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Published: 01/01/2006

Document Version
Publisher's PDF, also known as Version of record

Institut für Regional- und Umweltwirtschaft
Institute of Regional Development and Environment

WIRTSCHAFTS UNIVERSITÄT WIEN

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SRE-Discussion 2006/01 2006

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Draft version

January 2006

Abstract

The purpose of this paper is to explore the role of public policy in promoting interorganisational knowledge links in the biotechnology sector. Despite the significance of such interactions and the policy efforts devoted to them, there is a limited understanding of how different initiatives from various policy levels contribute to the formation of specific knowledge linkages within the biotechnology industry. The paper identifies four main types of knowledge exchange, including market relations, spillovers, formal co-operations and informal networking. Drawing on evidence from the Vienna biotechnology cluster we intend to show how national and regional policy programmes and government actions function as mechanisms to stimulate the establishment of such interactions.

1 Introduction

Biotechnology is acknowledged to be one of the key sectors of the emerging knowledge economy (Cooke 2002b, OECD 2004). Many studies have shown that government services and programmes are of utmost significance in moving the biotechnology sector forward (Reiss et al. 2003, Lofgren and Benner 2005). The crucial tasks of public policy include amongst others the funding of universities and the R&D system, training and education, support for entrepreneurship, and the commercialisation of science, arrangements to ensure the availability of finance, changes to taxation systems, and intellectual property rights. Policy makers are also key agents for facilitating knowledge sharing and networking in the innovation process. Despite the significance of knowledge links in biotechnology and the policy efforts devoted to them, there is still a limited understanding of how different initiatives from various policy levels contribute to the formation of such ties. In this paper an attempt is made to shed some light on this topic by dealing with the following research questions:

- What is the role of the state in developing the biotechnology industry?
- Which types of knowledge interactions are of importance in the Vienna biotechnology cluster and what is the particular spatiality of these linkages?
- How can different government initiatives and policy levels encourage the formation and functioning of knowledge interactions in this sector?

The structure of this paper is as follows. Section 2 deals with the role of the state for promoting innovation and growth in the biotechnology sector. Then we identify different types of knowledge interactions, distinguishing between market relations, spillovers, formal co-operations and informal networks. In Section 3 the main structuring of the Vienna biotechnology cluster as well as its knowledge links and their particular geography are investigated. Section 4 provides an overview on policy measures that are geared towards the stimulation of various types of knowledge links in this cluster. Finally, Section 5 summarises the main results and draws some conclusions.

2 Theoretical framework and literature review

2.1 Biotechnology policy

In the meantime there exists a large body of work dealing with the role of public policy in nurturing the development of biotechnology. Biotechnology is considered to be critically dependent on state intervention (Cooke 2004a, Lofgren and Benner 2005). As Bagchi-Sen et al. (2004: 201) put it: "This is an industry in which government policy plays an important role in almost every state of research, development, and commercialisation ... the experience from the past two decades shows that stable and supportive federal, as well as state and local, policy environments are necessary for the growth of this industry." A number of studies has demonstrated that even in less interventionist countries such as the USA, the biotech industry is heavily supported by federal and state government programmes and actions (Prevezer 2001, Audretsch 2003, Feldman and Francis 2003, Bagchi-Sen et al. 2004). Also many European countries and regions adopted explicit policies to promote the biotechnology sector (see, for example, Kaiser 2003, Reiss et al. 2003, van Geenhuizen 2003, Cooke 2004a, 2004b, Leibovitz 2004, Lehrer and Asakawa 2004, Eickelpasch and Fritsch 2005).

There is a widespread agreement in the literature that public funding of scientific R&D at universities and other research organisations is crucial for the evolution of the biotech industry (McMillan, Narin and Deeds 2000, Lofgren and Benner 2005). Indeed, a strong research base and the existence of world-class scientific talent constitute the common element in the origins of the firms in biotechnology clusters (Galambos and Sewell 1996). Prevezer (2001) concludes from her analysis of the early development of the U.S. biotech sector that it was the funding of the medical science base rather than of the biotech industry directly that has provided the foundations for start-ups to be created out of the science base. Research activity alone, however, is not enough to ensure the growth of this sector. There must also exist favourable conditions for the commercialisation of basic research (Audretsch 2003, Bagchi-Sen et al. 2004). To secure a steady flow of knowledge from academia to industry is a key challenge for policy makers. This holds in particular true for many European nations and regions as they traditionally lack such a close integration between industry and academia as it could be observed in the USA (Henderson, Orsenigo and Pisano 1999, Owens-Smith, Riccaboni, Pammolli and Powell 2003, Lehrer and Asakawa 2004). A favourable environment for commercialising scientific research rests on several key factors (Audretsch 2003), including the availability of venture capital and other forms of finance, a strong

entrepreneurial culture and regulations not hampering start-up and growth processes. These and other ingredients of successful biotech clusters such as an excellent stock of human capital or favourable legislative frameworks governing research and market structures, etc. also represent important fields for policy actions. There are several core themes in the literature that are related to the role of the state in biotechnology.

- There seems to be a growing consensus among many scholars that developing high tech industries cannot be done with old policy recipes and traditional instruments such as tax incentives, cheap land, low-costs labour and relocation subsidies (Audretsch 2003, Feldman and Francis 2004). New industries need new policy strategies such as fostering entrepreneurship and stimulating networks. This is corroborated by Cooke (2002b) who points out that public policies to foster the knowledge economy should not only cover investments in hard infrastructure, such as transportation and communication systems, but also in knowledge infrastructures, such as universities, research institutes, science parks, and technology-transfer centres.
- This observation is related to a new role of the state. There is a shift towards public policy for the purpose of co-ordination and facilitation within networks. Negotiations and interdependencies within networks provide the mechanisms for policy development and implementation, rather than hierarchy and commands (Lemke and Östohl 2005, Lofgren and Benner 2005).
- Furthermore, there is also the question of the appropriate level of policy intervention. Whilst not neglecting the importance of the national policies, in recent years many authors have argued that the regional policy level is also crucial for fostering high-tech development (Cooke 2004a, Lemke and Östhol 2005). Indeed, there seems to be a trend towards public sector decentralisation that has enabled local and regional governments to launch programmes to cluster development in sectors such as biotechnology (Asheim and Gertler 2005, Lofgren and Benner 2005).The effective division of labour between the national and regional policy level, however, remains little understood.
- There seems to be some consensus in the literature that biotech clusters cannot be built from scratch or by fiat (Feldman and Francis 2004). Case studies of the formation of industrial clusters suggest that a complex, self-organising process is at work (Feldman 2000, Feldman and Francis 2004). The formation of clusters can only be facilitated and stimulated, but not directed, by policy makers.

These are fairly relevant and interesting topics that capture many aspects of the influence of the public sector on biotechnology. What is missing so far in the literature is a systematic overview on how governments can and should promote different types of knowledge interactions in this sector. To be sure, there is an intensive discussion on the promotion of spin-offs as new firm formation is a critical element in the emergence and development of high-tech clusters such as biotechnology (Feldman, Francis and Bercovitz 2005). The comprehension of this process has become a matter of major interest in the recent past. This holds in particular true for academic spin-off ventures (Roberts and Melone 1996, Wright, Birley and Mosey 2004, Degroof and Roberts 2004). In order to foster entrepreneurship in biotechnology many states and regions have launched a large variety of support actions. The promotion of collaboration and networking by policymakers is also well documented in literature (Reiss et al. 2003). Spin-offs and formal networks, however, are only two forms of knowledge interactions in a broader set of such links. Policymakers must be aware that in the biotechnology sector knowledge is exchanged in various ways and they must have an idea of the relevance of the different types of knowledge links and of their geography. In the next section, we will provide such a taxonomy of knowledge interactions.

2.2 Knowledge links in biotechnology

In the recent past the knowledge base of biotechnology has attracted considerable research interest. It has been shown that knowledge base of the biotech industry is extremely complex, expanding rapidly, and the sources of expertise and knowledge are widely dispersed (Powell, Koput and Smith-Doerr 1996, Powell 1998). Consequently, all the necessary competencies needed to innovate successfully in biotechnology can hardly be found under a single roof. External knowledge sources and interorganisational linkages play an outstanding role. Their number and scope have grown rapidly over the last years (McKelvey 2004). The large-scale reliance on interorganisational ties can be seen as the outcome of a fundamental and pervasive concern with access to expertise and knowledge (Powell 1998). The character of those links and their spatiality, however, have still to be clarified (Gertler and Levitte 2003, Tödtling and Trippl 2005). While some authors argue that geographically localised knowledge spillovers from universities play an outstanding role (Zucker, Darby and Brewer 1998b, Keeble and Wilkinson 2000, Feldman 2001, Prevezer 2001), others stress that there is a dominance of contractual arrangements and embodied technology transfer through markets (Zucker, Darby

and Armstrong 2002, Gertler and Levitte 2003). Zucker, Darby and Armstrong (1998a) note that university scientists do not give away their knowledge freely but instead enter into contractual arrangements with enterprises or start their own firm in order to commercialise their scientific discoveries. Interestingly, they found that scientists work with or create firms within commuting distance of home or university, thus creating localised effects of university research. Another stream of literature also emphasises that biotechnology is characterised by a high proportion of formal alliances (Arora and Garmbardella 1990, Garmbardella 1995), covering university-industry links and inter-firm R&D partnerships such as those between large pharmaceutical companies and small biotechnology firms (Shan, Walker and Kogut 1994, Hagedoorn and Roijakkers 2002). Several studies on innovation networks have shown that there is some networking at the regional and national levels, often involving local universities, venture capitalists and smaller companies (Cooke 2002b, Powell, Koput, Bowie and Smith-Doerr 2002). However, more frequently the networks were among international partners (Hagedoorn 2002, McKelvey, Alm and Riccaboni 2003, Owen-Smith and Powell 2004) nurturing the view that non-local linkages are crucial. Recently, the argument has been put forward that both extensive relations within local clusters *and* strong connections to national and global knowledge sources are highly relevant (Gertler and Levitte 2003, Bathelt, Malmberg and Maskell 2004). This view clearly challenges the assumption of the dominance of one spatial level over another. On the contrary, Bathelt, Malmberg and Maskell (2004) have pointed out that "global pipelines" should be seen as important complements to the "local buzz" generated in clusters. Overall, in the literature there is thus a lack of consensus on the specific nature of knowledge flows and their geography. It is still unclear to which extent innovation in biotechnology is based on market relations, formal networks or spillovers and milieu effects. Furthermore, the issue whether these relations are local or global is far from being resolved and also the relation between these different spatial scales remains poorly understood. A further problem that has arisen from the literature discussed above is that it is not always clear what is meant by knowledge spillovers, market relations and networks. In the following we will present a model of knowledge flows which enables us to draw a clear distinction between these concepts.

In order to get a better understanding of the nature of knowledge flows in biotechnology we propose a taxonomy of interactions (see Tödtling, Lehner and Trippl 2005) that rests on two crucial dimensions (see Figure 1). The first dimension refers to a differentiation between traded and untraded interdependencies (see Storper 1997) in the innovation process. 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 and innovation interactions (Camagni 1991, Maillat 1998, Capello 1999). Static knowledge exchange here means 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., cooperation or other joint activities (Lundvall 1992, Camagni 1991, Capello 1999, Lawson 2000). In this case the collective stock of knowledge is increased through the interaction. This classification provides us with the following four main types of relations (Figure 1)

Figure 1: Types of relations in the innovation process

	Static (knowledge transfer)	**Dynamic (collective learning)**
formal / traded relation	market relations	cooperation / formal networks
informal / untraded relation	knowledge externalities and spillovers	milieu informal networks

Source: Tödtling, Lehner, Trippl (2005)

We have to consider that these four types of relations constitute "ideal types" which in real situations can rarely be observed in pure form. In fact many concrete knowledge links are in between these ideal forms and often there may exist combinations of these types.

Market relations: Market relations in the present context refer to the buying of "embodied" technology and knowledge in various forms. This includes the buying of machinery, ICT equipment or software, contract research or the buying of licenses. Since the traded technology or knowledge is more or less in a "ready" form, we consider this as a static relation or knowledge transfer. Trade partners could be changed swiftly and the level of interaction is often low. A number of studies have shown that the traded relations are usually at higher spatial levels, reaching clearly beyond the region (Storper 1997, Sternberg 2000). Policy actors can play a strong role in facilitating the formation of market relations. Key activities in this respect include, for example, the promotion of technology transfer from universities to industry by stimulating contract research at academic institutions or the creation of favourable framework conditions and incentives for patenting and licensing scientific discovering.

Local knowledge externalities or spillovers: A number of scholars have demonstrated through econometric methods that there are considerable local knowledge externalities or spillovers in particular from universities and research organisations to firms. Jaffe (1989), Audretsch and Feldman (1996), Anselin, Varga and Acs (1997) and Bottazi and Peri (2003) investigated local knowledge spillovers applying a knowledge production function approach. Jaffe, Trajtenberg and Henderson (1993) found considerable proximity effects with respect to patent citations. Local knowledge spillovers result from various kinds of mechanisms such as knowledge transfer, e.g. through spin-offs and mobile labour, through face-to-face contacts or simply through "monitoring" of competitors (Malmberg and Maskell 2002). To strengthen university research and to intensify positive externalities and spillovers by facilitating academic spin-offs or by promoting the inflow of highly skilled and experienced workers into the local industry turn out to be important elements of cluster initiatives in biotechnology.

Networks: Compared to market links, networks are more durable and interactive relations. There is not just an exchange of a given technology or piece of knowledge but a collective further development and an increase of the respective knowledge base, constituting a dynamic process of collective learning (Lundvall and Johnson 1994). Innovation networks are set up between specific partners and may take different forms (DeBresson and Amesse 1991, Powell and Grodal 2005). Some are based on formal agreements or contracts (R&D-cooperation, alliances, research-consortia) including formal statements on the sharing of tasks, cost, benefits and revenues. Since the search of partners is highly selective and targeted on specific strategic or complementary competences, formal innovation networks are often at an international scale (Archibugi and Iammarino 1999). In those cases where various barriers hinder the spontaneous emergence of such formal networks, policy makers can play a powerful role in spurring on the development of such linkages, e.g. by promoting university-industry partnerships and other types of research cooperations.

Informal links and milieu: Innovation networks may also include more informal links among companies and organisations (Saxenian 1994). These are based on trust, a shared understanding of problems and objectives, and the acceptance of common rules and behavioural norms. Although for a knowledge flow usually there is no formal and monetary compensation, some form of reciprocity exists in the long run. This is referred to as social capital (Putnam 1993, Wolfe 2002) or a shared culture leading to a specific innovative milieu

(Camagni 1991). The rapid exchange of ideas and knowledge are key to an innovative milieu, but there is also a dynamic aspect of a collective enhancement of the local knowledge base, resulting in collective learning (Camagni 1991, Capello 1999, Lawson 2000). To promote social capital and regional dialogue and, thus, an intense informal exchange of ideas and expertise by bringing, for instance, firms and academics together at meetings or fairs might be crucial policy measures in order to encourage innovation in the local biotechnology cluster.

The taxonomy of knowledge links presented above also allows us to be more specific about the role of governments in promoting innovation interactions in biotechnology. We might differentiate between the following functions of policy agents:

- facilitators of market links,
- intensifier of positive externalities,
- supporters of networks, and
- animators of milieu-effects.

To be sure, these reflections on the role of policy as promoter of knowledge links are not only inspired by the "classical" concept of market failure. Instead, the arguments put forward here draw on a new rationale for policy making, covering also "systemic" failures (OECD 1999, Edquist 2002, Lundvall and Borrás 1999, 2005) which could block the functioning of clusters and innovation systems and hinder the flow of knowledge and technology. Consequently, inappropriate interactions, the lack of communication and networking are seen to constitute important deficiencies which justify public intervention.

In the following two chapters we will explore for the Vienna biotechnology cluster the nature and geography of knowledge links as well as the role of public policies in promoting such ties.

3 The Vienna biotechnology cluster: Structuring and knowledge links

The Austrian biotech sector features a specific pattern of specialisation as there is a clear dominance of medical ("red") biotechnology (Baier et a. 2000, Oosterwijk et al. 2003). Austria has to be regarded as a latecomer in the commercialisation of biotechnology.

Although there is a good scientific base the commercial exploitation of research results is underdeveloped (Reiss et al. 2003). This is mainly due to weak incentives and conditions for commercialising research and a lack of tradition and culture for high-risk taking. The Austrian biotechnology sector features a strong tendency toward spatial concentration. Almost 70% of all biotech related firms are located in the Vienna region. Smaller clusters of biotechnological activities can be found in the provinces of Styria, Lower Austria and Tyrol (see Table 1). In the following the main structuring of the Vienna biotech cluster will be analysed.

Table 1: Proportion of biotechnology related companies in different Austrian provinces

Region	Number of firms	*Proportion of firms (%)*
Vienna	77	*67*
Styria	10	*8,7*
Lower Austria	10	*8,7*
Tyrol	9	*7,8*
Upper Austria	4	*3,5*
Salzburg	4	*3,5*
Vorarlberg	1	*0,8*
Burgenland	0	*0*
Carinthia	0	*0*
Total	115	*100*

Source: BIT (2004)[1], complemented by our own inquiry

3.1 Structuring of the Vienna biotechnology cluster

The Vienna region is Austria's most important centre for medical biotechnology, hosting about 80 biotechnology related firms. Key fields of activity in this cluster include therapeutics and specialised supply whereas diagnostics play only a minor role. The structure of the cluster is characterised by the existence of 6 subsidiaries of foreign big pharma companies, 25 small dedicated biotechnology companies, and several specialised and other suppliers (see Table 2).

Table 2: Classification of biotechnology related firms in three Austrian clusters

	Vienna	
	Number of firms	*Proportion of firms (%)*
Multinational Companies	6	*8*
Dedicated Biotech Firms	25	*32,4*
Specialised Suppliers	19	*24,6*
Other Suppliers	10	*13*
Other Firms	2	*2,6*
Sales and Distribution Firms	15	*19,4*
Total	77	*100*

Source: BIT (2004), complemented by our own inquiry

[1] http://www.bit.or.at/bioaustria/index.php

There is a long time presence of subsidiaries of multinational companies in the region which had been attracted by the strong research base and the easy recruitment of highly skilled scientists. Boehringer Ingelheim settled down in 1949, Novartis arrived in 1969 and Baxter opened its doors in 1983. Boehringer Ingelheim Austria includes the company's center for cancer research, one of its two centers of competence in biopharmaceutical production and its basic research subsidiary IMP. Novartis is the nation's largest pharmaceutical producer with a total of more than 3.000 workers. Baxter Austria is the company's most important research operation outside the U.S. Another key actor is Eli Lilly which mainly carries out clinical research projects in the area. Furthermore, there are about 15 sales and distribution firms located in Vienna. Among these are subsidiaries of Amgen, Aventis, Behring and Schering that all see the region as sales and distribution centre for the Eastern European market. The Vienna region hosts about 25 dedicated biotech companies. Examples include Intercell (vaccines against oncological and infectious diseases), Igeneon (oncology) which has recently been acquired by the US biopharmaceutical company Aphton, Austrianova (oncology, gene therapy) or Green Hills Biotechnology (oncology). About 40 % of the dedicated biotech firms were founded within the past 5 years and many of them employ less than 10 workers. There are about 20 specialised suppliers operating in the area. This segment mainly consists of producers of research agents (Bender Med Systems, Nano-S), bioinformatics providers (Emergentec, Insilico) and firms performing clinical trials services. Finally, there are 10 suppliers offering laboratory products and equipment. Venture capital firms and business angels are a missing ingredient in the cluster. There are only few such firms like, e.g., Horizonte Venture Management. The main reason for this is the bank-dominated landscape with a preference for traditional credit instruments and a widespread adversity to risk taking. Consequently, successful companies like Intercell or Igeneon had to attract external financing from international venture capitalists and funds.

Vienna has an excellent scientific base comprising five universities, several hospitals and a range of other public and private research institutes. There is the Institute of Molecular Pathology (IMP) which is Boehringer Ingelheim's cancer research centre. The Novartis Research Institute (NRI) was founded in the 1970. The Antibiotic Research institute Vienna (ABRI) is another privately owned basic research institute owned by Biochemie Kundl (part of Sandoz R&D). In the recent past a further strengthening of the local research base could be observed as the Austrian Academy of Sciences has established two new institutes, namely the

Institute of Molecular Biotechnology (IMBA) and the Research Centre for Molecular Medicine (CeMM) Moreover, in the recent past also five co-operative research centres between university institutes and firms have been set up. Besides research and provision of scientific knowledge the universities located in the region of Vienna also fulfill an important function as a source of highly skilled labour. Moreover, the General Hospital Vienna is also home of the Vienna School of Clinical Research (VSCR) giving postgraduate training to physicians. In the recent past, the education and training system has become further differentiated. In order to meet the growing demand for skilled biotechnology technicians several advanced technical colleges were founded. However, their alumni is not yet of considerable size.

3.2 Knowledge Links in the Vienna Biotechnology Cluster

This section summarises the main results of our analysis of knowledge flows within the Vienna biotechnology industry and between the local cluster and the outside world (for a more detailed discussion of our findings see Tödtling and Trippl 2005). We differentiate between market relations, formal collaborations and networks, spillovers and informal networks, spin-off processes, and labour market recruitment and mobility. Spin-off processes and labour market recruitment and mobility belong to the group of knowledge spillovers. Given their importance in the Vienna biotechnology cluster they will be dealt with separately in the following. Other types of knowledge externalities will be discussed jointly with informal networks (milieu) as in practice they could not always be clearly differentiated from each other. Table 3 provides an overview about our key results on the relevance of different types of knowledge links and their geography. Not included in Table 3 are labour market recruitment and mobility. This is due to the fact that our results on that issue are mainly qualitative in nature.

Spillovers and milieu

New firm formation constitutes an important mechanism for local knowledge transfer in the Vienna biotech cluster. The overwhelming majority of all spin-out companies originated from from academic institutions operating in the region, whereas firms have played only a minor role as incubators so far (see Table 4).

Table 3: Types of knowledge links and their geography in the Vienna biotechnology cluster

	Total		local			national			international		
	Number of links		With firms	With RO	*Total*	With firms	With RO	*Total*	With firms	With RO	*Total*
Spillovers and milieu											
Spin-Offs	15	(8%)	3	11	*14*	0	0	*0*	1	0	*1*
Other spillovers	40	(21%)	6	10	*16*	0	0	*0*	15	9	*24*
Networks	79	(43%)	14	25	*39*	2	5	*7*	17	17	*33*
Markets links	30	(16%)	2	8	*10*	0	0	*0*	13	7	*20*
Other relations	22	(12%)	1	6	*7*	0	0	*0*	7	8	*15*
	186	(100%)			*86*			*7*			*93*

RO ... research organisation (universities, clinics)

Table 4: Characterisation of spin-offs in the sample

		Vienna	
		number of companies	in %
Age of firm	not older than 5 years	9	60
	not older than 10 years	4	27
	older than 10 years	2	13
	Total	*15*	*100*
Location of parent organisation	Local	14	93
	National	0	0
	International	1	7
	Total	*15*	*100*
Type of parent organisation	Academic institution	11	73
	Firm	4	27
	Total	*15*	*100*
Firm size (number of employees)	1-10	8	53
	11-50	5	33
	more than 50	2	13
	Total	*15*	*100*

An analysis of the age of companies and firm size shows that most spin-off companies are not older than 5 years and many of them are very small employing less than 10 workers. Labour market recruitment and labour mobility of highly-skilled employees are also crucial for the circulation of knowledge in the Vienna biotech industry. For a large majority of the companies in our dataset the local labour market is an important external knowledge source. However, a more differentiated analysis has demonstrated that it is mainly the local universities that play an important role in this respect. Local inter-firm mobility is a rare phenomenon leading to a weak fluctuation of skilled workers within the system and little knowledge exchange among companies via this channel. Also the inflow of international scientific knowledge and managerial expertise could be observed. The latter is of particular

importance as there is the lack of local managerial know-how in the cluster. Apart from spin-offs and labour mobility there are also other spillovers, informal networks and milieu effects giving rise to knowledge flows in the Vienna biotechnology cluster. The geography of these flows reflects a coexistence of highly localised untraded interdependencies and international knowledge spillovers. The significance of the region in this respect results to a considerable extent from a rather intense informal networking between some local companies and research organisations within the cluster. Also between some few local firms people-based informal links could be identified. Knowledge spillovers are only partially geographically bounded. Several companies rated the reading of international scientific literature and patent specifications as rather important for getting access to new knowledge and for identifying and selecting partners for distant connections. Furthermore, international congresses and fairs have been identified to be crucial for monitoring the activities of international competitors and for establishing informal links to them and other distant firms. Interestingly, some evidence was also found that sometimes venture capitalists are vital information sources providing relevant "news" about international competitors and other firms to the local companies they are funding.

Formal cooperations and networks

Formal cooperations and networks constitute the most important type of knowledge flows in the Vienna biotech cluster. Almost 45% of all relations examined could be classified as such formal networks and they could be observed both at the local and global level. At the local level close network links between academic institutions and firms have been found. One the one hand there are several cooperations between university institutes, big pharma and young biotech firms that are financially supported by the Austrian government. These include the competence center "BioMolecular Therapeutics" (BMT), the Austrian Center for Biopharmaceutical Technology (ACBT) and two Christian Doppler Laboratories. Furthermore, there is evidence of a range of formal knowledge linkages between local universities and companies which have emerged spontaneously. Also partnerships among local firms such as joint projects between bioinformatics service providers and therapeutic firms seem to play a role in the Vienna biotechnology cluster. Innovation networks and R&D collaborations are far from being confined to the local level. The case of the Vienna biotechnology cluster clearly illustrates the importance of non-local connections as source of innovativeness in this industry. As our interviews have shown international universities, clinics and other research institutes are important partners in these networks. Furthermore, the

biotechnology firms in the Vienna region are also inserted into various innovation networks and R&D co-operations with foreign multinational pharmaceutical companies and young biotechnology firms.

Market relations and other linkages

There is some evidence that the companies of the Vienna biotechnology cluster make use of knowledge and expertise which can be "bought in the market place". About 15% of all contacts identified could be classified as "market relations". Table 3 illustrates that market links have been mainly found at the international level. Local interactions of this type play only a minor role by comparison. Some biotechnology companies have reported market relations with local university institutes and hospitals, whereas these links are largely about contract research, the testing of assays and the buying of patents and licenses. Partly due to the relative youth and the small size of the cluster, market relations between local firms are almost negligible. The international level clearly plays a stronger role than the local one. The Vienna biotech companies have some market links with international universities and clinics including the buying of patents and licenses as well as some contract research. Furthermore, some firms have close contacts to foreign commercial R&D firms, other clinical research organisations and international companies, from which patents and licenses have been bought. Finally, a number of relationships (12% of all links) have been found (see Table 3) which could not be subsumed to one of three main categories of links. This is due to the fact that the interview partners were not able or refused to characterise the relation. At the local level most of these links are with universities, whereas at the international level both companies and research organisations play a role as partners in these knowledge interactions.

4 The role of policy in promoting knowledge links in the Vienna biotechnology cluster

There are three policy levels influencing the development of the biotech cluster in Vienna (see Figure 2). Although Figure 2 does not include all institutions, programmes and initiatives, it displays the overall structure of the policy and supporting system. At the supranational level, EU programmes support and drive biotech related research through calls and funding. Moreover, legislation regarding biotechnology safe research as well as regulations of medical drug approval and clinical trials also play governing roles. The Austrian policy and supporting

system consists of national and regional institutions. Its strength lies in horizontal policies, which are not specifically designed to promote biotech but nevertheless have an impact on the development of its knowledge base through calls, grants and funding of research institutions (Reiss et al. 2003).

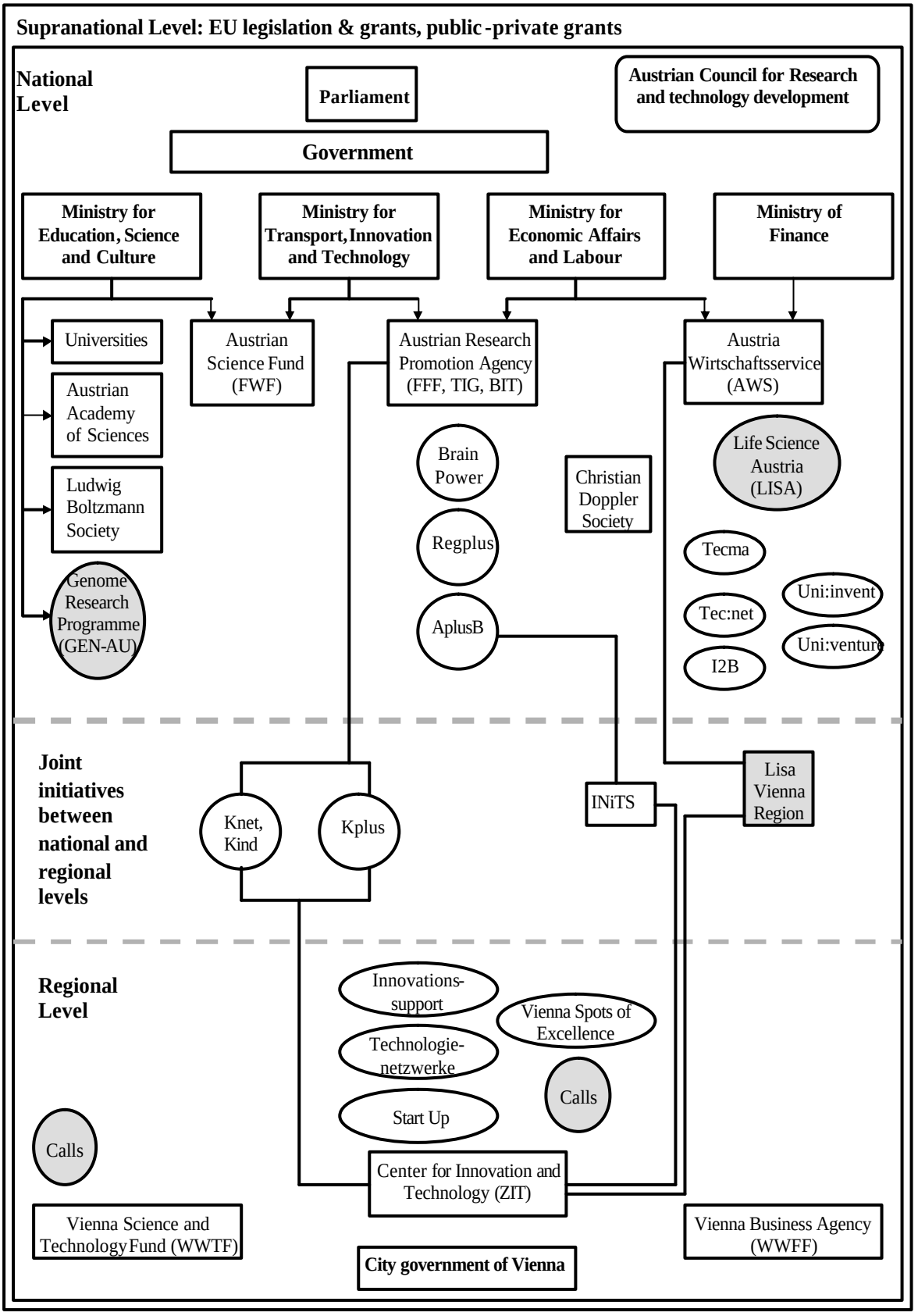
Focusing on the third research question, we are now going to investigate how public policy initiatives are contributing to the formation, existence and functioning of knowledge links. We selected those programmes that most clearly support the creation of knowledge flows within the cluster and listed them in Table 5 below. One has to realise, however, that most programmes can, and many times do, impact several types of knowledge interactions. To trace all possible direct and indirect impacts of every policy action, however, would be a too complex task. Thus, for every programme shown in the following we only marked the knowledge link with the strongest relevance. A more detailed display of the knowledge interactions these programmes or organisations promote is found in their descriptions, which also discusses the instruments they use to achieve the particular goals.

4.1 National programmes

The national policy level plays an outstanding role in fostering knowledge links in the Vienna biotechnology cluster. There are a variety of different policy measures and instruments in this respect. Many of them, however, are not biotechnology specific but aim at encouraging technological development per se. There are just two programmes which specifically focus on the promotion of biotechnology. These include the Austrian Genome Research Programme (GEN-AU) and the initiative Life Science Austria (LISA).

GEN-AU has been initiated in 2001 by the Ministry of Education, Science and Culture with a budget of 10,5 million Euros per year until 2010. It has the mission to strengthen genome research in Austria by funding interdisciplinary cooperative research projects undertaken by academic and/or industrial research teams. Consequently, its main focus is on facilitating dynamic and formal knowledge flows (networks) between regional and/or national partners. So far 27.8 million Euros have been allocated to 23 projects run by 91 partner organisations.

Figure 2: Overview of the different policy systems governing Vienna biotechnology



The majority of the funded institutions are located in Vienna, but a number of research teams in other Austrian provinces are receiving financial support, too. LISA is a programme of the Austrian Business Agency (AWS) launched in 1999 on behalf of two federal ministries. It mainly attempts to support local and national knowledge spillovers via the foundation of new biotech companies by providing financial support, advice and education. LISA consists of several components:

- LISA Preseed provides funds up to 100,000 Euros for a period of three years to potential entrepreneurs to establish the proof of principle.
- Moreover, LISA offers information and advice to firm founders with respect to technological and commercial issues.
- Best Of Biotech (BOB) is a business plan competition promoting the entrepreneurial activity of researchers in bioscience related fields. Its goal to increase the number of young life science firms by stimulating researchers to translate their ideas into business plans. BOB provides participants with advice and coaching with respect to prepare a business plan.
- Furthermore, lectures and training sessions are organised to enhance the commercial and managerial competencies of scientists.
- Finally, through the "Life Science Circles" meetings it also stimulates the informal exchange of ideas and experiences among actors. This is of particular importance in terms of enhancing milieu effects in the Vienna region.

Since 1999 in sum about 35 new firm foundations in the field of life sciences have been supported, a large majority of which have settled down in the Vienna region.

At the national level we can find many other initiatives which are of relevance for the purpose of this paper. Although they were not specifically designed to promote biotechnology, they nevertheless contribute to its development. There are, for instance, several programmes set up by the AWS that aim to advance high technology entrepreneurship. These include the initiatives "Seedfinancing" (loans), "High Tech Double Equity" (acceptance of guarantees) and "uni:venture". The latter is a fund established by the bank BAWAG but managed by the AWS.

Table 5: Policy programmes stimulating knowledge links

Programme	Organisation	Intention: promotion of ...	Key instruments	Types of knowledge links			
				static		dynamic	
				market links	spillovers	networks	milieu
National programmes							
GEN-AU	Min. for Education, Science and Culture	collaboration	funding			X	
LISA	Austrian Business Agency						
Life Science Circles		local interactions	meetings, conferences				X
LISA-Preseed		new firm formation	funding		X		
Best-of-Biotech		new firm formation	competition		X		
Tecma	Austrian Business Agency	patenting & licencing	Counselling, evaluating, funding	X			
Uni-invent	Austrian Business Agency	patenting & licencing	Promoting, training scouts, funding, patent accounting	X			
Seed financing	Austrian Business Agency	new firm formation	provision of loans		X		
Uni-venture	Austrian Business Agency& BAWAG	new firm formation	provision of venture capital		X		
i2b	Austrian Research Promotion Agency	links between business angels and companies	brokering			X	
Brain Power Austria	Austrian Research Promotion Agency	international labour inflow	information, advice, funding		X		
Christian Doppler Labs	Min. of Economics and Labour, members	university-industry partnerships	funding			X	
European and international programmes	Austrian Research Promotion Agency	RDT cooperation	information, advice, searching for partners			X	

Programme	Organisation	Intention: promotion of ...	Key instruments	Types of knowledge links			
				static		dynamic	
				market links	spillovers	networks	milieu
Regional programmes							
Infrastructure provision	Center for Innovation and Technology	new firm formation	provision of space		X		
ZIT 05 plus	Center for Innovation and Technology						
Vienna Spot of Excellence		university-industry partnerships	funding			X	
Innovations-Support		cooperation	funding			X	
Technologienetzwerke		networks	funding			X	
Start-Up		new firm formation	funding		X		
Joint regional and national programmes							
LISA VR	Austrian Business Agency & Center for Innovation and Technology	cluster formation and growth	cluster management services		X		
INITS (AplusB)	Austrian Research Promotion Agency & Center for Innovation and Technology	new firm formation	information, advice		X		
Kplus	Austrian Research Promotion Agency & Center for Innovation and Technology	collaboration in basic research	funding			X	
Knet/Kind	Austrian Research Promotion Agency & Center for Innovation and Technology	collaboration in applied research	funding			X	

It provides venture capital to academic spin-offs. Companies can receive up to 1.1 million Euros for a period of 10 years. “uni:venture” contains a total funding volume of 7.2 million Euros. These initiatives clearly foster spillovers and informal knowledge flows at the regional and national level.

Furthermore, there are the programmes “tecma” and “uni:invent” by which the AWS supports universities, researchers and companies to patent and license their research results. This is done by providing expertise, training as well as funding support for patenting. Moreover it is engaged in searching for license deals. These services, being free of charge, are an important precondition for universities and companies to go into market links or possible alliances with other partners. Moreover, these initiatives may indirectly promote spin-offs, as universities can utilise the licences or patents on their own.

“Brain Power Austria” is a programme carried out by the Austrian Research Promotion Agency” (FFG) on behalf of the Ministry for Transport, Innovation and Technology. It has the goal to attract talented Austrian scientist from abroad. Thus, it promotes global knowledge spillovers. Scientists who are currently living or working abroad are assisted in looking for career opportunities in Austria. The main activities in this respect include amongst others the provision of financial support, relocation services and coaching but also a promotion of Austrian job opportunities.

Furthermore, the FFG actively promotes the participation of Austrian firms and research organisations in international cooperative RTD projects. More specifically it provides information and assistance relating to the Framework Programme of the EU, EUREKA and INTAS. Key activities include creating awareness, motivating, informing, and assisting on European Union and international research and technology activities, informing and coaching for preparing projects, as well as informing on issues of eligibility, evaluation criteria and procedural administrative and legal aspects. It also assists in searching for partners in collaborative EU and EUREKA projects. In addition, as the coordinator of the Innovation Relay Centre Austria, the FFG is actively involved in the transfer of new technologies and in other measures supporting innovation.

The Christian-Doppler-Society, founded in 1989, promotes the collaboration between universities, research institutions and industrial partners for a length up to 7 years.

Specifically, it has the aim of bridging basic and applied research in a certain area. Although it sets out for a more general programme, it has two specifically targeting research in red biotechnology in the Vienna region. Thus, the programme is a promoter of interactive links in form of co-operations and networks.

4.2 Regional programmes

For a long time Vienna's economic policy was about providing subsidies to individual companies and attracting multinational firms. It was only by the end of the 1990s that a stronger focus on innovation and technology could be observed. Today, Vienna's strategic policy priorities are on life sciences, ICT, creative industries and the automotive sector. This reorientation of policy has been accompanied by a process of institution building. In 2000 the Centre for Innovation and Technology (ZIT) was established. Among its main activities are the funding of R&D activities of high tech companies. One year later the Vienna Science and Technology Fund (WWTF) was set up to provide financial support to research organisations. Both funding agencies have special programmes for biotechnology organised as contests of proposals, thus following a "picking the winner" approach. Looking specifically at the promoting of knowledge links in biotechnology, the ZIT turns out to be the key institution. One the one hand, it provides infrastructure (laboratories, offices) to newly founded firms, thus advancing knowledge spillovers in form of spin offs. On the other hand it has recently launched a comprehensive funding programme (ZIT 05 plus) that consists of several initiatives that are designed to be key drivers of formal and dynamic knowledge links at the regional level:

- The initiative "Vienna Spots of Excellence" aims at promoting longer term university industry partnerships.
- The new programme "Innovationssupport" provides funding for initiating and preparing partnerships with educational institutes as well as for cooperations in the fields of production, marketing and distribution.
- In order to support the formation and existence of networks in specific technological fields or centres the programme „Technologienetzwerke" has been launched. It provides funding for all networking activities that contribute to the success of the innovation network (e.g. information services, events, publications).

- Finally, the programme „Start Up“ aims at supporting the formation of research intensive enterprises by funding R&D projects of young companies.

4.3 Joint programmes between regional and national policy levels

In the recent past, regional policy-makers have managed to build up strong links with national actors, thus improving vertical coordination between the regional and national policy levels. The “Life Science Austria Vienna Region” (LISA VR) represents a good example in this respect, as it is a joint initiative between the ZIT and the AWS. LISA VR provides cluster management services to the local biotech industry and acts as a “one stop shop”. By bundling the support available at federal and local levels, it offers a variety of services including consulting, pre seed financing, education and mediation of incubation space. As an actor in the system it stimulates static knowledge transfer, more specifically spin-offs. Furthermore it also promotes non-local formal and informal knowledge flows by participating in international fairs and promoting the cluster in relevant international media sources.

The national AplusB programme has the task to support regions to establish centres that focus on the stimulation of new firm formation. In the case of Vienna this led to the creation of INITS. This centre has been founded in 2003 by the ZIT and two universities with the aim to promote technology-oriented spin-offs from the academic sector in Vienna by offering incubation space, counselling and assistance, specifically to academia, in the process of turning a good idea into a viable business. In this process, it promotes knowledge spillovers in terms of spin-offs.

The programmes Kplus and Knet/Kind focus on the formation of cooperative research centres between university institutes and companies. Both programs were initiated in the second half of the 1990s by national ministries. Funding for the centres, however, comes not only from the national policy level but also from the regional one (in the case of Vienna, ZIT). The programmes demand a minimum of 5 partners and have a limit of 7 years, some of which were described in Section 3.2. Kplus has the general strategic goal of enhancing knowledge (basic research) within a specific discipline whereas Knet/Kind has the goal of innovating within the specific discipline (applied research). In terms of the knowledge link analysis, these programs promote primarily formal networks.

4.4 Discussion

In the recent past biotechnology has attracted a lot of interest from policymakers in Austria and in the Vienna region. Compared to many other nations and regions, however, the support for this highly science based sector comes late. As already outlined above, it was only by the end of the 1990s that systematic efforts to promote the biotechnology sector can be observed. This might be explained with the fact that Austria has no tradition and little experience in promoting high tech industries. Whilst having a good research base, its national and regional innovation systems have not been ripe for breeding a strong and dynamic biotech sector as early and fast as it could be observed elsewhere. In the last years, however, an intensive stimulation of biotechnology set in, brought about by a deep institutional change. There exists now a broad range of activities to foster start-ups and knowledge links in this sector, indicating that policy actors act like spiders in the web. An analysis of all these measures reveals the following patterns:

- There are only few initiatives that focus specifically at encouraging the biotechnology industry. Horizontal measures and policy programmes which aim at stimulating high tech development per se clearly dominate. It is difficult to assess all these activities, as a large majority of them is rather young. Consequently, in most cases it is still not possible to determine their specific impact.
- A strong concentration on promoting formal networks and entrepreneurship (spillovers) could be observed, whereas the stimulation of other types of knowledge links such as market relations and informal interactions (milieu) play only a minor role. This orientation has both a positive and a negative side. Given the youth and small size of the cluster a focus on new firm foundation seems to be a sound strategy as it contributes to coping with the challenge to reach a critical mass of young firms. Nevertheless, other types of knowledge links such as labour mobility and informal contacts might not be ignored as they are also essential for a dynamic development of biotech clusters. National and regional policymakers in Austria seem to assume to a too large extent that they always arise spontaneously. Thus, we might conclude that the policy and support system is strongly oriented at fostering formal networks and the creation of new ventures.
- Furthermore, the overall set of policy measures is characterised by a strong focus on promoting regional and national knowledge interactions. In comparison, only few policy initiatives such as "Brainpower" and the actions undertaken by the BIT are designed to

explicitly stimulate international knowledge flows. The competence centre programmes Kplus and Kind/net as well as the CD Lab's welcome international partners but do not explicitly enforce it or have special initiatives to encourage international partnerships. As we have pointed out above, knowledge sources from outside the region or nation are considered to play a crucial role in securing the growth and innovativeness of biotech clusters. To place too much emphasis on local and national interactions as it is observable in Austria and the Vienna region might have detrimental effects in the long run as it raises the danger of lock-ins.

- Looking at the types of instruments in use it is clearly visible that more traditional approaches such as funding and provision of infrastructure are still very important. They are, however, combined with newer forms of intervention such as brokering, advice and cluster management services, resulting in a relatively balanced mix of older and newer modes of governance.
- It is obvious that national policymakers play a key role in the multi level governance system. Nevertheless, the regional policy level must not be neglected, as it plays a complementary role. Furthermore, there is a good vertical coordination in the policy and supporting system that manifests itself in the establishment of the initiative LISA Vienna region. Interestingly, a comparison of the policy actions undertaken at the regional and national level shows some unexpected results: National policymakers adopt a broader strategy, focusing on the promotion of many different types of knowledge links including collaboration, informal contacts, new firm formation, international labour inflow etc. Furthermore, they fulfil various tasks such as financing and funding, brokering as well as provision of information and advice. They, thus, play a multifarious role. At the regional policy level, in contrast, the focus is narrower, as new firm formation and formal networks are the key targets with funding as the main instrument. This is somewhat astonishing as in most cases it is in particular the regional level where softer forms of intervention can be observed. We might conclude that policy makers in the Vienna region are addressing important barriers for the development of the biotechnology industry but are so far not using the full spectrum of instruments which might be derived from cluster theories and innovation system approaches.

5 Conclusions

Many studies have shown that government services and programmes are of utmost significance in moving the biotechnology sector forward. The key tasks of public policy comprise the funding of universities and the R&D system, training and education, support for entrepreneurship, and the commercialisation of science, arrangements to ensure the availability of finance, etc. Policy makers are also important agents for facilitating knowledge sharing and networking in the innovation process. This paper endeavoured to highlight the role of policy in promoting knowledge interactions in the biotechnology industry. Despite the significance of such ties in this sector and the policy efforts devoted to them, there is still a limited understanding of how different government initiatives from various policy levels contribute to their formation.

To reflect the role of the state as facilitator of knowledge interactions preconditions a fine grasp of how knowledge is transferred and exchanged in biotechnology. Drawing on a comprehensive model of knowledge flows based on the formal / informal character and the static or dynamic features of such links, a distinction between market relations, formal networks, knowledge spillovers and milieu effects has been drawn.

For the emerging Vienna biotechnology cluster it has been shown that innovation is the outcome of a complex interplay of various types of relations at different spatial scales. Knowledge spillovers and informal milieu effects have been found to be significant, but more formalised network relationships are the most frequent type. Both the local and the global levels are relevant spaces for innovation relations. Different from most studies we found that informal relations (milieu or "buzz") are not exclusively local and that formal networks or cooperations ("pipelines") are not predominantly global. Instead, we demonstrated that innovation in the Vienna biotech sector is stimulated and supported by "buzz" and "pipelines" both at local and global levels.

In the past few years a variety of different policy measures and instruments have been created to stimulate the formation of knowledge linkages in the Vienna biotechnology cluster. Many of these initiatives are designed to promote formal networks and entrepreneurship (spillovers), whereas the stimulation of market relations and milieu effects play only a minor role. Consequently, policy agents play a strong role as supporters of networks and intensifiers of positive externalities, but rarely act as facilitators of market links and animators of milieu

effects. Overall, a strong orientation of policy makers on promoting regional and national knowledge interactions could be observed and little has been done so far to encourage international knowledge flows which are of utmost importance for young biotechnology clusters in non high technology regions. Furthermore, in terms of government modes it has been demonstrated that traditional instruments such as funding and the provision of infrastructure are combined with modern forms of intervention, covering activities such as brokering, advice or cluster management services. Many of the programmes have been initiated by national policy agents. Some of them are executed jointly with regional authorities, reflecting a good vertical coordination in the policy and supporting system. Also the regional policy level plays an important role, even if it still does not use the full spectrum of instruments. It is in particular the softer forms of intervention which are a missing ingredient at the regional policy level so far.

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