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Emergence, growth and transformation in local clusters - Environmental industries in the region of Upper Austria

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Abstract

The environmental technology industry is considered to be a growing industry driven by urging climate-, energy- and waste problems and environmental regulation, among others. It seems, however, that not all locations and regions have the same preconditions for its emergence and growth. Based on regional economic, geographic and cluster theories it may be argued that particular factor- and demand conditions, regional industry structures and institutional configurations should play a role, but so far little is known on these aspects. This paper focuses on a region in Austria that appears to have a highly developed environmental technology industry and studies its characteristics and growth. We investigate the region of Upper Austria, where the environmental technology industry has evolved since the beginning of 1970s with roots in engineering, machinery, and instruments firms. The aim is to improve our understanding of the development of the environmental industry in the region and the factors and conditions affecting it. Characteristic changes of the cluster in relation to national level industry are addressed. The paper uses findings from national survey data (1993-2007) and exploratory interviews with local industry experts and stakeholders.

The preliminary findings from our analyses suggest that Upper Austria´s environmental technology industry is characterized by higher growth relative to the national level. The region is also the dominant location in Austria in terms of number of firms and employees in this sector. The sector seems to benefit from existing industries and engineering competences in the region and is also supported by a number of organizations. Possible factors and conditions for understanding localized changes are explored underpinning these cluster life cycle changes.

1. Introduction

The environmental label is used for a broad variety of sectors such as energy, materials, IT, transportation and recycling. Two useful categories are first what may be considered emerging technology areas and industrial structures (e.g. cleantech clusters in Europe and the US composed of firms specialized in bio-nanotech, photovoltaics and fuel cells) and second, shifts of traditional manufacturing engineering, machinery equipment and chemical industries into more efficient and less resource-intensive end-of-pipe products and processes. The former group is well addressed in the literature on clusters (e.g. Burtis et al., 2004; Cooke,

2008), whereas the latter, remains relatively understudied through the cluster perspectives. Particular factor- and demand conditions, regional industry structures and institutional configurations may be considered to play a role, but so far little is known about these aspects for the emergence, growth and change of such environmental technology clusters. To address this gap, this paper focuses on an industrial region in Austria that demonstrates technological diversification and industrial branching from engineering, automotive, and steel industries into environmental technologies, products and services.

The paper uses ideas from the cluster life cycle (CLC) framework, regional innovation systems and evolutionary economic geography to investigate emergence and change in environmental industries in the Upper Austria region. This paper tries to address the following questions:

- Is there an 'environmental industries' cluster in the Upper Austria region?
- If so, what are its characteristics, patterns of emergence and changes over time?
- What are the factors underlying its change, and which stylized characteristics of cluster change are exhibited in the evidence?

To answer these questions, this paper uses a case study approach informed by a literature review on clusters and environmental technology studies with a regional emphasis, to understand factors underlying the development of Upper Austrian environmental industries and their change over time. This paper uses primary data from interviews and secondary data from Austrian national surveys carried out between 1993 and 2007 to illustrate changes in size, structure and composition of environmental industries in the Upper Austrian region and factors underlying these changes.

In the following, we offer a brief literature review and conceptual framing of approaches to cluster change. Subsequently we present empirical findings for the environmental technology industry in Upper Austria. Characteristic changes of the cluster in comparison to the industry on the national level are analysed. The paper relies on data from national surveys (1993 - 2007) and on exploratory interviews with local industry experts and stakeholders. Section 3 characterizes the environmental technology industry, whereas section 4 gives some background to the evolution of the industry in Upper Austria. Section 5 addresses growth, composition, and activities of Upper Austrian environmental industries. The paper ends with a

synthesis and conclusion of the main findings generalizable to CLC and other theories, as well as those considered idiosyncratic to the case examined.

2. Conceptual approaches to the evolution of clusters

One of the most popular approaches to the development and growth of industries and clusters has been provided by Michael Porter (1990, 2008). Porter and in particular his Diamond model have focused on the factors that help to explain why some clusters are more competitive than others, or than companies in non-clustered locations. The factors Porter refers to in his well-known "Diamond" are factor conditions, demand conditions, supporting industries and organizations, and the context for firm strategy and rivalry. Although he sees a role for government and cooperation he clearly puts more emphasis on the propelling force of competition among the cluster firms. For the environmental industry his approach has been applied e.g. by Lehtinen et al. (2006) to the Finnish region of Oulu. The region has strengths in high tech sectors such as electronics and IT and due to policy initiatives has developed an emerging environmental technology cluster (mainly water technology). The authors identify an emerging cluster based on small firms that are linked and supported by IT firms and supporting organizations such as universities. Environmental legislation has been identified as a main driver for the industry. Although Porter's approach is illustrative and widely applied, it lacks a more systematic dynamic view of cluster emergence, transformation and change over time.

Cluster Life Cycles

Menzel and Fornahl (2009) provide a more dynamic view by looking at cluster life cycles (CLC). The concept was developed from product and industry life cycle approaches, and it combines those with factors underlying change in local industrial clusters. It argues that clusters exhibit cyclical properties in their evolution and change over time. The concept suggests that a cluster is moved through a set of stages (emergence, growth, sustaining, decline, rejuvenation) underpinned by local technological heterogeneity, localized learning and innovation capacities of firms that exist to different degrees and find differing local expressions in the various stages. Key elements and driving factors are actors, networks or institutions that may be inside or outside the cluster, the industry or the region. Driving factors

differ by stage, i.e. the factors driving the emergence may be different for the ones responsible for growth or maturity.

For the first stage – emergence – the authors argue that the beginning of clusters is generally hard to identify and they hypothesise that "clusters are established in those regions where the knowledge bases of companies converge around technological focal points" (Menzel and Fornahl, 2009:231). The emergence stage is characterized by spin-offs, small numbers of technologically diverse companies, supportive science and skills base, and policy support. This stage is quite similar to the beginnings of a new industry in the locality, and might resemble the emergence of new IT and science-based clusters in the US and UK. In the second stage of the CLC, local firms are characterized by growth, increased numbers of start-ups, and increased specialization of the cluster. But there is also a shake-out of companies, and a decreasing heterogeneity of knowledge. A more focused development leads to the emergence of a dominant design, and the cluster demonstrates a clear structure, getting close to the technological frontier. Due to the growing density of companies and institutions the cluster offers possibilities for innovation networks or customer-supplier relations.

The third stage – maturity – is characterized by a relatively stable state, and dense networks. External connections, however, may bring in new knowledge and keep the networks open. Thematic boundaries are shifting incrementally and the cluster is shaping increasingly its regional environment. The fourth stage of the cluster – decline – is characterized by decrease in the number of firms and employment, firm failures, lay-offs and closures, closed networks that are underperforming in their knowledge linkages and low absorptive capacity of local firms. The region 'lags behind' other global regions in the same industrial areas, structures are rigid, over-specialisation is prevalent and firms' production is overly narrow and internal structures are inflexible to changing requirements of competitiveness. These stage characteristics may exist in various guises in the cluster, and indeed it may be difficult to find a cluster that exhibits all of them.

Clusters are considered to be able to renew themselves as their companies integrate and apply new knowledge and technologies, and enter new growth phases. As such, there may be different elements of the cluster that exhibit different stage characteristics (Menzel and Fornahl, 2010). Different parts of the cluster can move at different stages, different elements may progress while others remain the same. The movement of the cluster through its life cycles is not performed by the cluster (which is only a concept) but is the result of internal

activities and cluster elements as well as external factors (Menzel and Fornahl, 2009). Focus is on endogenous processes that arise from the position of the cluster at the interface between industrial and local dynamics (Menzel and Fornahl, 2009)[1]. Cluster growth is not just about size but about heterogeneity in the cluster and the ways in which technological heterogeneity is exploited in the cluster. As the cluster moves through different phases, factors that were once important in sustaining it may be a disadvantage in a later phase (Grabher, 1993). Menzel and Fornahl (2009) support their conceptual model of cluster development through a broad literature review and give examples from various industries and regions. No specific reference is given to the environmental technology industry, however, although their frame certainly has some relevance for it.

Regional Innovation Systems (RIS)

The regional innovation systems (RIS) approach offers additional insights to the evolution of industries. It is broader than clusters or cluster life cycles since it refers to several clusters or industries of a region as well as to the regions knowledge organizations, universities and schools, and intermediaries, among others. There is a strong role of formal and informal institutions as well as government bodies (Cooke et al. 2000, 2004; Doloreux 2002; Tödtling and Trippl 2005). Thematically there is a narrower focusing on innovation processes, however. By including the broader set of industries and knowledge organizations of a region the approach helps to understand also horizontal or cross industry effects e.g. the branching of industries or clusters, diversification or the emergence of new industries or technology paths (Tödtling and Trippl, 2012). Cooke (2010) has distinguished between "entrepreneurial" and institutionally based" RIS and applied the concept as well as an evolutionary perspective to the environmental technology industry in the Danish Northern Jutland (case of an institutionally based RIS) and to California (entrepreneurial based RIS). He sees the emergence of the Californian green tech industry as an example that is driven by visionary entrepreneurs and venture capitalists, whereas the Northern Jutland eco-energy industry is the result of a more systemic interplay of interrelated companies, suppliers, knowledge organizations and policy agents.

[1] The endogeneity of technology argument in the CLC approach derives from authors such as Audretsch (1997) who states that the knowledge conditions shaping the technological regime underpinning the industry is what makes local industrial structures change, shift, and evolve. Underpinning change in industrial structures are technological regimes (Nelson and Winter; Schumpeter) which are characterized by waves of innovations in particular fields (Schumpeter). Audretsch (1997) also states that no tendency can be generalized, but rather processes vary from industry to industry, and it is knowledge conditions and technology underlying the industry and its innovative activities that explains variations in industry evolution (Audretsch, 1997: 79).

Evolutionary Economic Geography

Helpful for exploring the emergence and development of environmental technology industry in particular regions is the Evolutionary Economic Geography approach. Here we find arguments that industries and regions often emerge from and follow particular paths that are rooted in the past and in (pre)-existing industrial and institutional structures (Martin and Sunley, 2006 and 2010). This implies that the emergence of new industries such as environmental technology can be understood from evolutionary processes of firm variation, creation and selection, which emerge from past and existing industrial trajectories and structures. Frenken et al. (2007) and Boschma and Frenken (2011) have argued in this context that industries in regions emerge and grow based on the relatedness of their knowledge base other existing sectors in the region. Competences can be transferred from old to new sectors e.g. through the branching of firms, spin-offs, or the mobility of entrepreneurs or qualified labour. They have distinguished such situations of "related variety" from highly specialized industrial localities as well as from unrelated diversity. Cooke (2012) has applied concepts of path development to the study of "clean-tech" industries in Denmark and Sweden. He finds that "transversality" (which he considers as a more active and social agency driven dimension of the rather passive notion of related variety) and platforms of innovation (characterized by horizontal knowledge flows between sectors) as more useful for analyses in the emergence of clean-tech industries than Porter´s cluster concept. Using these concepts Cooke shows differences in the creation of new paths in Clean Tech by comparing Danish North Jutland (a local green platform in energy markets) and the peripheral region of Norrland in Sweden (developing a technology platform based on forest products and process industries including biofuels, biochemicals, substitute cotton, food and construction materials).

Clusters, thus, are composed of heterogeneous elements such as firms, universities, and government organizations, whose learning processes, interactions and relationships are considered to move the cluster along a path of emergence, growth and decline (Menzel and Fornahl, 2009). Localized value-adding interactions between firms are considered to be embedded in regional innovation systems (Cooke, 2010; Tödtling and Trippl, 2012), whose systemness properties and institutions shape firm learning conditions, innovation and thereby underpin growth. In the evolutionary view, clusters change through emergent processes, characterized by variations in firm populations, their technological heterogeneity, and degree of specialization. Together these explanations for cluster change are used to understand the empirical results in section 5. The following section provides a definition of the

environmental technology industries and a brief background to the main factors that have shaped their change and growth according to the literature.

3. Background to the 'environmental technology' industries

Environmental technologies are defined by Kemp (1997: 11) as "... each technique, process or product which conserves or restores environmental qualities." This definition includes technologies, products and processes which, relative to existing technologies, reduce and repair environmental damage (both directly and indirectly). Environmental damage may be categorised as damage to water, air, soil, waste, noise and eco-systems (OECD/Eurostat, 1999:9). Given the breadth of environmental technology, it is unsurprising that the category encompasses a broad range of sectors and sub-sectors which contain a highly heterogeneous mix of firms (Weber, 2005).

Environmental technologies in Western Europe can be traced back to the early 1970s when pollution problems from heavy manufacturing spurred on the creation of end-of-pipe products for abatement (OECD, 1999; Weber 2005). During these initial years firms were selling to small domestic markets to reduce local pollution, such as in North-Rhine Westphalia in Germany (Hilbert et al., 2004). Later in the 1980s and 1990s two parallel processes can be observed: the emerging ICTs and high-tech sectors brought on new technologies focused on resource efficiency, and the more traditional manufacturing environmental industries began their convergence with the newer high-tech sectors, and incremental shifts towards the production of relatively more integrated, clean and process-oriented environmental technologies and products (www.umweltcluster.at). End-of-pipe products continued to be prominent although these became more difficult to separate from process technologies, which differ from sector to sector (Frondel et al., 2007). In the 2000s the integration of diverse technology areas into process-based environmental products such as ICTs, biotechnology, nanotechnology, and materials science for resource conservation, energy efficiency and pollution abatement within the production process itself, what may be called 'sustainable' technologies, continues (Weber, 2005; Frondel et al., 2007). At the regional level, these processes are reflected in transitions of manufacturing industries into cleaner production, convergence and branching between manufacturing and high-tech industries, and the emergence of 'cleantech' clusters notably in Germany and in the US (Cooke, 2008).

Societal challenges and factors such as environmental pollution, increased and unsustainable resource use and resource scarcity have an essential impact on the development of the environmental technology industry. This is to some extent different from other industries for which more traditionally economic factors such as skills, capital, supply and demand are considered to be the main drivers. However, these latter factors are not unimportant, and also have an impact on the development of the environmental technology industry. Another important factor associated with growth and proliferation of environmental technology sectors are regulations for environmental standards and penalizing firms for not meeting them (Porter and van der Linde, 1995; Jaffe et al., 2002). In addition to economic factors such as the search for efficiency and profit by firms, environmental protection is increasingly a broader societal and policy concern in many countries. For example, social concerns for environmental ethics and the conservation of the environment for future generations are considered an important force shaping production of more environmentally sound products and processes (Simonis, 1989; Kemp, 1993; Mol, 1997).

In Austria, environmental technologies and environmental policy has a relatively long history. Environmental concerns have to a certain degree been integrated into industrial production, agriculture, transport, planning, education, and policy since the early 1970s. An important part of the national transition to environmental protection has been local industries in regions such as Upper Austria and Styria. The following section describes in more detail how the environmental industries in the Upper Austrian region have developed, and factors that have shaped its emergence and change over time.

4. Factors underlying the development of environmental technology industries in Upper Austria

Upper Austria can be regarded as one of the leading regions in Austria with respect to environmental technology industries. Industrial branching and development of environmental industries began in the early 1970s, as in the rest of the country, but the industry has grown at a faster rate compared to the Austrian average. The industry in the region shares some similarities and some differences with the rest of Austria. The comparison between Upper Austria and Austria as a whole is used for understanding the genesis and development of the cluster, its factors of emergence (see also section 5). This section uses a brief literature review

and a series of exploratory interviews to describe the factors that have influenced the emergence and growth of the regional environmental industry. Both the literature review and the interviews aim to provide a contextual backdrop to the empirical findings in Section 5.

To begin with, Upper Austria is a relatively large region with 1.4 million inhabitants, a size of 11,980 km^2, and borders with German Bavaria and the Czech Republic. In 2009 its GDP per capita was 33,920 €, slightly higher than the 33,600 € Austrian average (Eurostat). The industrial base is mainly composed of manufacturing, with capabilities in steel production, machinery, mechanical engineering and chemicals, among others. Upper Austria is thus often referred to as an industrial region specialised in traditional industries (Tödtling et al., forthcoming). Although Upper Austria's RIS comprises universities, colleges and research organizations in different fields, the number and quality of such organizations is clearly smaller compared to the capital Vienna, or to Styria, another industrial region in Austria. The region exhibits high private (business) but low public R&D activities. Upper Austria's RIS shows strong links between business and academia (Tödtling et al., 2011). This is partly due to support organizations such as for instance the Upper Austrian Business Agency (TMG Group) as well as a number of cluster organizations in the region.

Although the growth in the environmental technology industry is driven by similar factors as in Austria, some factors are specific to the region. The roots of the Upper Austrian environmental technology firms are predominantly in the engineering, machinery and instruments sectors and firms which have, based on their technical competencies, been diversifying into environment technology areas. These firms have applied and further developed their existing capabilities to the production of environmental products. Firms have integrated environmental solutions into their product lines and tried to gain competitive advantages through such innovations (De Marchi, 2012). The environmental technology industry in the region is characterized by rapid growth as will be shown in 5.1. The strongest areas are renewable energy, water, energy efficiency and waste. Growth in these sectors is attributed in Upper Austria to a number of factors.

Similarly to the Ruhrgebiet in Germany (Hilbert et al., 2004), pollution problems caused by manufacturing industries were important for the industrial branching and growth of environmental industries in the region. Pollution and contamination to air, water and soil of heavy industry in this area prompted local activism for its reduction and control. For example, VOEST, a leading global steel producer located in the region, caused a lot of pollution in its

high growth years in the 60s and early 70s. Local protests and reactions later on pushed the industry towards reducing emissions and wastewater.

Regulations and policies for pollution control (particularly for manufacturing) were a further important factor gaining momentum during this period (Pirgmaier, 2011). Such regulations were formulated and implemented in particular at the national and EU levels. This has been an incentive for searching for new solutions to reduce industrial pollution and it also created demand from local and other firms for environmental technology products. Existing industries in Upper Austria possessed the capabilities to produce such technologies (for example, reducing emissions of gas furnaces which were both produced and used in the local industries). Factors such as existing technological capabilities, supply chains and sophisticated local buyers were, thus, essential factors for the emergence and production of these new product lines and technology areas. The close relationship between the environmental problems of the local manufacturing industries and respective solutions in air purification, energy recuperation and energy efficiency technologies were essential factors giving rise to a local environmental technology industry. The importance of demanding local customers for cluster development has been stressed e.g. by Porter (1990, 2008).

Since the 1990s these local environmental industries have to a greater extent an international, mostly European, orientation. Nowadays, target markets are increasingly South-East Europe (due to the need to follow EU regulations) and Asia (due to intense environmental problems). As a consequence, the industry exhibits a high export ratio of about two thirds. Global demand for environmental technology products and services has also been pushed by higher energy consumption and –prices, and a pressure on natural resources.

The competitiveness of the Upper Austrian environmental technology industry is attributed also to its innovativeness and a well performing regional innovation system (Tödtling et al., 2011). Highly educated employees and a good skills base constitute a key factor for the development of the local industry. The importance of skills for enhancing absorptive capacity and innovation has been stressed by Cohen and Levinthal (1990), Lam (2000, 2002) and Zahra and George (2002) among others. With regards to knowledge generating organizations, the environmental technology institute and the energy institute at the Johannes Kepler University in Linz, as well as the environmental technology institute at the technical college in Wels play an important role. Nevertheless, the region is characterized by rather weak knowledge generating institutions when compared to other regions in Austria with well-

performing environmental technology industries. This finding has been confirmed by most of our interview partners, some of them who work at the respective organizations. Furthermore, Upper Austria has two cluster initiatives that serve as intermediaries and offer a number of services to member firms. The membership in both cluster organizations is open to outside firms and organizations, as complementary knowledge and competence from external partners are considered as important for cluster development and innovation (Camagni, 1991; Mytelka, 2000; Wolfe and Gertler, 2004; Gertler and Wolfe, 2006). These cluster organisations are important focal points for fostering horizontal platform-type linkages between relevant knowledge organizations and firms (Cooke, 2008), and for enhancing cluster 'openness' and branching into related industries (Tödtling et al., 2011).

The first cluster organization, the "Eco-energy Cluster Upper Austria", was founded in 2000 by the Upper Austrian Energy Efficiency Association and focuses on areas of renewable energy and eco-efficiency. In 2012 the Eco-Energy Cluster Upper Austria had 164 members (firms and organizations), of which all are located in Upper Austria. The cluster also has partners in Bohemia (Czech Republic) expanding its scope beyond the region. Member firms in this cluster organization are relatively old (average age is 31 years) when compared to the members of the "Environmental Technology Cluster" organization (average age is 16 years). The age difference can be explained by the fact that rather traditional firms and industrial sectors are represented in the Eco-Energy Cluster in comparison.

The second cluster initiative, the "Environmental Technology Cluster Upper Austria" organization was founded in 2006 by the Upper Austrian business Agency (TMG Group) to provide services to their member companies and organization in the field of environmental technology. This cluster organization focuses on the areas of resource efficiency, water, waste, soil and air. In 2012 the organization recorded 136 firm members, 91 of which are located in Upper Austria and the remainder in other Austrian regions and internationally (notably Germany). 80% of the cluster organization members are environmental service firms. Member firms are rather young with an average age of 16 years. The cluster organization, according to our interviews, is important in particular for supporting start-ups and young firms.

Overall we find that the development of the environmental technology industry in Upper Austria is strongly based on the traditional industries of the region such as mechanical engineering, steel, chemicals and automotive. On the one hand, these traditional industries

contributed the specific technological and other capabilities which were relevant also for the emerging environmental technology industry. On the other hand, these industries generated demand for relevant products and services in order to deal with environmental problems they caused such as for example pollution of air, soil and water. This created pressure on existing industries to invest in environmental technologies. Some leading companies such as the steel producer VOEST acted as "demanding" customers and asked environmental technology firms to come up with innovative and appropriate solutions. Last but not least, the policy side had a strong impact on the development of the environmental technology industry in Austria and the region. First, we find interventions such as laws, regulations and subsidies at the national as well as the European (EU) level. The second factor was the foundation of two cluster organizations with the aim of supporting young and other firms in the region and beyond.

5. Characteristics and change of the environmental industries in Upper Austria: Empirical findings

This section presents empirical findings on the structure, markets, growth, and innovation activities of the environmental technology industry in Upper Austria. In order to find out whether this regional industry has distinct characteristics and performance, we compare the industry in the region with the Austrian national industry, using a series of studies carried out by the Austrian Institute for Economic Research (WIFO).

This section uses findings from our personal face-to-face interviews with regional and national industry experts and stakeholders[2] as well as secondary data from Austrian national firm surveys to examine these clustering aspects for the Upper Austrian region. The quantitative empirical analysis of the environmental technology firms in both Austria and Upper Austria is based on a special sample of a survey of environmental technology firms

[2] We conducted 5 face-to-face interviews based on a semi-structured interview guideline. The interviews lasted approximately one hour. Questions were directed at finding out how the regional environmental technology industry has been developing, the most important factors affecting its change in recent years, its strengths and weaknesses, challenges, and importance of local and global factors for its transformation and change. Our interview partners included representatives from the Upper Austrian Environmental Technology Cluster, the Technical College Wels, the Chamber of Trade, Commerce and Industry, the Governmental Organization for Environmental Concerns and the Environmental Department of the Provincial Government of Upper Austria.

carried out by the Austrian Institute of Economic Research (WIFO)[3]. The survey builds the basis for the reports on the Austrian environmental industry, which started in 1995 and has since then been conducted in 1998, 2005 and 2008 respectively. The response rates for the different surveys was with roughly 40% relatively high and fluctuated only slightly between 1995 (41.9%), 2000 (40.3%), 2005 (43.6%) and 2008 (39.3). The response rate for the different regions in Austria showed a different picture. These ranged from 25% and 60%, with Upper Austria having the highest response rate (Kletzan-Slamanig and Köppl, 2008). One reason for the high response rate in Upper Austria was the cooperation of WIFO with the "Environmental Technology Cluster Upper Austria" for this survey. For more on these studies see Köppl and Pichl (1995), Köppl (2000, 2005) and Kletzan-Slamanig and Köppl (2008). At present, a further survey of the Austrian environmental industry is being carried out and is expected to be published in 2012. The tables in this paper are the result of these existing surveys and specific calculations for the Upper Austrian region. Table 1, however, is different from all the other tables presented in this paper. Since it represents an estimate of the total size of the Austrian and Upper Austrian environmental technology industry, the other tables exhibit the results only of the surveys for the respective years.

5.1 Size and development of the environmental industry in Upper Austria

What is the size of the Upper Austrian environmental technology industry? How did it develop in recent years? In 2007 more than a quarter of all environmental technology firms in Austria were located in Upper Austria. There were 105 environmental technology firms employing more than 6,000 people with a turnover of 1.81 billion € (see Table 1). The Upper Austrian share of turnover in these sectors for the region was 30% of the Austrian total. Based on these indicators, Upper Austria has a rather high proportion of firms, employees and turnover in environmental industries relative to the rest of Austria.

As stated in the previous section, this region has a concentration of manufacturing, electronics, chemicals and ICTs industries that branched into environmental technology areas since the 1970s, the more recent data in part shows a continuation of this technological trajectory. A higher concentration of firms in specific industries relative to other regions and

[3] We want to thank the Austrian Institute of Economic Research (WIFO) for their assistance and the close cooperation in providing the data.

relative to the national average is an important indicator of industrial agglomeration, if not clustering.

Table 1 below shows the rate of change of the number of firms, turnover, employees and export ratio of the environmental industry in the region between 1993 and 2007, and the change in the share of these figures within the national total. Of these, a number of findings stand out. First, the region demonstrates a high growth rate of 133% in terms of firm population, indicating a prospering local environmental industry. Second, in terms of turnover, the high growth rate of 762% between those two time periods is indicative of a relatively mature industry expanding through high levels of production and sales. The high relative change in the share of regional to national turnover of 16% indicates the existence of particularly high-performing firms. Third, the number of employees between 1993 and 2007 grew by 286%, and a 13% increase in the share of the Austrian total during this period.

Table 1: Size of the environmental technology industry in Upper Austria (estimate)

	1993		2007		Growth rate (%)	Change in share of Austrian total (%)
	Upper Austrian total	Share of Austrian total (%)	Upper Austrian total	Share of Austrian total (%)		
Number of firms	45	18	105	28	133	10
Turnover in €M	210	14	1810	30	762	16
Employees	1593	14	6147	28	286	13
Export ratio (1997)	59	-	70	-	19	-

Source: Special sample from WIFO Environmental Technology Industry surveys

Together, these findings are suggestive of a cluster in the growth phase characterised by a focus on production and expansion through the sale of new and existing products, the creation of new firms, growth of existing firms, employment, and increased exports (as suggested by Audretsch and Feldman, 1996; Bathelt, 2001; Menzel and Fornahl, 2009).

5.2 Entry into the environmental technology industry

When and how did the environmental technology industry in Austria and Upper Austria develop? Which factors affected its development? Recent studies have attempted to look further into the theoretical and empirical explanations for why clusters emerge and the

processes through which they may begin their formation and growth (Menzel and Fornahl, 2009; Wolfe and Gertler, 2004). The entry of Upper Austrian local firms into the environmental technology sectors, presented in Table 2 below, gives an indication of the time periods at which signs of cluster formation first became visible and shifted along different cluster stages in this region. Up until 1975 the share of environmental industries in Upper Austria and in Austria were relatively similar, showing little if any signs of intensification of regional specialisation in these areas. Indeed, the increase in the shares of cohorts entering into these sectors remained lower than the Austrian national average by about 10% points up until the mid-1980s. In the mid-1980s the shares of entering firms in the region gradually began to overtake the national rate. In the 2000s this difference increased quite considerably by 5.5 percentage points, which may indicate a shift to a higher growth phase (Menzel and Fornahl, 2009) of the cluster.

Table 2: Entry of firms into the environmental technology sector

Entry into environmental technology sector in ...	**Austria** % share	**Upper Austria** % share	Difference of Upper Austrian and Austrian share in % points
Up to 1975	17.8	16.1	-1.8
1976 - 1980	9.4	5.4	-4.0
1981 - 1985	11.4	7.1	-4.2
1986 - 1990	10.4	10.7	0.3
1991 - 1995	14.9	16.1	1.2
1996 - 2000	17.8	17.9	0.0
2001 - 2005	12.4	17.9	5.5
2005 -	5.9	8.9	3.0
Total	100.0	100.0	0.0

Source: Special sample from WIFO Environmental Technology Industry surveys

Upper Austrian environmental technology firms entered the environmental technology industry for a variety of reasons (Table 3). Of these, the expectation that markets for environmental products would increase was the most important motivation. This is similar to the biotechnology industry where large firm expectations of a ‘biotechnology revolution’ drove firm investments in the area (Nightingale and Mahdi, 2006). Over time, the importance of market expectations remained relatively high for all firms both national and regional, but increased in importance for Upper Austrian relative to Austrian firms, which confirms our

hypothesis of the growth phase for the local cluster occurring between the 1990s and 2000s and continuing.

Table 3: Main reason for entry into the environmental technology market

Market entry based on:	Austria			Upper Austria		
	1997	2007	% change (1997-2007)	1997	2007	% change (1997-2007)
	% of companies			% of companies		
Market expectations	50.0	46.7	-3.3	40.7	47.2	6.4
Environmental reasons	20.6	25.5	5.0	25.9	28.3	2.4
Technological developments	3.7	14.7	11.0	3.7	15.1	11.4
Competitive strategy	2.2	8.7	6.5	22.2	3.8	-18.4
Laws and regulations	18.4	2.2	-16.2	7.4	0.0	-7.4
Inhouse environmental problems	5.1	2.2	-3.0	0.0	5.7	5.7
Total	100.0	100.0	0.0	100.0	100.0	0.0

Source: Special sample from WIFO Environmental Technology Industry surveys

According to Table 3, laws and regulations, a key initial determining factor of national and local industrial branching into the environmental area declined dramatically in importance for firm entry over this period. This may indicate that regulation was a more important factor initiating the environmental industries, but other economic factors became more important for firm and industry growth over time. Of these, technological developments increased in their importance for both local and national firms, suggesting a phase in which the regional and national innovation systems play a bigger role. A further interesting difference between the environmental industries in Upper Austria and Austria can be identified in the significance of competitive strategy as a factor for firm entry into the environmental technology market. While the importance of competitive strategy as an entry reason increased from 1997 to 2007 for the Austrian environmental technology firms, it strongly decreased during the same period of time for the Upper Austrian environmental technology firms.

Upper Austrian environmental technology firms entered the market through a variety of different ways. Table 4 below shows that the vast majority of environmental technology firms entered the market either through new firm foundation or through a change or expansion of an existing production program. In 2007, more than half of the companies in Austria and Upper Austria entered the market with a start-up. This is also reflected in the young age of member

firms in the Environmental Technology Cluster organisation. The cluster organization offers a variety of services and activities especially relevant for young firms and thus attracts their membership.

Table 4: Ways of entering into the environmental technology market

Market entry via:	Austria			Upper Austria		
	1993	2007	% change (1997-2007)	1993	2007	% change (1997-2007)
	% of companies					
Foundation of company	37.0	54.3	17.3	40.9	54.4	13.5
Foundation or purchase of a subsidiary	4.1	5.3	1.2	4.5	3.5	-1.0
Usage of current production programmes for environmental protection	13.7	9.1	-4.6	22.7	10.5	-12.2
Change or expansion of production program	41.8	29.3	-12.5	31.8	29.8	-2.0
Solution of own in-house environmental problems	2.1	1.0	-1.1	0.0	0.0	0.0
Other reasons	0.0	1.0	1.0	0.0	1.8	1.8
Total	100.0	100.0	0.0	100.0	100.0	0.0

Source: Special sample from WIFO Environmental Technology Industry surveys

Whereas in 2007 a larger share of companies entered the market through a start-up compared to 1993, this share decreased for the expansion of a production program as a form of entry. It appears that new firm foundation is an increasingly important way of entering the environmental technology market. On its own, this indicates favourable growth conditions of this local industry. In this region, regional and national innovation policies in the form of direct government support of firms and through intermediary technical organisations are implemented to encourage growth and counteract decline (Tödtling and Kaufmann, 2002).

Furthermore, the share of companies entering the market through the usage of an existing production program declined from 1993 to 2007 by 12.5% points. In Upper Austria the strongest decline (12.2 % points) for the same time period can be found for the usage of current production programs for environmental protection. The foundation or purchase of a subsidiary, the solution of the own in-house environmental problems and other reasons were

also less important ways of entering the market of both Austrian and Upper Austrian environmental technology firms.

5.3 Structure of the environmental technology industry in Upper Austria

How is the environmental technology industry market in Upper Austria structured? What size are the firms and in which sectors are they active in? In 2007 the vast majority (84.2%) of firms active in the environmental technology industry in Upper Austria were domestic-owned (as shown in Table 5 below). The figures also indicate a trend towards increasing domestic ownership of environmental industry firms. This trend is visible both in the region and nationally. Domestic ownership suggests endogenous technological capabilities and local embeddedness (Granovetter, 1985). A higher degree of embeddedness may affect the ability to network and source knowledge from other firms and organizations in the region positively. Moreover, different types of organisational proximities (Boschma and Frenken, 2010) had a long period of time to be built up in this region, arising from and generating new firm interconnections important for the growth of the local cluster.

Table 5: Firm ownership

Company owned by:	**Austria**			**Upper Austria**		
	1993	2007	Change in % points	1993	2007	Change in % points
Total Austrian ownership	65.6	74.4	8.8	81.8	84.2	2.4
Majority Austrian ownership	7.4	5.3	-2.1	9.1	5.3	-3.8
Majority foreign ownership	27.0	2.9	-24.2	9.1	1.8	-7.3
Total foreign ownership	0.0	17.4	17.4	0.0	8.8	8.8

Source: Special sample from WIFO Environmental Technology Industry surveys

An important indicator of industry structure is firm size. These results, presented in Table 6, show that the majority of local environmental firms are SMEs. The shift from the smaller firms (10-49) to the intermediate segment (50-249) was particularly high in Upper Austria. One explanation for this can be that a number of smaller firms has grown during 2003 and 2007 and can now be found in the higher category. This finding is in line with the high growth rates described in section 5.1. A further interesting characteristic of the firm population, both regionally and nationally, is that approximately 25% have less than 10 employees. However, the proportion of these micro firms grew in Upper Austria while decreasing nationally. These

characteristics are indicative of consolidation of the local industry on the one hand, as well as cluster vitality through small firms and small firm start-ups, on the other.

Table 6: Firm size

Number of employees (2007)	**Austria**			**Upper Austria**		
	in % of companies			in % of companies		
	2003	2007	Change in % points	2003	2007	Change in % points
0 - 9	31,9	24,7	-7,2	29,2	27,4	-1,7
10 - 19	16,0	14,8	-1,1	10,4	8,1	-2,4
20 - 49	21,1	23,4	2,3	29,2	27,4	-1,7
50 - 249	17,4	22,6	5,3	16,7	24,2	7,5
250+	13,6	14,4	0,8	14,6	12,9	-1,7
Total	100,0	100,0	0,0	100,0	100,0	0,0

Source: Special sample from WIFO Environmental Technology Industry surveys

The majority of the Austrian and Upper Austrian environmental technology firms are active in a market with less than 5 competitors (i.e. in an oligopoly), which would be an indicator that the firms are active in small niche markets. However, the share of companies that are in a market with less than 5 competitors has decreased since 1993 for both Austrian and Upper Austrian firms. This could be an indicator that competitiveness, even in the niche markets, has increased over the last couple of years as an increasing number of firms, mainly through start-ups, are entering the market. At the same time the share of companies that is in a market with many competitors has increased from 12.1% to 20.3% for the Austrian firms and from 9.5% to 23.1% for the Upper Austrian firms, in line with the industry life cycle hypothesis (Klepper, 1997). Overall, competition seems to have increased since the beginning of the 1990s and in particular for Upper Austrian firms.

Table 7: Market structure

Number and size of competitors	Austria			Upper Austria		
	1993	2007	Change in % points	1993	2007	Change in % points
Up to 5 competitors	61.2	51.2	-10.0	61.9	46.2	-15.8
Some large, many small competitors	26.7	28.5	1.8	28.6	30.8	2.2
Many competitors	12.1	20.3	8.2	9.5	23.1	13.6
Total	100.0	100.0	0.0	100.0	100.0	0.0

Source: Special sample from WIFO Environmental Technology Industry surveys

Table 8 below shows the product classes of Austrian and Upper Austrian environmental technology firms, providing a good overview of product specialisation and technological variety in the local and national environmental industry. According to the information provided in this table, the majority of environmental technology firms in both Austria and Upper Austria have their products in the field of machinery and equipment, and especially so in the manufacture of other general-purpose machinery, ovens, furnaces and furnace burners, and non-domestic cooling and ventilation equipment. These are areas in which Upper Austria exhibits a specialisation compared to the Austrian environmental technology firms. The technological legacy and path dependence of manufacturing capabilities in these areas is also particularly evident. Another important area is the manufacture of electrical equipment, where Austria shows a higher specialization compared to Upper Austria. Upper Austria, however, features a specialization in the fields of chemicals and chemical products, computer, electronic and optical products and civil engineering. Although Upper Austria -is relatively more active in these fields, they only represent a small share of the regional total.

Table 8: Product classes (NACE)

Product classes (manufacturing)		**Austria 2007**	**Upper Austria 2007**	Share of Upper Austria in % of Austrian Total
		in % of companies		
20	Chemicals and chemical products	3.77	6.33	38.46
22	Rubber and plastic products	1.74	0.00	0.00
23	Other non-metallic mineral products (Glass and glass products, refractory products, …)	2.32	0.00	0.00
25	Fabricated metal products, except machinery and equipment	2.61	0.00	0.00
26	Computer, electronic and optical products	8.41	12.66	34.48
27	Electrical equipment	15.07	12.66	19.23
28 Machinery and equipment				
2811	Engines and turbines, except aircraft, vehicle and cycle engines	2.61	0.00	0.00
2813	Other pumps and compressors	5.22	5.06	22.22
2821	Ovens, furnaces and furnace burners	11.59	16.46	32.50
2825	Non-domestic cooling and ventilation equipment	10.14	11.39	25.71
2829	Other general-purpose machinery	12.75	18.99	34.09
2830	Agricultural and forestry machinery	1.74	0.00	0.00
2892	Machinery for mining, quarrying and construction	1.16	0.00	0.00
2899	Other special-purpose machinery	4.35	5.06	26.67
33	Repair and installation of machinery and equipment	6.67	0.00	0.00
38	Waste collection, treatment and disposal activities; materials recovery	1.16	0.00	0.00
41	Construction of buildings	2.03	0.00	0.00
42	Civil engineering	1.45	5.06	80.00
	Other NACE codes	5.22	6.33	27.78
	Total	100.00	100.00	22.90

Source: Special sample from WIFO Environmental Technology Industry surveys

5.4 Changes in investments and exports

How did the environmental technology firms perform? And how did the markets change? Changes in investments and export ratios are a further important indicator of cluster performance and growth (Porter, 2008). In both the region and nationally, investments decreased in the period 1997-2007, as shown in Table 9 below. However, while in Upper Austria the investment ratio stayed relatively stable at 4.7% in Austria it decreased more than 5 percentage points, from a high investment quota of 8.2% in 1997 to a relatively low investment quota of 3.1%. Increased concentration and growth in Upper Austrian industry relative to the national level is (as in Table 2 in section 5.2), also visible in the switch in investment ratios in the 2000s. While in 1997 Austria outperformed Upper Austria in terms of investment ratios, in the 2000s this was reversed: higher investments were made regionally than nationally overall.

Table 9: Investment and export ratios

	Austria			**Upper Austria**		
	1997	2007	Change in % points	1997	2007	Change in % points
Investment ratio	8.2	3.1	-5.1	4.9	4.7	-0.2
Export ratio	59.6	71.5	11.9	38.2	75.2	37.0

Source: Special sample from WIFO Environmental Technology Industry surveys

The intensification of investments in the region relative to Austria may be explainable by the different times at which the environmental technology industry was entered regionally and nationally. Austria entered the environmental technology industry earlier than Upper Austrian firms. From the life cycle hypotheses we know that in the emergence and growth stage investments are high, whereas at later stages investments decline (Menzel and Fornahl, 2009). It would appear, then, that the environmental technology firms in Austria are at a later stage of the cluster life cycle compared to their Upper Austrian counterparts.

Table 9 above also shows that the export ratios in 2007, both regionally and nationally, were very high at 75.2% and 71.5% respectively. A further important finding that stands out is that in 1997 the Upper Austrian region had a much lower export ratio compared to Austria, and in 2007 overtook it. High levels of exports may be indicative of several aspects of performance

such as technological and production capabilities and closeness to the global technological frontier. Both the big jump in exports as well as the 'forging ahead' above the national level of exports by the Upper Austrian firms is indicative of a definitive shift in the cluster stage from emergence to growth.

Table 10 below shows the results for export markets of the Austrian and Upper Austrian environmental firms. According to these, domestic and EU markets are the most important. The results also show a decrease in importance of these markets, or market saturation, over time. As domestic and EU markets become more saturated both the Austrian and Upper Austrian environmental technology firms have to find other foreign markets for their environmental products and services. A dramatic increase in the importance of South East Asian markets, of 12% between 1997 and 2007, is also evident for the Austrian industry. For the Upper Austrian industry however, China and countries in the 'other' category (probably Latin America) increased in importance during this period.

Table 10: Export markets

Export markets (in % of turnover)	**Austria**			**Upper Austria**		
	1997	2007	Change (%)	1997	2007	Change (%)
Austria	38.8	28.5	-10.3	40.4	26.7	-13.7
EU 15	38.7	34.2	-4.5	29.6	28.9	-0.7
Other Western European countries	1.6	3.0	1.4	1.6	3.9	2.4
New EU member states	9.2	5.6	-3.7	7.7	5.0	-2.7
USA, Canada	3.9	5.2	1.3	0.6	4.1	3.5
South-East Asia	2.4	14.4	12.0	1.3	1.6	0.3
China	2.6	1.8	-0.8	0.0	2.9	2.9
India	0.0	0.6	0.6	0.0	0.0	0.0
Russia	0.0	1.0	1.0	0.0	1.8	1.8
Other countries	2.7	5.7	3.0	18.8	25.1	6.3
Total	100.0	100.0	0.0	100.0	100.0	0.0

Source: Special sample from WIFO Environmental Technology Industry surveys

Overall, the highly competitive products of the domestic environmental technology industry which had benefited from a competitive home market and sophisticated buyers are now

increasingly sold in international markets that face similar environmental costs of rapid industrialisation as Austria and Upper Austria faced in the past.

5.5 Innovation and R&D

Dynamic industries are characterised by high levels of investments in R&D and product innovation. In 2007 investments in R&D of the large Austrian environmental technology firms were high at 9% of total turnover. This is a very high figure for firms in manufacturing, chemicals and electronics industries (from which these environmental industries evolved from), which are normally around 6% (Cohen and Klepper, 1992). As R&D is an important foundation for future growth in the area, it can be expected that the growth phase of the national environmental industries will continue in the future. Moreover, high levels of large firm R&D are also important indications of a well-functioning national innovation system. At the regional level, in contrast, R&D investments in Upper Austria either declined or increased only marginally over the same period. Overall, it may be concluded that environmental industries at the national level are expected to remain innovative, whereas the Upper Austrian firms will continue to reap their growth from increases in sales of existing products and innovations arising from non-R&D spending.

Table 11: R&D intensity (in % of total turnover)

Company size in number of employees	**Austria**			**Upper Austria**		
	2003	2007	Change in % points	2003	2007	Change in % points
up to 9	6.6	7.7	1.1	3.0	1.8	-1.3
10 - 19	6.0	5.7	-0.3	1.2	3.1	1.9
20 - 49	3.8	3.3	-0.5	2.2	3.0	0.7
50 - 249	3.8	3.0	-0.8	6.6	2.0	-4.7
250 and more	6.3	9.1	2.8	3.3	2.6	-0.7
Total	5.6	6.5	0.8	4.2	2.4	-1.8

Source: Special sample from WIFO Environmental Technology Industry surveys

Table 12 below provides details on the innovativeness of these firms, which is regarded an important factor in the cluster and cluster life cycle theories. The percentage of Austrian and Upper Austrian environmental technology firms that generated products new to the Austrian

market decreased by 4.8% for Austria and by 12% for Upper Austria respectively, supporting our previous findings. However, the share of companies that generate product innovations is at 78.7% of the Austrian firms and 78% of the Upper Austrian firms still considerably high.

Table 12: Product innovations

Types of innovation (in % of the companies)	Austria			Upper Austria		
	1993	2007	Change in % points	1993	2007	Change in % points
Product new to the market - Austria	83.5	78.7	-4.8	90.0	78.0	-12.0
Product new to the market - International	60.9	68.4	7.5	83.3	61.0	-22.3

Source: Special sample from WIFO Environmental Technology Industry surveys

This decline in product innovation (new to the Austrian market) was much higher in Upper Austria than in Austria. However, product innovations that are new to the international market show a very interesting but diverging picture. While the percentage of the Austrian companies with new-to-the-international-market innovations increased from 1993 to 2007 by 7.5%, it decreased during the same period of time by 22.3% for the Upper Austrian companies. However, still more than 60% of firms in both Austria and Upper Austria introduced products new to the international market. While in 1993 the share of companies that generated products new to the international market was much higher (83.3% compared to 60.9%), in 2007 the opposite is true, when a higher share of the Austrian environmental technology firms introduced product innovations for the international markets compared to their Upper Austrian counterparts (68.4% of Austrian firms and 61% of Upper Austrian firms). While a larger share of the Austrian environmental technology firms generated radical innovations, the overall level of innovativeness of the industry in both Austrian and Upper Austria declined. However, it has to be mentioned that the innovativeness is still at a high level. The decline in innovations can be seen as an indicator for the growth stage in the cluster life cycle and can have an important impact on the future development of the environmental technology industry in both Austria and Upper Austria. This finding of seemingly decreasing innovativeness of firms in the region requires further investigation.

Table 13: Cooperation during the innovation process

Cooperation during innovation process with:	Austria			Upper Austria		
	1997	2007	Change in % points	1997	2007	Change in % points
	% of companies			% of companies		
Own company alone	57.0	48.8	-8.1	68.8	32.8	-36.0
Together with other companies	27.3	37.8	10.5	15.6	36.1	20.4
Other companies and institutes	4.7	4.1	-0.6	6.3	4.9	-1.3
Parent company and subsidiary	11.0	9.3	-1.7	9.4	26.2	16.9
Total	100.0	100.0	0.0	100.0	100.0	0.0

NB: Multiple responses possible

Source: Special sample from WIFO Environmental Technology Industry surveys

Innovativeness, which is an important factor for the development of an industry, does not exclusively depend on the level of R&D expenditures, but also to a high degree on external knowledge sources (von Hippel, 1986; Freeman, 1988; Lundvall, 1988, 1992; Gertler and Levitte, 2005; Tödtling et al., 2006; Tödtling et al., 2011). Besides the embedding in the RIS, the engagement into innovation networks is considered as an important factor to enhance the innovation of firms. To what extent is this the case? The Austrian and Upper Austrian environmental technology firms generate their innovations predominantly in collaboration with other companies. While the proportion of Austrian companies which generated innovations alone decreased from 57 % to 48.8% in 1997-2007, this decrease was much more dramatic in Upper Austria (from 68.8% to 32.8%). During the same time, firm collaboration for innovation increased from 27.3% to 37.8% for the Austrian companies and from 15.6% to 36.1% for the Upper Austrian companies. For the Upper Austrian environmental technology firms the share of companies which innovate together with their parent company and subsidiary increased from 9.4% in 1997 to 26.2% in 2007. These types of interactions are a common characteristic of clustering and well-functioning innovation systems.

Innovation has clearly become more interactive in Upper Austria. These firms interact more both with other firms and within corporate networks. Firms in Upper Austria, on the one hand, seem to overcome RIS weaknesses by engaging in inter-firm and corporate networks. On the other hand, more generally, the knowledge requirements of current innovation and production of environmental technology industries might at this point in time be prevalent in firms more so than in universities.

6. Conclusion

This paper finds that evolution and convergence to environmental technologies, products and services in the Upper Austria region started in the 1970s from firm capabilities in manufacturing engineering, plastics, electronics and chemicals. Environmental technology firms in Upper Austria featured a strong growth in the past and exhibited higher growth rates relative to the national average. Although the environmental technology industry in Upper Austria appears to have started later, it grew strongly since 1990s and is now in a better position compared to the Austrian environmental technology firms. The region is one of the dominant locations in Austria in terms of number of firms and employees in environmental industries. The main drivers for growth for the Upper Austrian firms were similar to the ones for the Austrian firms, such as pollution, the change in people‘s environmental consciousness, laws, regulations and subsidies (especially from the EU level) that have led to increased demand by mainly traditional industries and created new market opportunities for existing and new firms. The environmental technology firms in the region are also supported by extensive cluster policies addressing local firms such as the two cluster organizations in the field of environmental technology, namely the Environmental Technology Cluster Upper Austria and the Eco-Energy Cluster Upper Austria.

Upper Austria is characterized as an industrial region with strengths in a number of traditional industries such as manufacturing, steel, automotive and plastics. These industries have a high demand for environmental products and services, and Upper Austria also has some strong companies in these industries which are highly demanding and “sophisticated” customers for the environmental technology firms in Upper Austria. These demanding customers forced the firms to innovate, thus creating competitive advantage of the Upper Austrian environmental technology companies. The market leadership in certain areas as well as the competitiveness allowed them to export their products and services to other markets which are in need for these products once the home market was becoming saturated. In recent years the export orientation shifted from geographically close to geographically more distant markets. The environmental technology industry in Upper Austria has developed successfully as shown by the growth of the number of firms, the turnover, number of employees and high export rate. However, the industry has shown signs of moving to or already being in a later stage of the

cluster life cycle which can be seen in the decrease in the investment ratio, R&D intensity and the product innovations.

Menzel and Fornahl (2009) suggest that the emergence of a cluster is characterized by spin-offs. In the Upper Austrian case, the cluster did not emerge from spin-offs only but from the diversification of existing firms into new areas. The firms were already there, the cluster is characterized more by the application of existing engineering capabilities to new problem areas, rather than by spin offs and the creation of new technologies or even a new 'industry'. Rather than large numbers of new start-ups, we find a reorientation of existing firms to new problem areas and new types of products, as well as some new or modified technologies. This is much in line with the "related variety" concept by Frenken et al. (2007). Instead of exhibiting all the characteristics of the stages, we see combinations of different characteristics in the cluster. There are also some new characteristics which are context- and sector-specific, such as regulatory pressure and demand factors regional and national, which may also be considered as factors of emergence which are not addressed by Menzel and Fornahl (2009) in their conceptualization of the first stage of the cluster life cycle.

On the point that technological heterogeneity is a defining characteristic of cluster emergence, the idea of Menzel and Fornahl (2009) can be confirmed by our results. The Upper Austrian region has a considerable degree of technological heterogeneity and sectoral diversity, a significant enabler in this case of environmental technology that is conditioned by technological and sectoral convergence, expansion into new product areas, and incrementally giving rise to new types of clusters.

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