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From the ivory tower to the market place? The changing role of knowledge organisations in spurring the development of biotechnology clusters in Austria

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Abstract

Over the past two decades, universities have experienced far reaching changes in their tasks and roles. Their main mission is no longer confined to education and research, but increasingly also covers technology transfer and commercialisation activities. The aim of this paper is to examine as to which extent this phenomenon could also be observed in Austria. We differentiate between four key tasks of universities, including their roles as "antenna" for receiving external knowledge, source of highly skilled labour, cooperation partner for industry and seedbed for new firm formation. Focusing on the biotechnology sector we will demonstrate that an opening of the ivory tower and a move of Austrian universities towards the market place has occurred. Furthermore, we will show that these changes have been to some extent policy-driven in nature.

1 Introduction

Universities are recognised to be critical contributors to economic prosperity (Mowery and Sampat 2005) and key institutions of innovation systems (Edquist 2005; Coenen 2006; Gunasekara 2006). Over the past two decades, universities and other public research organisations have experienced substantial changes in their tasks and roles. Their main mission seems to be no longer confined to education and research, but increasingly also covers technology transfer and commercialisation activities. In most developed countries, a growing attention is paid to the economic utilisation of publicly funded research. This holds particularly true for high-technology sectors with an analytical knowledge base, where scientific knowledge is of utmost importance in the innovation process (Laestadius 1998; Asheim and Gertler 2005; Tödtling et al. 2006). The advent of the "entrepreneurial university" (Etzkowitz et al. 2000; Etzkowitz 2004; Etzkowitz and Klofsten 2005) in the Western world is widely discussed and documented in the literature. The purpose of this paper is to examine as to which extent this phenomenon could also be observed in Austria and to highlight its main features. Focusing on the biotechnology sector we address the following questions:

- What are the key functions of public research organisations for fostering the development of biotechnology clusters in Austria?
- Which changes could be observed in Austria in this respect?
- What is the role of policy agents in promoting a more direct and proactive contribution of universities to cluster growth and innovation in biotechnology?

The paper provides a short literature review on the changing role of universities and identifies four core functions of public knowledge generating institutions in the emerging knowledge economy: We deal with the task of universities as "antenna" for receiving and absorbing external knowledge, examine their importance as source of highly skilled labour, discuss various forms of university-industry partnerships, and address the role of academia as seedbed for new firm formation (Section 2). Section 3 presents empirical results from a research project on the Austrian biotechnology sector on these aspects. Drawing on 31 interviews with university researchers and representatives from the policy and supporting sector, we demonstrate that an opening of the ivory tower and a move of Austrian universities towards the market place has occurred. Furthermore, we will show that these changes have been to some extent policy-driven in nature. Finally, Section 4 summarises the main findings and draws some conclusions.

2 The changing role of universities and other public research institutions

Universities and other public research organisations are acknowledged to be important contributors to economic growth (Mowery and Sampat 2005) and crucial elements of national and regional innovation systems (Fritsch and Schwirten 1999; Edquist 2005; Coenen 2006; Gunasekara 2006). Throughout the Western World, the science system has undergone far reaching reforms over the past two decades. The traditional teaching and research university is being transformed into an "entrepreneurial university" (Etzkowitz et al. 2000; Etzkowitz 2004; Etzkowitz and Klofsten 2005), reflecting a growing and more direct role of academia as engine of innovation dynamics and economic development. Promoting academic entrepreneurship has been high on the political agenda since the midst 1990s (see, for instance, OECD 2003). Universities and other public research organisations have been encouraged to enter into relationships with industry in order to stimulate the production of more practical, applied research outputs (Godin and Gingras 2000, Simpson 2004). The ever increasing significance of universities for technological and economic progress (Goncalves and Papon 2004) can particularly be observed for knowledge intensive economic activities such as biotechnology or information technology where scientific inputs are acknowledged to be essential for the innovation process (Laestadius 1998; Asheim and Gertler 2005; Tödtling et al. 2006).

There are two main conceptual approaches dealing with the changes of the science system and the strong role of universities and other public research institutions for economic dynamics: According to Gibbons et al. (1994) and Nowotny et al. (2001, 2003) the process of knowledge production has been radically changing from a traditional disciplinary model (Mode 1), where knowledge was produced in universities with little social or other external influences, to a more recent Mode 2, which is characterised by a transdisciplinary inquiry that involves not only scientists but also other stakeholders, working together to find solutions in a context of practical application. Another approach reflecting on the new role of universities is provided by the triple helix model (Etzkowitz and Leydesdorff 2000, Etzkowitz et al. 2000). It is argued that universities are increasingly being transformed into entrepreneurial agents, encompassing a "third mission" in addition to research and teaching. Universities are translating research into economic development through various forms of technology transfer.

Both the proponents of "Mode 2 of knowledge production" and the advocates of the triple helix model, thus, point to an enhanced role of public research organisations as source of economic prosperity and to a growing significance of interfaces between universities and the private sector. The emergence of the "entrepreneurial university", however, is not universally embraced (Renault 2006). It has also provoked strong concerns and criticism among some scholars. Lerner (2005) points to the fear that commercial activities may subvert the core academic missions of universities. According to Nelson (2004) the increasing commercialisation efforts by universities pose a threat to academic freedom, independence, autonomy and basic research.

Although not acclaimed by all observers, the third mission of academic actors outlined above has become a reality in the past years. The United States clearly have the lead in this regard. Mowery et al. (2001) have stated that universities are at the heart of the commercial leadership of the United States in key science-based sectors. Compared to the US, university-industry interfaces in Europe have lagged behind due to a number of reasons such as a lack of incentives for and legal obstacles against faculty collaboration with commercial entities or cultural predispositions against academic involvement with commerce. In the meantime, not only in the US but also in Europe "academic capitalism" is advancing. This is particularly apparent in the field of biotechnology, which is the focus of this paper. Excellent universities and research organisations have been found to constitute the core of strong biotechnology clusters (Galambos and Sewell 1996).

Universities contribute in various ways to the evolution of high-technology clusters. Lawton Smith and De Bernardy (2000, p. 93) suggest a rather comprehensive typology of influences of universities in this context, comprising the dimensions

- location (spin-offs, sources of foreign capital through inward investment)
- innovation (technology transfer/innovation, information resources, localisation of foreign technology, technological spill-over)
- labour (mix of labour skills, training), and
- identity (contribution to cultural characteristics of the region, refocusing of region/spatial and technical segmentation or integration, prestige, participation in territorially organised policy processes).

It is beyond the scope of this paper to examine all these roles of research organisations in cluster development. In this article we concentrate on four main functions of universities. We deal with their roles as

- "antenna" for the receipt of external knowledge,
- source of highly qualified labour,
- knowledge provider in university-industry linkages, and
- incubator for academic spin-off companies.

In the following, we will discuss these four roles of universities and other public research institutes in more detail.

Universities as "antennas" for receiving external knowledge and its circulation within the regional and national science system

A key task of universities and other publicly funded research institutions consists in absorbing, accumulating and storing knowledge that has been produced elsewhere (Fritsch and Schwirten 1999, 2002; Fritsch 2003). Universities, thus, take over the role of an "antenna" (Fritsch 2003) for receiving external scientific knowledge that is not available locally. There are several mechanisms underlying this important function of public research organisations. These comprise amongst others the reading of literature, participation in conferences, as well as international scientific collaborations. Therefore, various forms of international scientific linkages are crucial underpinnings for the inflow of new knowledge that has been generated abroad. It must not be neglected, however, that also the local or regional levels are significant spaces for scientific interaction. Local linkages between universities and other public research organisations are relevant, because they represent eminent channels for the local circulation of external competences, expertise and knowledge. Scientific contacts, both at the local and global level, can be regarded to be of utmost importance in the emergent knowledge economy, reflecting a growing need of specialisation and interdisciplinary research. Collaboration and cooperation within academia are, however, not enough when it comes to identify the foundations of innovation. Dynamic regions and clusters rest on extensive knowledge flows between the science system and the business sector. In the following, we will deal with three core mechanisms in this respect.

Universities as a source of highly skilled labour

In the past years a considerable body of work has enhanced our understanding of the critical role played by human capital and talent in spurring (regional) development and growth. Human capital has been recognised to constitute a key factor for economic prosperity (Romer 1990). Lucas (1988) has put forward the argument that the spatial concentration of (skilled) labour generates strong external economies (or in his words "external human capital"), and that these externalities increase productivity and growth. In the meantime there exist a large number of empirical studies providing evidence for the strong relationship between talent and the growth of cities and regions (Florida 2002, 2005; Glaeser 2004; Glaeser and Saiz 2004).

Universities are considered to be a key source of highly skilled labour, providing trained researchers and engineers to the industrial sector (Martin and Salter 1996; Lawton Smith and De Bernardy 2000; Pavitt 2005). The production of trained personnel corresponds to the traditional educational mission of academic institutions. The movement of well educated talent into industrial occupations represents a powerful mechanism for the diffusion of scientific research (Mowery and Sampat 2005) and regional collective learning (Keeble 2000). Qualified scientists, engineers and managers are acknowledged to constitute a key element of biotechnology clusters (Casper and Karamanos 2003, Casper and Murray 2005). A survey of Californian firms has revealed that the availability of qualified workers is the most important location factor for companies in this sector (Audretsch 2003).

Keeble (2000), drawing on a comparative study of several European high-technology milieux, notes that the movement of talent within high-technology clusters is essential for the transfer of embodied expertise and a deepening and broadening of the regional pool of knowledge. He adds that "local universities with their continuous output of young qualified scientists and engineers, may play a particularly significant role in this regard, with graduate and postgraduate recruitment by local firms helping local dissemination and commercial application of new scientific knowledge derived from university research" (Keeble 2000, p. 209f.). Taken the above raised arguments together, it can be stated that the conventional mission of universities as provider of human capital remains crucial for fostering the development of high-technology clusters. In the past years, however, many academic institutions are expected to play an even more direct role in innovation and development by entering into co-operative relations with industry and spinning-off new ventures.

University-industry linkages

There is strong evidence that collaborative ventures between academic institutions and industry are increasing in number, size and complexity (Goncalves and Papon 2004), reflecting a new function of universities that go beyond teaching and the carrying out of (basic) research for its own sake. In particular in science-based sectors with an analytical knowledge base universities are playing an essential role as knowledge providers and co-operation partners for industrial companies (Laestadius 1998; Asheim and Gertler 2005; Tödtling et al. 2006). Such relationships can take different forms, including amongst others informal networks, formal R&D co-operations, co-authorship, the shared use of laboratory facilities and contract research (Mowery and Sampat 2005; Pavitt 2005), pointing to a broad spectrum of mechanisms of technology transfer and joint production of new knowledge.

The trend towards a rise in significance of university-industry linkages has been actively promoted by policy agents. Many governments have set up programmes and measures to strengthen the relationships between universities (and other public research organisations) and private companies, in order to enhance the contributions of university research to the innovation performance and economic growth of regions and nations (Mowery and Sampat 2005).

Looking specifically at the biotechnology sector, there is considerable empirical evidence that university-industry relations are of high relevance in that sector (see, for example, Audretsch and Stephan 1996; McKelvey 2004; Metha 2004; Gertler and Levitte 2005; Rothaermel and Deeds 2006). Several studies have documented the existence of a wide array of such links (Murray 2002, 2004; Porter et al. 2005; Lynskey 2006; Tödtling and Trippl 2007a, 2007b). The complexity and rapid expansion of the knowledge base in the field of biotechnology, and the wide dispersion of relevant sources of expertise (Powell et al. 1996; Powell 1998) are a key reason for the strong interactions found between the academic and industrial spheres. The growing significance of university-industry ties is the outcome of an increased focus on technology transfer and the economic exploitation of scientific discoveries and the skills and research resources of public knowledge generating organisations. The recent rise of academic spin-off companies signals that universities and other public research organisations are nowadays pursuing strategies to commercialise their knowledge in even more direct ways.

Universities as incubator for spin-offs

Over the last years, there has been a considerable rise in the formation of university spin-out firms (Keeble and Wilkinson 2000; Cooke 2002; Locket et al. 2005), reflecting new routes of commercialisation of publicly funded research and inventions. This applies particularly to industries which draw on an analytical knowledge base (biotechnology, information technology, etc.), where scientific knowledge represents a key input in the innovation process. Substantial public resources are increasingly being committed to support "science entrepreneurship" (Lehrer and Asakawa 2004), as in most industrialised countries policy initiatives have been launched to promote university spin-offs (Bower 2003; Meyer 2003; van Loy et al. 2003; Rasmussen et al. 2006; Wright et al. 2006).

In the meantime there exists a large amount of literature on academic spin-offs, indicating that new firm formation by academic scientists is driven by a set of factors including resources for opportunity search and intellectual property protection, the capabilities of technology transfer organisations, and the extent of science and engineering funding (Lockett and Wright 2005; O'Shea et al. 2005). Furthermore, the entrepreneurial climate and the innovative milieu of the region, the network capabilities of academic firms (Walter et al. 2006) and the density and strength of university-firm linkages (Rothaermel and Thursby 2005) seem to play a significant role.

In most cases science-based start ups face serious challenges in their development, brought about by a narrow range of competencies and a too strong focus on technical aspects (Meyer 2003). As academic founders emanate from a non-commercial environment, they often lack market knowledge and contacts, management skills, business experience and awareness (Bower 2003; Niosi 2006). Another key factor for the success of start-ups is access to venture capital (Wright et al. 2006). Looking specifically at the biotechnology sector, it has been revealed, that new venture creation is a crucial ingredient for innovation and the emergence and dynamic development of clusters in this field (see, for example, Audretsch 2003; Feldman and Francis 2003, 2004; Fuchs and Krauss 2003; Feldman et al. 2005). Research has shown that university researchers do not only act as consultants and members of scientific advisory boards of science based start up firms, but are also playing a pivotal role as founders of new companies in biotechnology. In other words: Universities and other public research institutes have become a main source of new technology-based firms in this sector (Cooke 2002; Lehrer and Asakawa 2004; Tödtling and Trippl 2007a, 2007b).

3 The case of biotechnology in Austria

Austria has the status to be a latecomer in biotechnology (see Tödtling and Trippl 2007a, 2007b). The sector features a strong specialisation in "red" biotechnology and comprises 115 biotechnology related companies (Bureau for International Research and Technology Cooperation and Life Science Austria 2004). The Austrian biotechnology industry exhibits a strong tendency towards spatial concentration. No less than 77 firms (67 % of the Austrian total) are located in the region of Vienna. Smaller clusters could be found in Styria (10 firms), Lower Austria (10 firms) and Tyrol (9 firms). Table 1 provides an overview of the structuring of the biotechnology clusters in the provinces of Vienna, Styria and Tyrol which will be examined in the following.

Table 1: Structuring of biotechnology clusters in three Austrian regions

	Vienna	**Styria**	**Tyrol**
	Number of firms	Number of firms	Number of firms
Multinational Companies	6	1	1
Dedicated Biotech Firms	25	2	7
Specialised Suppliers	19	4	1
Other Suppliers	10	3	0
Other Firms	2	0	0
Sales and Distribution Firms	15	0	0
Total	77	10	9

Source: Own inquiries

Vienna is the key biotechnology centre of Austria, not only regarding the number of firms but also with respect to the presence of scientific excellence. The region hosts five universities, several hospitals and a range of other public and private research institutes. There are the Institute of Molecular Pathology (IMP) which is Boehringer Ingelheim's cancer research centre, the Novartis Research Institute (NRI), and the Antibiotic Research institute Vienna (ABRI) which is owned by Biochemie Kundl (part of Sandoz R&D). Recently, the Austrian Academy of Sciences has established two new institutes, including the Institute of Molecular Biotechnology (IMBA) and the Research Centre for Molecular Medicine (CeMM). Additionally, five co-operative research centres between university institutes and firms have been set up (see below). Finally, a technical college for biotechnology has also been created in order to improve the supply of specialised and highly skilled labour. The scientific base in Tyrol is made up of three universities, the Tyrolean Cancer Research Institute, and the Institute for Biomedical Aging Research of the Austrian Academy of Sciences. Furthermore, there is one co-operative research

centre located in the region (see below). The province of Styria hosts three universities and two recently established co-operative research organisations carrying out bio-scientific research present in Styria (see below).

As we have argued elsewhere, until recently the Austrian science sector in the field of biotechnology was not used to commercialise its scientific expertise. The most important reasons for this weakness in academic entrepreneurship include the lack of tradition, culture and incentives at universities to commercialise scientific results, as well as a weakly developed public support infrastructure (Tödtling and Trippl 2007b).

In the following we will demonstrate that in the recent past substantial changes have set in, reflecting a more active role of Austrian universities in economic development. Our results are based on qualitative face-to-face interviews[1]. In the three regions of Vienna, Tyrol and Styria 17 interviews have been taken with university institutes, other public and semi-public research organisations and cooperative research centres. Furthermore, some 14 interviews have been carried out with policy agents, supporting institutions at universities and other organisations that aim at promoting technology transfer from universities to the industry.

3.1 Scientific collaborations at the global and local levels

As outlined in Section 2 international scientific contacts are a key channel for getting access to knowledge, expertise and competences which have been produced elsewhere. The scientists included in our sample reported rather intensive collaborations with international research organisations. For the majority of them contacts with international partners – mainly from Europe and the United States – are more important than local ones. Almost all interview partners noted that the key reason for establishing contacts with foreign universities has been the specific complementary knowledge possessed by them. Unsurprisingly, in the majority of cases joint publications have been found to constitute the crucial aim of scientific interactions. Other motives for entering into relations with international universities included joint problem solving, getting new ideas and intellectual discussions.

[1] The interviews have been collected in the context of two research projects: "Collective Learning in Knowledge Economies: Milieu or Market?" (2002-2004) funded by the Austrian Science Fund; "Cluster development and policy in the Vienna biotechnology sector" (2005-2006) funded by the Jubilee Fund of the City of Vienna for the Vienna University of Economics and Business Administration.

Notwithstanding the significance of the international level as space for scientific interactions, also the local and national levels turned out to play a prominent role in this respect. At these scales, it is also the access to complementary knowledge that is decisive for cooperating with specific partners. Additionally, and similar to international interactions, joint publications have been identified to represent the most essential goal of collaborations within the national and regional science systems. Since a few years such interactions are actively promoted by public policy in the context the "Austrian Genome Research Programme", which has led to a local bundling of scientific competences and the achievement of critical mass in this field (see Table 2). As it is also revealed in Table 2, this policy initiative has also stimulated the joint production of new knowledge and the circulation of scientific competences and expertise at the interregional level.

Table 2: Collaborations stimulated by the Austrian Genome Research Programme

Project	Partners (location)
COOPERATIVE PROJECTS	
Epigenetic Plasticity of the Mammalian Genome	▪ Research Institute of Molecular Pathology IMP (Vienna) ▪ Center f. Molecular Medicine, Austrian Academy of Sciences (Vienna) ▪ Instit. of Medical Biochemistry, Medical University Vienna
Ultra-sensitive Proteomics and Genomics	▪ Instit. for Biophysics, University Linz (Upper Austria) ▪ Profactor Produktionsforschungs GmbH (Upper Austria) ▪ Fuzzy Logic Laboratorium, University Linz (Upper Austria) ▪ Lambda GmbH (Upper Austria) ▪ Instit. of Genetics and General Biology, University Salzburg ▪ Instit. of Immunology, Medical University Vienna ▪ Elisabethinen Hospital Linz (Upper Austria)
Genomics of Lipid-Associated Disorders	▪ Instit. for Molecular Biology, Biochemistry and Microbiology, University Graz (Styria) ▪ Instit. f. Genomics and Bioinformatics, Technical University Graz (Styria) ▪ Dep. of Biochemistry, Technical University Graz (Styria) ▪ Instit. of Medical Biochemistry and Medical Molecular Biology, Medical University Graz (Styria) ▪ Dep. of Medical Biology and Human Genetics, Medical University Innsbruck (Tyrol) ▪ Instit. for Molecular Biology, Biochemistry and Microbiology, University Graz (Styria)
Genomic Approaches to Tumor Invasion and Metastasis	▪ Boehringer Ingelheim Austria (Vienna) ▪ Medical University Vienna ▪ Clinical Instit. of Clinical Pathology, Medical University Vienna ▪ University Clinics for Dermatology, Medical University Vienna

PILOT PROJECTS

Functional analysis using the "screen-out" method	▪ Instit. of Animal Breeding & Genetics, University of Veterinary Medicine Vienna ▪ Dep. of Vascular Biology and Thrombosis Research, Medical University Vienna ▪ Research Institute of Molecular Pathology IMP (Vienna)
A Comprehensive Disease Bank for Functional Genomics	▪ Instit. of Pathology, Medical University Graz (Styria) ▪ Instit. for Virology, University of Veterinary Medicine Vienna ▪ Instit. of Cancer Research, Medical University Vienna ▪ Dep. of Internal Medicine, Medical University Graz (Styria) ▪ Oridis Biomed GmbH (Styria)
Functional genomics of childhood malignancies	▪ Children´s Cancer Research Institute (Vienna) ▪ Tyrolean Cancer Research Institute (Tyrol)
Cancer in the Hematopoietic System	▪ Instit. for Molecular Biotechnology IMBA, Austrian Academy of Sciences (Vienna)
Proteomics in Tumor Biology	▪ Instit. of Analytical Chemistry and Radiochemistry, University Innsbruck (Tyrol) ▪ Dep. of Anatomy, Histology, and Embryology, Medical University Innsbruck (Tyrol)

NETWORKS

Bioinformatics Integration Network	▪ Instit. for Genomics and Bioinformatics, Technical University Graz (Styria) ▪ Tyrolean Cancer Research Institute (Tyrol) ▪ Research Institute of Molecular Pathology IMP (Vienna) ▪ Instit. for Theoretical Chemistry and Structural Biology, University of Vienna ▪ Instit. for Chemistry, University Graz (Styria)
Austrian Proteomics Platform	▪ Dep. of Anatomy, Histology, and Embryology, Medical University Innsbruck (Tyrol) ▪ Instit. for Medical Chemistry, University of Veterinary Medicine Vienna ▪ Research Institute of Molecular Pathology IMP (Vienna) ▪ Instit. of Pharmaceutical Chemistry & Pharmaceutical Technology, University Graz (Styria) ▪ Instit. of Analytical Chemistry and Radiochemistry, University Innsbruck (Tyrol) ▪ Dep. of Anatomy, Histology, and Embryology, Medical University Innsbruck (Tyrol)

Source: Own inquiries

3.2 Linkages between research organisations and industry

After the brief discussion of scientific interactions (see Section 3.1) we are now going to deal with different types of relationships between research organisations and private companies. Our results indicate that a transformation of Austrian universities into more outward-looking and entrepreneurial facilities has occurred. Their role is no longer restricted to the provision of highly skilled labour. It increasingly includes being a cooperation partner of industry and more recently to act as incubator for spin-offs.

Knowledge organisation as source of highly qualified labour

The production of highly skilled labour represents a key function performed by universities in the Austrian biotechnology sector. In particular in the region of Vienna this more traditional task of academic knowledge organisations has been of importance for the emergence of the local biotechnology industry. Between the 1950s and 1980s the availability and easy recruitment of scientists have been among the main reasons for the arrival of big multinational pharmaceutical companies such as Boehringer Ingelheim, Novartis and Baxter (Oosterwijk et al. 2003). As we have argued elsewhere the attraction and "anchoring" of these companies to the region have been vital for the gradual evolution of the Vienna biotechnology cluster (Tödtling and Trippl 2007a). The provision of graduates still represents an essential function of universities in Austria. It has to be considered as an important contribution of academia to the development and growth of the three biotechnology clusters investigated here. Many academic institutions included in our sample reported that their alumni have found jobs in subsidiaries of multinational corporations located in the region. This holds in particular true for the Vienna biotechnology cluster, where the movement of trained personnel from universities to companies such as Baxter, Boehringer Ingelheim and Novartis constitutes an important mechanism for regional collective learning, as it leads to the dissemination of new scientific knowledge at the local level. It is, however, not only the Vienna biotechnology industry, where local economic dynamics is linked to the educational mission of universities. Also in the smaller biotechnology clusters which have been identified in the regions of Tyrol and Styria this type of knowledge transfer from academia to industry has been found to be of high relevance. In the former case it is mainly the firm Biochemie Kundl which is a key employer of university graduates. Consequently, big pharmaceutical companies are the main absorbers of highly skilled young

scientists in the Austrian biotechnology sector. Labour mobility from universities to the dedicated biotechnology firms located in the investigated regions is not so intensive yet. This finding has to be traced back to the fact that many of these companies are still very young and of a small size. The early stage of development of the biotechnology sector in Austria, thus, has to be regarded as an essential reason for the poor use by dedicated biotechnology firms of the knowledge and skills embodied in the graduates of academic institutions. Importantly, our interviews have shown that several academic knowledge organisations maintain close contacts with their former students that are now employed in local firms. These relations are manifold, ranging from a more informal exchange of information and ideas to joint activities in formal university-industry partnerships. The good personal knowledge that professors and the graduates have from each other facilitates the exchange of knowledge in cooperative endeavours enormously and helps to overcome interaction barriers between universities and industry. As one interview partner from the university scene put it: "These alumni have a good understanding of the research that is done at our institute, they are familiar with our philosophy. There is reciprocal trust which is a very important point and communication with them is so easy." In the recent past, in the Vienna region the educational system has become further differentiated. Two technical colleges for biotechnology and bioengineering have been established in order to meet the growing demand for skilled technicians. Some important actors from industry have been involved in specifying the content of teaching and representatives from local firms also offer lectures. Given this close interaction between industry and the technical colleges, it is likely that the colleges' output of qualified workers is fine-tuned to the needs of the local companies.

University-industry partnerships

A key function of universities and other research organisations that has become important in the past decades is to be a partner of pharmaceutical and biotechnology firms in different types of university-industry relationships. The Austrian biotechnology sector clearly demonstrates that universities do not only accomplish their traditional function as human capital providers. They are also increasingly involved in cooperative projects with companies in the past years. This reflects a more modern and active role of knowledge institutions in spurring industrial innovation in the Austrian biotechnology clusters studied here. A closer look to the university-industry partnerships reveals that the Austrian university

institutes included in our sample have built up a range of ties to local and international companies. At the local level different types of industrial actors seem to represent important partners of knowledge organisations. First, there is evidence that big pharmaceutical companies, in particular Baxter, Novartis and Boehringer Ingelheim Austria, exploit the scientific capabilities and expertise of Austrian universities by engaging in co-operative projects with them. Second, also linkages between academic research institutions and small dedicated biotechnology firms have been found. Finally, very close contacts between universities and their spin-off firms could be identified (see also below).

An analysis of the nature of all these relationships shows that formal interactive co-operations between knowledge organisations and local firms appear to dominate. Additionally, also evidence was found that contract research, the selling of licenses, the development of assays and diagnostic products and tests, and informal relationships play a role. In this context, one university professor stated: "In former times industrial companies had a clear problem and a clear goal when they built up contacts with universities. The universities carried out contract research to solve this clearly defined problem. However, things have changed. The actual questions and problems that companies face are far more complex, they could no longer be specified in detail at the beginning of the project. This demands a new form of relationships between universities and industries that is about a joint definition of the problem during the project. This leads to a shift from classical contract research to more interactive cooperative endeavours". Several of the aforementioned formal cooperation projects have been encouraged by public policy. Various cooperative research centres carrying out longer-term projects have been established in this context. The overwhelming majority of these publicly funded university-industry partnerships can be found in the Vienna region (see Table 3), promoting collective learning in the local cluster. Policy efforts undoubtedly explain a part of the trend toward stronger links between universities and industries in the Austria biotech clusters.

Table 3: Cooperative research centres in biotechnology in Austria

Cooperative research centre	academic partners	industry partners (location)
	Region of Vienna	
Christian Doppler Lab Gene therapeutic vector development	Inst. for Virology and Biomedicine (Univ. of Veterinary Medicine Vienna)	Sanochemia (Vienna), Austrianova (Vienna)
Christian Doppler Lab: Molecular Recognition Materials	Inst. of Analytical Chemistry (Univ. of Vienna)	Merck (Germany) Astrazeneca (Sweden)
Christian Doppler Lab: Proteomics Analysis	Inst. of Biochemistry and Molecular Cell Biology (Univ. of Vienna)	IMP (Vienna)
Kplus: BMT Biomolecular Therapeutics	Dep. of Dermatology (Medical Univ. Vienna), Dep. of Vascular Biology and Thrombosis Research (Medical Univ., Centre for Nanobiotecnology (Univ. of Natural Resources and Applied Life Sciences)	Baxter (Vienna), Polymun (Vienna), Technoclone (Vienna)
K-ind: ACBT Austrian Centre of Biopharmaceutical Technology	Inst. of Applied Microbiology (Univ. of Natural Ressources and Applied Life Sciences), Inst. of Biochemistry (Univ. of Innsbruck)	Boehringer Ingelheim Austria (Vienna), Polymun Scientific (Vienna), Sandoz (Tyrol)
	Region of Tyrol	
K-ind: Medical Centre of Excellence Projects (selection)		
Dendritic Cell-Based Tumour Vaccine / Kidney	Medical Dep. of Dermatology and Venerology (Innsbruck Medical Univ.)	Sentimmun (Tyrol), V&F medical development (Tyrol), Biocrates (Tyrol)
Dendritic Cell-Based Tumour Vaccine / Skin	Medical Dep. of Dermatology and Venerology (Innsbruck Medical Univ.)	Sentimmun (Tyrol), Immumetrics (Tyrol), Biocrates (Tyrol)
Islet cells	Medical Dep. of Dermatology and Venerology (Innsbruck Medical Univ.) Dep. of General and Transplant Surgery (Innsbruck Medical Univ.)	Sentimmun (Tyrol)
	Region of Styria	
Christian Doppler Lab Genomics and Bioinformatics	Inst. for Genomics and Bioinformatics (Graz Univ. of Technology)	Sandoz (Tyrol), Eccocell (Styria), Oridis Biomed (Styria)

Source: Own inquiries

The research organisations in our sample do not only have contacts with local firms. Most of them are also be inserted in various linkages with international companies. Large pharmaceutical firms, mainly from Europe, constitute the most important partners in this respect. There is a wide array of different types of knowledge interactions between Austrian universities and international firms, covering consulting activities, cooperations in EU projects, contract research, selling of patents as well as joint publications. Although there is increasing evidence of knowledge links between the universities and companies, the interaction between the academic and industrial world is far from being smooth and unobstructed. Several interview partners mentioned the existence of several barriers such as problems of communication, a mismatch of philosophies, as well as diverging interests and incentives. A key problem is often that the research activities on the universities do not meet the demand of firms.

Knowledge organisations as sources of new firms

Apart from teaching as traditional academic mission and the more modern role as cooperation partner for industrial firms, since a few years Austrian universities have also become an important source of new firm formation. This signals a very new role of scientists. Setting-up a company in order to translate academic research discoveries into innovative commercial products is no longer frowned upon in academic departments. Academic spin offs are key for the development of the three Austrian biotechnology clusters investigated here. About 30 firms originating from the public research sector are located in the three clusters examined here. Although the first academic spin-off firm (Immuno) has already been created in the 1950s, followed by two spin-outs (Technoclone and Nanosearch Membrane) in the 1980s, it was only since the year 2000 that the academic spin-off process has gained momentum. As we have shown elsewhere, the overwhelming majority of them is still in an early stage of development and earn no or only few revenues so far (Tödtling and Trippl 2007b). From the 15 knowledge organisations which are included in our sample 10 have spun-off new local businesses. The majority of these firms has been established between 2001 and 2004 (see Table 4). Only three companies, which are all located in the region of Vienna, are older, including Technocone (founded in 1987), Polymun (created in 1992) and Intercell (established in 1997).

Table 4: Characterisation of academic spin-offs included in the sample

Parent organisation (location)	Spin-off company (location)	Year of foundation	Number of employees
Medical University (Vienna)	Technoclone (Vienna)	1987	-
University of Natural Resources and Applied Life Sciences (Vienna)	Polymun (Vienna)	1992	24
University of Vienna (Vienna)	Intercell (Vienna)	1997	130
University of Veterinary Medicine (Vienna)	Austrianova (Vienna)	2001	16
University of Natural Resources and Applied Life Sciences (Vienna)	Nano-S (Vienna)	2003	6
Austrian Academy of Sciences (Vienna)	Appeiron (Vienna)	2003	-
Medical University Graz (Styria)	Oridis (Styria)	2001	17
University of Innsbruck (Tyrol) and Austrian Academy of Sciences (Tyrol)	Amynon (Tyrol)	2002	6
University of Innsbruck (Tyrol)	Inteligand (Lower Austria)	2003	-
University of Innsbruck (Tyrol)	AlcaSynn (Tyrol)	2004	3

Source: Own inquiries

Our results show some interesting details with respect to the academic spin-off phenomenon:

- In the Austrian biotechnology sector, the large majority of academic founders continue to hold their position as researcher or professor at the university. These people act as "border crosser" between the academic and the industrial spheres.

- Therefore, the relation between the research organisation and the firm is very close. We found a wide array of such linkages, including R&D co-operations, the joint use of infrastructure, the exchange of staff, the buying of patents as well as the use of the academic networks by the spin-off firms. It can be argued that to some extent the boundaries between the academic and the industrial world have become too blurred. In some cases the firm even has its location at the university institute, giving rise to an unclear use of public resources.

- Unsurprisingly, we found that in most cases a lack of business skills is a dominant feature of many of these academic spin outs.

The recent advent of research-based spin-off firms in the Austrian biotechnology sector has been essentially supported by two main factors: First, successful companies such as Intercell and Igeneon have certainly played a key role in enhancing the rate of new venture creation in biotechnology. By acting as "role models" these companies animated academic scientists to commercialise their research results by establishing new firms. Second, the intensification the academic spin off process has also to be seen against the background of explicit policy efforts. To stimulate academic spin-offs has become an important goal of Austrian policymakers in the recent past (Austrian Council 2005). At the national policy level in 1999 the initiative "Life Science Austria" (LISA) has been launched to support the foundation of new biotechnology companies. LISA comprises the provision of preseed capital, information and advice to firm founders concerning technological and commercial issues, a business plan competition, as well as the organisation of lectures and training sessions to enhance the commercial and managerial competencies of scientists. At the national scale there is also a range of other programmes aiming to advance high technology entrepreneurship. These include the initiatives "Seedfinancing" (provision of loans), "High Tech Double Equity (acceptance of guarantees) and "uni:venture" (a fund that provides venture capital to academic spin-offs).

Also regional policy agents in Austria pursue strategies to create favourable conditions for academic entrepreneurship. In the recent past, in all three regions investigated here academic spin-off centres have been established geared towards the promoting of technology-oriented spin offs from the science sector. These centres offer incubation space, counselling and assistance to academic founders. In the region of Vienna, additionally, the policy initiative "Start Up" has been set in, which aims at supporting the formation of research intensive enterprises by funding R&D projects of young companies (for a more detailed overview, see Trippl et al. 2006).

4 Summary

Over the past two decades, universities and other publicly funded research institutions have experienced essential changes in their functions. Their main mission is no longer confined to education and the carrying out of basic research, but increasingly also covers technology transfer and commercialisation activities. In this paper, it has been demonstrated that Austrian universities have been slowly changing from an ivory tower towards an economic engine. In the past years, their altruistic missions of education and the pursuit of knowledge for its own sake has been complemented by new tasks and functions. Our results reveal that specifically in biotechnology public knowledge organisations in Austria play a multifarious role. They are inserted in a range of international scientific collaborations, acting as "antenna" for receiving external expertise and competencies produced elsewhere. At the national and regional levels we also found intensive interaction within the scientific system, indicating a rather intense local and national circulation of academic knowledge. Furthermore, it has been shown that universities and other knowledge organisations should be regarded as key providers of qualified labour and skills. Additionally, they have expanded their tasks and enlarged their role in innovation. The existence of university-industry partnerships and even more important the intensified process of new firm formation by university researchers signals the emergence of an entrepreneurial culture within academia. Universities have been found to play a pivotal role in seeding new biotech ventures, pointing to a direct transformation of scientific knowledge and technology into marketable products. As revealed in this article, policy interventions have been significant for promoting closer relations between academic faculties and firms and for fostering a transformation of scientific knowledge into marketable products by forming academic spin-offs.

The above outlined development from a traditional university towards an entrepreneurial university seems to be positive from the perspective of university-industry interaction, regional development and innovation. However, it should be pointed out here that universities have to maintain also their original roles (basic research, education) in order to serve their respective role in national and regional innovation systems. Furthermore, well functioning university-industry linkages require well defined boundaries and tasks, appropriate organisations, rules as well as clear and consistent incentives for achieving excellent basic research and alumni as well as knowledge interactions with industry.

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