. The pattern of knowledge interactions differs to a great extent between technological and market related knowledge. Concerning technological knowledge, we found contacts to universities, research institutes and customers are most frequent. However, firms evaluate technology related contacts to firms of the same sector as the most important ones. University contacts and contacts to research institutes are clearly considered to be less important. Another surprising result is the fact, that it is not the exchange of complementary knowledge that seems to be most highly regarded. On the contrary, firms especially seem to appreciate knowledge exchange with partners, who obtain a similar type of knowledge. Technological contacts with partners who share a common background and understanding seems to be more important than the combination of different sectoral or organisational backgrounds. Especially firms seem to have reservations or difficulties to gather and apply scientific knowledge.

Table 7: Number and importance of different knowledge sources

	Customers	Suppliers	Firms of the same sector	Firms of different sectors	Universi-ties	Research Institutes	others
Technological Knowledge	-	-	-	-	-	-	-
Number of firms with con-tacts to…	9	8	6	6	10	9	4
Percentage of firms with con-tacts to…	50,00%	44,44%	33,33%	33,33%	55,56%	50,00%	22,22%
Number of contacts	29	20	9	11	32	13	6
Average im-portance of contacts	1,69	2,06	1,33	1,75	2,39	2,89	1,63
Average simi-larity of knowl-edge exchanged	2,66	3,03	3,83	3,17	2,8	2,98	3,25
Market Knowl-edge							
Number of firms with con-tacts to…	13	3	4	8	2	1	2

Percentage of firms with contacts to…	72,22%	16,67%	22,22%	44,44%	11,11%	5,56%	11,11%
Number of contacts	44	3	7	23	5	1	4
Average importance of contacts	1,7	2	2,25	2,33	1,33	2	1
Average similarity of knowledge exchanged	2,38	1	3,67	2,79	4	1	3,34

Source: Own

If we look at knowledge interactions for market knowledge, we see that customers by far prove to be the most important knowledge source. More than 70% of the firms rely on customers to find out about new market trends. On average these contacts are perceived to be very important. While contact to firms of other sectors also seems to be valuable in this regard, knowledge exchange on market issues between firms and universities and research institutes is insignificant.[4]

In comparison, Trippl et al. (2007a) and Trippl et al. (2007b) found that in the case of the Vienna ICT sector as a whole and for the software sector in particular, the importance of contacts to competitors and especially to customers is considerably higher, whereas university links seem to be less frequent. However, in these studies, we did not differentiate between market knowledge and technological knowledge.

Table 8 also suggests that knowledge interactions concerning technological and market related issues show different patterns. Whereas for both types of knowledge conferences and fairs are most important, magazines and academic journals play a much bigger role for gathering technological knowledge. Unsurprisingly market studies, are rarely used to get technological input.

4 The "Siemens" effect mentioned above does not distort the results of the analysis of knowledge interactions because the company only revealed the most important contacts.

Table 8: Importance of different sources of information

	Market Knowledge	Technological Knowledge
	Important; very important (%)	Important; very important (%)
Conferences, fairs	66,7	64,7
Magazines	44,4	70,6
Markets surveys	33,3	17,6
Academic journals	22,2	35,3

Source: Own

Tables and 9 and 10 highlight the geography of knowledge links and show the differences between technological and market related knowledge exchange. For the exchange of market knowledge the international level is the most important space of interaction; 46% of all market related knowledge sources are to be found abroad. This is particularly obvious for contacts with universities, competitors and firms of other sectors. Vienna is the second most important region: about a third of the knowledge sources for market knowledge are located in this region. At the regional level contacts to customers, to universities technical colleges and research institutes are of the biggest relative importance. Knowledge exchange at the national level is of less importance, although contacts to suppliers are predominately found at this level.

Table 9: Geography of knowledge links (% of knowledge sources)

	Market knowledge (87)			Technological knowledge (120)		
	Vienna	Austria	Interna-tional	Vienna	Austria	International
Number of links	29	18	40	53	31	36
Suppliers	0,0	66,7	33,3	55,0	15,0	30,0
Customers	43,2	15,9	40,9	31,0	3,4	65,5
Firms of the same sector	14,3	28,6	57,1	33,3	44,4	22,2
Firms of different sectors	26,1	21,7	52,2	45,5	36,4	18,2
Universities and technical colleges	40,0	0,0	60,0	53,1	31,3	15,6
Research institutes	100,0	0,0	0,0	53,8	38,5	7,7
Others sources	0,0	50,0	50,0	16,7	66,7	16,7
Total	33,3	20,7	46,0	44,2	25,8	30,0

Source: Own

Table 10: Geography of knowledge links (% of spatial level)

	Market knowledge (87)			Technological knowledge (120)		
	Vienna	Austria	Interna-tional	Vienna	Austria	International
Number of links	29	18	40	53	31	36
Suppliers	0,0	11,1	2,5	20,8	9,7	16,7
Customers	65,5	38,9	45,0	17,0	3,2	52,8
Firms of the same sector	3,4	11,1	10,0	5,7	12,9	5,6
Firms of different sectors	20,7	27,8	30,0	9,4	12,9	5,6
Universities and tech-nical colleges	6,9	0,0	7,5	32,1	32,3	13,9
Research institutes	3,4	0,0	0,0	13,2	16,1	2,8
Others sources	0,0	11,1	5,0	1,9	12,9	2,8
Total	100,0	100,0	100,0	100,0	100,0	100,0

Source: Own

For the exchange of technological knowledge the regional level is most important; 44,2% percent of the contacts are to be found here. The second most important level is the international level with 30% of the contacts followed by the national level with 25,8% of the contacts. At the regional level contacts to universities, technical colleges, research institutes and to suppliers are most important. At the international level contacts to customers clearly dominate which shows that Vienna ICT manufacturing firms focus strongly on international markets. At the national level technology contacts to universities, technical colleges and research institutes are important. Moreover, technology contacts to other firms to a large extent take place at the national level. Analysing the Vienna ICT sector as a whole and the Vienna software sector we found, without distinguishing between market knowledge and technological knowledge a much clearer dominance of local knowledge interactions. Even contacts to customers and competitors were predominantly local (Trippl et al. 2007a, 2007b).

Table 11 confirms that differences in the geographical pattern of sources for technological knowledge and market knowledge are statistically significant.

Table 11: Geography of knowledge links

		Vienna	Austria	International	Total
Market Knowledge	Number of links	29	18	40	87
	% of knowledge type	33,3	20,7	46,0	100
	% of spatial level	35,4	36,7	52,6	42,0
Technological Knowledge	N umber of links	53	31	36	120
	% of knowledge type	44,2	25,8	30,0	100
	% of spatial level	64,6	63,3	47,4	58,0
Total	Number of links	82	49	76	207
	% of knowledge type	39,6	23,7	36,7	100
	% of spatial level	100	100	100	100

Chi-Square	5,564
Sig.	0,06
Cramer-V	0,163

Source: Own

As shown in table 12, analysing only the contacts to companies - with available industry codification (NACE codes) - we found a majority of contacts to partners outside the ICT sector[5], but still a relatively high share of contacts with ICT firms. 21,7% of the contacts were held with other ICT manufacturing firms and 20,9% with ICT service firms.

Table 12: Company contacts: Sectoral composition

	Total	%
ICT sector (OECD)		
ICT manufacturing	27	21,77%
ICT services	26	20,97%
Other sectors	71	57,26%
Total	124	100,00%

Source: Own

5 According to OECD classification.

For technology related knowledge interactions we tried to further analyse various mechanisms of knowledge exchange. Table 13 shows the relative importance of different mechanisms. The most frequent mechanisms for exchanging technological knowledge are informal contacts and formalized R&D cooperation. Milieu effects and formalized networks seem to be of the biggest relative importance in the Vienna ICT manufacturing sector. However, market relations (contract research) also are frequent ways to gather new knowledge, whereas knowledge spillovers seem to be of less importance. This is in sharp contrast to earlier findings (Trippl et al 2007a, 2007b), which have shown for software firms and the Vienna ICT sector as a whole a big importance of knowledge spillovers, especially via labour mobility, reading of journals and magazines and monitoring of competitors and an even stronger impact of milieu effects. Formal networks, however, are considerably less important in the Vienna software sector and the ICT sector in general.

Table 13: Technological knowledge: Knowledge transfer channels

	Number	Percent
Contract research	47	17,8
Licences, machinery, software	19	7,2
R&D cooperation	66	25,0
Informal contacts	77	29,2
Employment of specialists	16	6,1
Monitoring of competitors	15	5,7
Conferences, fairs	21	8,0
Academic journals, magazines	3	1,2
Total	264	100,0

Source: Own

Table 14 gives an overview of the geography of knowledge transfer channels. Looking at the individual mechanisms of knowledge exchange it shows that in the Vienna region contract research, R&D cooperation and informal contacts are of particular relative importance. This is also the case for contacts held at the national level, which is also important as a labour market. As expected, competitors are predominantly monitored at the international level. More surprising however, is the finding that also informal contacts are said to be mainly held globally, whereas international formalized networks seem to be of less importance. This finding contradicts the local buzz and global pipelines hypothesis.

Table 14: Technological knowledge: Importance of knowledge transfer channels (% of spatial levels)

	Contacts to partners in ...		
	Vienna	Austria	International
Number of channels	118	60	86
Contract research	19,5	15,0	17,4
Licences, machinery, software	9,3	6,7	4,7
R&D cooperation	28,0	35,0	14,0
Informal contacts	28,0	21,7	36,0
Employment of specialist	5,9	13,3	1,2
Monitoring of competitors	1,7	1,7	14,0
Conferences, fairs	7,6	1,7	12,8
Academic journals, magazines	0,0	4,9	0,0
Total	100,0	100,0	100,0

Source: Own

In table 15 we summarize the individual knowledge transfer channels in the four categories introduced in the theoretical part of this paper and tested for each individual category whether the geographical pattern is significant. It shows that milieu effects, formal networks and spillovers are characterized by geographies that significantly differ from the distribution of knowledge sources in general. The strength of the relationships however is rather weak, as the Cramer-V test confirms. Market relations and formal networks seem to be strongly localized in our sample; spillovers rather occur at the international level. Surprisingly, milieu effects are almost as important at the international as at the local level.

Table 15: Crosstab: Geography of knowledge transfer channels (% of channel classification)

	Contacts to partners in ...						
	Vienna	Austria	International	Total	Chi-Square	Sig.	Cramer-V
Market relations	51,7	20	28,3	100	3,22	0,2	0,164
Spillovers	34	24	42	100	6,232	0,044	0,228
Formal Networks	50	31,8	18,2	100	9,99	0,007	0,289
Informal Networks	42,9	16,9	40,3	100	14,286	0,001	0,345
Total	44,2	25,8	30	100			

Source: Own

Table 16 shows in what ways the firms make use of different knowledge sources. Not surprisingly suppliers are mainly needed for the purchase of licenses, machinery and software. However, informal technology related contacts are also frequent. Contacts with customers are also frequently of informal nature. Quite often Vienna ICT firms also engage in R&D cooperation with customers or subcontract specific research tasks. In the case of firms of the same sector informal contacts and R&D cooperation dominate. The latter are also important knowledge transfer channels between Vienna ICT firms and companies of other sectors. Contacts with universities, technical colleges and research institutes are predominately formal R&D cooperation. Moreover theses institutions are frequently used for recruiting skilled personnel.

Table 16: Technological knowledge: Knowledge sources and knowledge transfer channels (% of knowledge sources)

	Number	Contract research	Licences, machinery, software	R&D cooperation	Informal contacts	Employment of specialists	Monitoring of competitors	Conferences, fairs	Academic journals, magazines
Suppliers	20	40,0	70,0	25,0	70,0	0,0	0,0	20,0	5,0
Customers	29	62,1	3,4	41,4	89,7	3,4	34,5	34,5	0,0
Firms of the same sector	7	28,6	14,3	57,1	100,0	0,0	28,6	42,9	0,0
Firms of different sectors	11	36,4	0,0	45,5	18,2	0,0	18,2	18,2	0,0
Universities and technical colleges	32	28,1	0,0	81,3	65,6	34,4	0,0	0,0	0,0
Research institutes	13	30,8	15,4	67,9	46,2	30,8	7,7	7,7	7,7

Source: Own

Table 17 shows the column percentages. Contract research is mainly related to contact with customers, the purchase of machinery to suppliers. R&D cooperation are most frequently held with universities and technical colleges. These organisations are also the most important sources for hiring skilled personnel. While conferences and fairs mostly seem to serve as an opportunity to get in contact with customers, informal contacts are important mechanisms of knowledge exchange with many different knowledge sources. As table 19 confirms, these differentiated patterns of knowledge sources and knowledge transfer channels are not just accidental, but statistically significant.

Table 17: Technological knowledge: Knowledge sources and knowledge transfer channels (% of knowledge transfer channels)

	Contract research	Licences, machinery, software	R&D cooperation	Informal contacts	Employment of specialists	Monitoring of competitors	Conferences, fairs	Academic journals, magazines
Suppliers	17,8	77,8	8,1	18,4	0,0	0,0	20,0	50,0
Customers	40,0	5,6	19,4	34,2	6,3	66,7	50,0	0,0
Firms of the same sector	4,4	5,6	6,5	9,2	0,0	13,3	15,0	0,0
Firms of different sectors	8,9	0,0	8,1	2,6	0,0	13,3	10,0	0,0
Universities and technical colleges	20,0	0,0	41,9	27,6	68,8	0,0	0,0	0,0
Research institutes	8,9	11,1	16,1	7,9	25,0	6,7	5,0	50,0

Source: Own

Table 18: Technological Knowledge: Types of knowledge transfer channels and knowledge sources (% of knowledge transfer channels)

	Suppliers	Customers	Firms of the same sector	Firms of different sectors	Universities and Technical colleges	Research Institutes	Total	Chi-Quadrat	Sig.	Cramer-V
Market relations	29,3	32,8	5,2	6,9	15,5	10,3	100	20,584	0,001	0,425
Spillovers	10,4	39,6	6,3	8,3	22,9	12,5	100	10,226	0,069	0,3
Formal Networks	8,1	19,4	6,5	8,1	41,9	16,1	100	21,623	0,001	0,439
Informal Networks	18,4	34,2	9,2	2,6	27,6	7,9	100	21,61	0,001	0,435
Total	17,5	25,4	7,9	9,6	28,1	11,4	100			

Source: Own

Summary and conclusions

In this paper we explored the nature and spatial dimension of innovation and knowledge sourcing activities in the ICT manufacturing sector in the region of Vienna. Vienna is usually regarded as a prime example of a fragmented metropolitan regional innovation system (Tödtling and Trippl 2005), strongly endowed with innovation relevant organisations but suffering from a lack of local networking and knowledge circulation. Looking specifically at the ICT manufacturing industry, we have examined whether this key deficiency of the regional innovation system, i.e. fragmentation, is also an essential feature of this knowledge based sector located in the region. The literature on sectoral innovation differences has suggested that the ICT industry is based on an analytical knowledge base, showing a high propensity towards knowledge interactions in particular with universities and other research institutes. Furthermore, a review of recent work has shown that knowledge and innovation linkages are characterised by a specific pattern, indicating a coexistence of "local buzz and global pipelines".

Our empirical analysis of the Vienna ICT sector has revealed that innovation seems to be a key competitive strategy for the firms in this industry. We found an outstanding high share of firms which have introduced product innovations, most of them of radical nature. Furthermore, we could also observe process innovation – and to a smaller extent – organisational changes in the sector under investigation. The Vienna ICT manufacturing sector, thus, seems to be highly innovative. The strong inclination towards radical changes provides clear evidence for the existence of an analytical knowledge base. This finding is further substantiated by the high average turnover of new products, the high rate of patenting and the high number of in-house R&D departments.

The firms in the Vienna ICT manufacturing sector make extensive use of external knowledge during the innovation process. However, the number of contacts, the type of contact and the channels through which knowledge is exchanged show remarkable differences, depending on the type of knowledge the entities are exchanging, i.e.

market or technological knowledge. To gain market related knowledge, firms interact mostly with customers and with firms from other sectors while most interaction regarding technological knowledge takes place with universities and customers. Looking at the importance of these contacts for the firms' innovation performance, customers are regarded to be important for both technological and market related knowledge. However, while for technological knowledge important customers are located outside of Austria, important customers for market-related knowledge are located in Vienna as well as outside of Austria. Customers in other Austrian regions play a minor role. Besides customers, local and national firms of the same sector are another important source for technological knowledge exchange while, surprisingly, local and international universities, even though not named very often, are rated as important for market related knowledge.

Looking at the geography of the knowledge links, we found that what is true for the most important knowledge sources can also be shown in general: not only localised contacts are maintained but also interactions with international knowledge providers are sought after. For technological knowledge the local level is the most important one, whereas for market knowledge it is the international level that matters most. Particularly the knowledge sources suppliers, firms from different sectors and knowledge generating organisations can mainly be found in the region. Customers are mainly international, whilst competitors are regional and national. For market knowledge the international level is most important.

Looking at the mode of knowledge exchange it shows that R&D cooperation and informal contacts are the most frequently named channels. This indicates that innovation in the Vienna ICT manufacturing sector is the result of dynamic knowledge exchange, i.e. of interactive or collective learning leading to an increase of the stock of knowledge. Static knowledge transfer, in comparison, plays a minor role. This is in sharp contrast to earlier studies investigating the Vienna ICT sector as a whole and the Vienna software sector (Trippl et al. 2007a, 2007b). For these sectors we found a bigger importance of milieu effects on the one hand and static knowledge transfer on the other, but less evidence for collective learning.

Concerning the geography of knowledge transfer channels we found no support for the "local buzz global pipelines" concept. A far more complex pattern was identified. Informal modes of knowledge transfer are far from being confined to the local level, but characterised by a duality of local-global scales (informal contacts, conferences, fairs) or are even predominantly global (monitoring of competitors). Similarly, formal linkages could not overwhelmingly be found at the global level, but they had also a very strong regional dimension.

The high importance of the local level found in the Vienna ICT manufacturing sector, in fact also apparent in the biotech sector (Tödtling and Trippl 2007; Trippl and Tödtling 2007), shows that even a fragmented regional innovation system can host dynamic knowledge based industries which are characterised by a high level of local collective learning and interactions, whilst at the same time tapping into international knowledge sources.

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