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# Factors for the Emergence and Growth of Environmental Technology Industries in Upper Austria[1)]

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with 13 Tab. in the text

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## *Zusammenfassung*

*Faktoren des Entstehens und des Wachstums von Industrien der Umwelttechnologie in Oberösterreich*

*Umwelttechnologien gelten heute als ein wachsender Wirtschaftszweig, der unter anderem von dringlichen Klima-, Energie- und Abfallproblemen angetrieben wird. Allerdings haben nicht alle Standorte und Regionen diesbezüglich gleich gute Vo-*

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*raussetzungen. Folgt man regionalökonomischen, wirtschaftsgeographischen und Cluster-Ansätzen, kann man feststellen, dass spezifische Faktor- und Nachfragebedingungen, regionale Industriestrukturen und institutionelle Bedingungen eine Rolle spielen sollten. Bislang wurde dies aber nur wenig untersucht.*

*Dieser Beitrag behandelt die Region Oberösterreich, die einen gut entwickelten Umwelttechnologie-Sektor aufweist. Dieser Wirtschaftszweig hat sich hier seit den 1970er Jahren entwickelt und er hat seine Wurzeln in den Branchen Anlagen-, Maschinen- und Instrumentenbau. In den letzten beiden Jahrzehnten ist er stark gewachsen und hat sich auch gewandelt. Der vorliegende Beitrag untersucht die Faktoren und Bedingungen, die seine Entwicklung beeinflusst haben im Vergleich mit der Entwicklung des gesamten Sektors in einer Erhebung, die den Zeitraum 1993 bis 2007 abdeckt. Darüberhinaus wurden explorative Interviews mit lokalen Experten dieses Sektors sowie mit Interessensvertretern durchgeführt und aktuelle Materialien einbezogen.*

*Die Ergebnisse zeigen, dass die Region Oberösterreich in Bezug auf Firmenanzahl und Beschäftigung einer der wichtigsten Standorte dieses Sektors in Österreich ist und dass dieser in Bezug auf Umsatz und Exporte stark gewachsen ist. Dabei konnte der Sektor von bereits ansässigen Wirtschaftszweigen und von Kompetenzen im Anlagenbau profitieren und er wurde auch von zwei Clusterinitiativen der Region unterstützt.*

## *Summary*

*Environmental technologies are considered a growing industry driven by urging climate, energy and waste problems and related regulations, among others. However, not all locations have the same preconditions for its emergence and growth. Based on regional economic, geographic and cluster theories it can be argued that particular factor and demand conditions, regional industry structures and institutional configurations play a role, but so far this has not been sufficiently explored.*

*This paper focuses on the region of Upper Austria [Oberösterreich] that has a highly developed environmental technology industry. The sector has evolved since the beginning of the 1970s with roots in engineering, machinery, and instruments firms and has experienced fast growth and transformation. The paper explores the development of this sector in Upper Austria and the factors and conditions affecting it. Characteristics and performance of the regional industry are compared to the national level. Empirical findings are based on national survey data covering the period 1993–2007, exploratory interviews with local industry experts and stakeholders and recent materials.*

*Findings suggest that the region is one of the dominant locations for environmental technologies in Austria in terms of number of firms and employees and that it has been characterised by high growth and expanding export markets. The sector seems to benefit from pre-existing industries and engineering competences and is supported by two cluster initiatives in the region.*

## 1 Introduction

Environmental technologies are defined by Kemp (1997, p. 11) as "… techniques, processes or products that conserve or restore environmental qualities." This definition includes technologies, products and processes that reduce and repair environmental damage, i.e. damage to water, air, soil, waste, noise and eco-systems (OECD 1999, p. 9). Due to its breadth it encompasses a broad range of industries such as energy, materials, Information Technologies (IT), transportation and recycling, containing a highly heterogeneous mix of firms (Weber 2005). In the present paper, we call the ensemble of these environmental technology related activities "environmental technology sector". Environmental technology clusters, in addition, represent local concentrations of such activities, and they include related activities along the value chain, as well as related knowledge organisations, and supporting industries and services (Porter 2008). In the following, we are focussing on the processes of emergence, growth and transformation of such clusters. By "emergence", we understand the first appearance or setting up of such activities in the respective location, and by "growth" the expansion of the number of firms, employment and sales. "Transformation" refers to a process of structural change, e.g. in the composition of subsectors, firm types, technologies or markets.

Different forms of emergence and growth are observed in this sector. On the one hand, we find the emergence of new industries such as photovoltaics, fuel cells and bio-nanotech. In some cases this can lead to the growth of new clusters that have been studied, e.g., in the literature on "clean-tech" clusters (e.g. Burtis et al. 2004; Cooke 2008). On the other hand, we see shifts and branching of traditional industries such as engineering, machinery equipment, and materials into environmental technology-related products and processes. This latter process of branching has remained underexplored from a cluster perspective. Particular factor and demand conditions, regional industry structures and institutional configurations seem to be relevant, but so far little is known on their role for the emergence, growth and transformation of environmental technology clusters. To address this gap, this paper focuses on an industrial region in Austria that demonstrates technological diversification and industrial branching from traditional sectors into environmental technologies, products and services. The paper uses ideas from the cluster life cycle (CLC) framework, evolutionary economic geography and regional innovation systems literature to investigate emergence and change of the sector in Upper Austria [Oberösterreich]. It addresses the following questions:

- What are the characteristics of the environmental technology sector in Upper Austria, how did it emerge and grow in comparison to the national level industry?
- What regional and higher level factors were underlying its growth and transformation?

We start with a review of conceptual and sector specific literature to the emergence, growth and transformation of clusters. Empirically we use data from Austrian national surveys on the environmental technology industry carried out between 1993 and 2007 to analyse changes in size, structure and composition of the sector in Upper Austria comparing it to Austria. In addition, exploratory interviews with cluster and industry experts were applied to study factors underlying these changes. Findings from these interviews will be used for interpreting results of the survey data analysis.

## 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 has focused on the factors that help to explain why firms in clusters are more competitive than those in non-clustered locations, or why some clusters perform better than others. The factors Porter refers to in his well-known Diamond-model are factor conditions, demand conditions, supporting industries and organisations, and the context for firm strategy and rivalry. Despite there is a role for policy and cooperation among actors he clearly puts more emphasis on the propelling force of competition among 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 been able to develop an 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 organisations 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, growth and transformation over time.

### 2.1 Cluster life cycle

Menzel & Fornahl (2009) provide such a dynamic view by looking at cluster life cycles (CLC). The concept derives from product and industry life-cycle approaches investigating factors underlying change in local industrial clusters. Clusters are said to move through a set of stages (emergence, growth, sustaining, decline, rejuvenation) that show differences in local technological heterogeneity, and in localised learning and innovation capabilities of firms. Key elements and driving factors are actors, networks and institutions that may be inside or outside the cluster, the industry or the region. Driving factors vary by stage, i.e. the factors driving the emergence stage may be different from the ones responsible for growth or maturity.

The exact beginning of clusters is often hard to identify because they may have various historical roots. The authors in this context hypothesise that "clusters are established in those regions where the knowledge bases of companies converge around technological focal points." (Menzel & Fornahl 2009, p. 231) The emergence stage is characterised by start-ups and spin-offs, few and technologically diverse companies, and a supportive science and skills base. 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 United States and the United Kingdom (Saxenian 1994; Keeble & Wilkinson 1999). In the second stage of the CLC, local firms are characterised by growth, increased numbers of start-ups and specialisation of the cluster. However, there is also a shakeout 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 characterised by a relatively stable state and dense networks. External connections, however, may bring in new knowledge and keep networks open. Thematic boundaries are shifting incrementally and the cluster is shaping increasingly its regional environment. In the fourth stage of the cluster – decline – we find a decrease in the number of firms and employment, firm failures, lay-offs and closures, and often too rigid network structures and knowledge relationships. Over-specialisation and structures that are too inflexible to changing requirements of competition might result in a "lock-in" (Grabher 1993; Hassink 2007). The region then 'lags behind' other global regions in the same industrial fields. Under certain conditions, clusters might be able to renew themselves as their companies integrate and apply new knowledge and technologies, and they may enter new growth phases (Tödtling & Trippl 2004; Trippl & Tödtling 2008).

However, these stage characteristics may be difficult to identify in the ideal-typical form, and there may be few clusters in reality that exhibit all of them (Martin & Sunley 2006, 2010). The movement of the cluster through its life cycle is the result of internal cluster elements and activities as well as of external factors. Of key importance is not the size of the cluster but the heterogeneity of knowledge and the way this is exploited. Menzel & Fornahl (2009) support their conceptual model of cluster development through a broad literature review and give examples from various industries and regions. However, no specific reference is given to the environmental technology industry, although their frame certainly has some relevance for it.

## 2.2 Evolutionary Economic Geography

The Evolutionary Economic Geography approach also helps to understand the emergence and development of industries in certain regions. It argues that these often emerge from and follow particular paths that are rooted in pre-existing industrial and institutional structures of regions (Martin & Sunley 2006, 2010). In the centre are evolutionary processes of firm variation and creation that are related to already existing industrial trajectories. In this context Frenken et al. (2007) and Boschma & Frenken (2011) have suggested that particularly those industries emerge and grow that are in their knowledge-base related to other existing sectors in the region. Competences can be transferred from old to new sectors through various modes, e.g. through the branching of firms, spin-offs, and the mobility of entrepreneurs or of qualified labour. Such situations of "related variety" are regarded as more favourable for industry performance than specialisation or unrelated diversity. Cooke (2012) has applied concepts of path development to the study of "clean-tech" industries in Denmark and Sweden. He considers "transversality" (which is a more active and social agency-driven dimension of the rather passive notion of related variety) and platforms of innovation (characterised by horizontal knowledge flows between sectors) to be 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 [Nordjylland] (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 bio-fuels, bio-chemicals, substitute cotton, food and construction materials).

### 2.3 Regional innovation system (RIS)

The regional innovation system (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 organisations – universities and schools, and intermediaries, among others. There is a strong role of formal and informal institutions as well as of government bodies (Cooke et al. 2000, 2004; Doloreux 2002; Tödtling & Trippl 2005). Thematically there is a narrower focus on innovation, however. By including the broader set of industries and knowledge organisations 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 & Trippl 2012). Cooke (2010) has distinguished between "entrepreneurial" and "institutionally based" RIS and applied the concept in addition to an evolutionary perspective to the environmental technology industry in the Danish North 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 North Jutland eco-energy industry is the result of a systemic interplay of interrelated companies, suppliers, knowledge organisations and policy agents.

Clusters, thus, are composed of firms, universities, and government organisations, whose learning processes, interactions and relationships are considered to move the cluster along a path of emergence, growth and decline (Menzel & Fornahl 2009). Localised value-adding interactions between firms and knowledge organisations are considered to be embedded in regional innovation systems (Cooke 2010; Tödtling & Trippl 2012), whose systemic properties and institutions shape the firms' learning conditions, innovation and growth. In the evolutionary view, clusters change through emergent processes, characterised by variations in firm population, their technological heterogeneity, and the degree of specialisation. We will use these different concepts of cluster change for interpreting empirical results in section 4. The following section 3.1 provides a literature-based background to the environmental technology sector and to the factors that have influenced its emergence and growth in the region of Upper Austria (section 3.2).

## 3 Sectoral and regional background

### 3.1 Environmental technology sector

Environmental technologies in Western Europe can be traced back to the early 1970s, when pollution problems from heavy manufacturing spurred the creation of end-of-pipe products for their abatement (OECD 1999; WEBER 2005). During these initial years, firms were selling to small domestic markets to solve such problems, as in North-Rhine Westphalia [Nordrhein-Westfalen] in Germany (HILBERT et al. 2004). In the 1980s and 1990s, the emerging ICTs and other high-tech industries brought on new technologies focusing on resource efficiency. This allowed environmental technology industries related to manufacturing to shift towards more integrated, clean and process-oriented technologies and products (*www.umweltcluster.at*). End-of-pipe products continued to be prominent although they became more difficult to be differentiated from process technologies (FRONDEL et al. 2007). In the 2000s the integration of diverse technology areas such as ICTs, biotechnology, nanotechnology, and materials science into process-based environmental technologies continued, aiming for resource conservation, energy efficiency and pollution abatement within the production process itself. These have been called 'sustainable' technologies (WEBER 2005; FRONDEL et al. 2007). At the regional level, these processes are reflected in transitions of manufacturing industries towards cleaner production, the convergence of environmental and high-tech industries, and the emergence of 'cleantech' clusters notably in Germany and in the United States (COOKE 2008).

Societal challenges such as environmental pollution, unsustainable resource use and emerging resource scarcities, thus, have an essential role for the development of the environmental technology industries. To some extent, these concerns have found their way into regulations for environmental standards, penalising firms for not meeting them (PORTER & VAN DER LINDE 1995; JAFFE et al. 2002). Moreover, environmental protection has increasingly become a broader societal and policy concern in many countries in addition to goals of economic efficiency and profitability (SIMONIS 1989; KEMP 1993; MOL 1997). Overall, this pattern is to some extent different from other industries for which more traditional economic factors such as skills, capital, supply and demand are considered to be the main drivers for growth. However, these latter factors are also relevant for the development of the environmental technology industries.

### 3.2 Factors underlying the development of environmental technology industries in Upper Austria

In Austria, environmental technologies and environmental policy have a relatively long history. Environmental issues have been taken into account to a certain extent in industrial production, agriculture, transport, spatial planning, education, and economic policy since the early 1970s. Environmental concerns have in particular been taken up in industrialised regions such as Upper Austria, which is nowadays one of the leading regions in Austria. Industrial branching and development of environmental industries began also in the 1970s, but the industry has grown faster later on compared to the rest of Austria. The present section investigates how the environmental industries in Upper Austria have developed, and which factors have shaped their emergence and growth. The intention is to provide a background for the data analysis in section 4. We rely on existing studies, own previous analyses of the region as well as on face-to-face interviews with regional and national industry experts and stakeholders.[2)]

Upper Austria is a relatively large province with 1.4 million inhabitants, covering 11,980 km$^2$ and sharing borders with German Bavaria [Bayern] and Czechia. In 2009 its GDP per capita was 33,920 €, slightly higher than the 33,600 € Austrian average (Eurostat). Its economy is based on manufacturing, with strengths in steel production, machinery, mechanical engineering, vehicles and chemicals, among others. Upper Austria's regional innovation system (RIS) comprises universities, colleges and research organisations in different fields, but the number and quality of these knowledge organisations are clearly lower compared to Vienna [Wien], or to Styria [Steiermark], another industrial region in Austria. The region exhibits high private (business), but low public R&D activities. There are intensive links between business and academia and the RIS appears to be well-networked (Tödtling et al. 2011). This is partly due to support organisations such as the Upper Austrian Business Agency (TMG Group) as well as a number of cluster organisations.

Although the growth in the environmental technology industry is driven by similar factors as elsewhere in Austria, some are specific to the region. The roots of the Upper Austrian environmental technology firms are predominantly in engineering, machinery and instruments sectors and firms, which have, based on their technical competencies, been branching into these areas. Firms have applied and further developed their existing capabilities to the production of environmental technology products. Relying predominantly on a synthetic knowledge base (i.e. innovating by recombining existing knowledge: Asheim et al. 2011) and a DUI mode of innovation (i.e. innovating by "doing, using and interacting": Johnson et al. 2002), firms have integrated environmental solutions into their product range, trying to gain competitive advantages through such innovations (De Marchi 2012). The strongest areas are renewable energy, energy efficiency, water and waste. Emergence and growth in these technologies in Upper Austria is attributed to a number of factors.

Similarly to the Ruhrgebiet in Germany (Hilbert et al. 2004), pollution problems caused by manufacturing industries were an important driver. Contamination of air, water and soil by heavy industries prompted local activism for its reduction and control. VOEST, a leading global steel producer located in the region, has been one of the key polluters during the years of high growth in the 1960s and 1970s. Local protests

[2)] We conducted five 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 Organisation for Environmental Concerns and the Environmental Department of the Provincial Government of Upper Austria.

pushed the firm and the industry towards the reduction of emissions and wastewater. Regulations and policies for pollution control in manufacturing were further factors gaining momentum during this period (Pirgmaier 2011). Such regulations were implemented in particular at national and EU levels setting incentives for searching for new solutions to reduce pollution. It also created demand for environmental technology products. Existing industries in Upper Austria were able to produce such technologies, e.g. gas furnaces with reduced emissions were both manufactured and applied in local industries. Existing technological capabilities, supply chains and sophisticated local buyers (such as steel and engineering firms), stressed, e.g., by Porter (1990, 2008), were, thus, essential factors for the emergence and growth of these new product lines and technology areas such as air purification, energy recuperation and energy efficiency.

A key factor for the growth and transformation of the Upper Austrian environmental technology sector, furthermore, seems to be a well-performing regional innovation system (Tödtling et al. 2011). Highly qualified employees and a good skills base enhance the absorptive capacity and innovation capabilities of firms as stressed by Cohen & Levinthal (1990), Lam (2000, 2002) and Zahra & George (2002) among others. With regard to knowledge generating organisations, 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 as knowledge providers for local firms. Nevertheless, the region is characterised by rather weak knowledge infrastructure in general, when compared to other regions such as Vienna or Styria. This finding has been confirmed by most interview partners, some of them even working in respective organisations.

Furthermore, Upper Austria has two related cluster initiatives that are offering a number of services to their member firms. The membership in both cluster organisations is open to outside firms and organisations as well, as complementary knowledge and competence from external partners are considered important for cluster development and innovation (Mytelka 2000; Wolfe & Gertler 2004; Gertler & Wolfe 2006). These cluster organisations are key focal points for fostering horizontal platform-type linkages between relevant knowledge organisations and firms (Cooke 2008), and for enhancing cluster 'openness' and branching into related industries (Tödtling et al. 2011).

The first, the Eco-energy Cluster Upper Austria, was founded in 2000 by the Upper Austrian Energy Efficiency Association and focuses on areas such as renewable energy and eco-efficiency. In 2012, it had 164 members (firms and organisations), all of which are located in Upper Austria. However, the cluster has also partners in Bohemia [Čechy] (Czechia) in order to expand its scope beyond the region. Member firms in this cluster organisation are relatively old (the average age is 31 years), which can be explained by the fact that rather traditional firms and industries are represented in the Eco-energy Cluster.

The second cluster initiative, the Environmental Technology Cluster Upper Austria, was founded in 2006 by the Upper Austrian Business Agency (TMG Group). It focuses on activities related to resource efficiency, water, waste, soil and air. In 2012, the organisation recorded 136 firm members, 91 of which were located in Upper Austria and the remainder in other Austrian regions and internationally (notably Germany). 80% of the cluster organisation members are environmental service firms. Member firms are rather young with an average age of 16 years. The cluster organisation, according to our interviews, has been important in particular for supporting start-ups and young firms in the past few years.

## 4 Characteristics and change of the environmental sector in Upper Austria: Empirical findings

To what extent does the environmental technology sector in Upper Austria differ from the sector in Austria as regards the structure, markets, growth, and innovation activities? Is it performing better than the sector overall as the cluster theory would suggest? In order to find this out we compare the sector in the region with the Austrian aggregate, using a series of surveys carried out by the Austrian Institute for Economic Research (WIFO)[3)] for the environmental technology sector in Austria. The present analysis is based on special samples for Upper Austria from these national surveys. They started in 1995 and have since then been conducted in 1998, 2005 and 2008, respectively. Whereas some variables were covered in all of the surveys, other indicators were introduced only in later surveys. This implies that we cannot observe all indicators for the whole period. In the following tables, thus, we present all indicators for the last survey (2007), although the starting year may vary (i.e. 1993, 1997, 2003). The response rates were in average about 40% and fluctuated only slightly between 1995 (41.9%), 2000 (40.3%), 2005 (43.6%) and 2008 (39.3%). Response rates varied between regions (i.e. provinces), ranging from 25% to 60%, with Upper Austria having the highest shares (Kletzan-Slamanig & Köppl 2008). One reason for this was the involvement of regional cluster organisations in the surveys. For more details on these surveys and results for Austria see Köppl & Pichl (1995), Köppl (2000, 2005), and Kletzan-Slamanig & Köppl (2008).

As regards the size of the Upper Austrian environmental technology sector we find that in 2007 there were 105 firms employing more than 6,000 people with a turnover of 1.81 billion € (see Tab. 1). They represent 28% of firms and employment and 30% of turnover of the respective Austrian totals. These figures indicate clearly over-proportional shares of Upper Austria in the overall sector of Austria. This shows, thus, a concentration of this industry in the study region or of a cluster in the sense of Porter (1998). Table 1, furthermore, indicates strong growth of the sector in Upper Austria between 1993 and 2007. The number of firms has more than doubled (+133%), employment has grown by a factor of about 3 (+286%), and turnover by a factor of almost 8 (+762%). This demonstrates growth not just in the number of firms, but also in average firm size. The 8-fold increase in turnover reveals also strong productivity increases in this period. Overall, these findings are in line with characteristics of a cluster in the growth phase as indicated by Menzel & Fornahl (2009). Looking at the Upper Austrian shares of the Austrian totals regarding these indicators we can see that

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

the environmental technology sector in Upper Austria grew also stronger in relative terms since the respective shares increased from 14–18% to 28–30%. We can conclude that the sector grew in the region about twice as fast as in Austria.

| | 1993 | | 2007 | | Growth rate (%) | Change in share of Austrian total (%-points) |
|---|---|---|---|---|---|---|
| | 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 | 1.810 | 30 | 762 | 16 |
| Employees | 1.593 | 14 | 6.147 | 28 | 286 | 13 |
| Export ratio (1997) | 59 | - | 70 | - | 19 | - |

Source: Special sample from WIFO Environmental Technology Industry surveys

Tab. 1: Size of the environmental technology industry in Upper Austria (estimate)[4)]

These figures suggest that (1) there is a growing environmental technology cluster in the region (above average shares of firms and employment), and (2) that in this period the cluster has clearly outperformed the industry in Austria (strong growth of turnover, employment and export rates). Between 1993 and 2007 we find, thus, a cluster in the growth phase characterised by the establishment of new firms, employment growth, strong production expansion, and increased exports (as suggested by Audretsch & Feldman 1996; Bathelt 2001; Menzel & Fornahl 2009).

### 4.1 Entry into the environmental technology sector

When did the environmental technology sector in Upper Austria emerge and develop? Which motives and modes of entry by the firms can we observe?

The entry of Upper Austrian local firms into the environmental technology sectors, presented in Table 2, gives an indication of the period in which cluster formation has become more visible in the region. Until 1975, the share of firm entries into environmental technologies was relatively similar in Upper Austria and at the Austrian average, showing no signs of clustering. Indeed, the shares of cohorts entering into the sector remained lower by about 10%-points in the study region than at the Austrian average up to the mid-1980s. Subsequently, 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 and 3 percentage points, indicating a growth phase of the cluster in the region (Menzel & Fornahl 2009). Environmental technology industries in Upper Austria, thus, started at a slower pace, but grew more rapidly since the 1990s.

4) Table 1 represents an estimate of the total size/population of the Austrian and Upper Austrian environmental technology industry ("Hochrechnung"). It differs from the rest of the tables in this section that are mere aggregates of the survey data.

| Period of entry into environmental technology sector | Austria | Upper Austria | Difference of Upper Austrian and Austrian share in %-points |
|---|---|---|---|
| | % share | % share | |
| 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

Tab. 2: Entry of firms into the environmental technology sector (% of firms)

Why did firms enter into the sector? Upper Austrian firms entered the environmental technology industry for a variety of reasons (see Tab. 3). Of these, the expectation that markets for environmental products would increase was the most important motivation followed by "environmental reasons". This is similar to the biotechnology industry, where expectations of a 'biotechnology revolution' and market opportunities drove firm investments in this field (NIGHTINGALE & MAHDI 2006). Over time, this market motive even increased in importance for Upper Austrian firms confirming our findings of a cluster in the growth phase in this period.

| Market entry based on: | Austria | | | Upper Austria | | |
|---|---|---|---|---|---|---|
| | 1997 | 2007 | change in % points | 1997 | 2007 | change in %-points |
| | % 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

Tab. 3: Main reason for entry into the environmental technology market (% of firms)

Interestingly enough, laws and regulations, a key initial determining factor of branching into environmental industries declined in importance for firm entry over this period. Obviously, regulations were an important factor in the early phase of sector development, but other factors became more important for firms entering later on. Of these, technological developments (or opportunities) increased in their relevance for both local and national firms, suggesting that regional and national innovation systems started to play a bigger role.

How did firms enter the industry? Table 4 shows that the vast majority of firms entered the market either through a start-up process or through change or expansion of an existing production program. In 2007, more than half of the companies in Austria and Upper Austria responded to have entered the market via start-up. This is also reflected in the young age of member firms in the Environmental Technology Cluster organisation.

| **Market entry via:** | **Austria** | | | **Upper Austria** | | |
|---|---|---|---|---|---|---|
| | **1997** | **2007** | **change in %-points** | **1997** | **2007** | **change in %-points** |
| | **% of companies** | | | **% 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

Tab. 4: Ways of entering into the environmental technology market (% of firms)

Whereas the frequency of entry through a start-up has increased from 1993 to 2007, its share decreased for the use of existing production programs as a form of entry. This indicates that products and customer needs have become more specific, requiring new solutions instead of available products and technologies. New firm formation, thus, is an increasingly important way of entering the environmental technology market. On its own, this indicates favourable conditions for start-ups and firm growth in the local cluster. In addition, specific measures of cluster support (see section 3.2) as well as regional and national innovation policies were implemented to encourage firm formation, innovation and growth (Tödtling & Kaufmann 2002; Tödtling et al. 2011). In contrast, the foundation or purchase of a subsidiary, the solution of own in-house environmental problems and other reasons were less important ways of entering the market of both Austrian and Upper Austrian environmental technology firms.

## 4.2 Structure of the environmental technology industry in Upper Austria

How is the environmental technology sector in Upper Austria configured? What ownership types and firm sizes can we observe and in which industries are they active? As regards ownership, we find that in 2007 the vast majority (84.2%) of firms active in the sector in Upper Austria were totally domestic-owned (see Tab. 5). Domestic ownership was smaller for Austria but also reached 74%. Furthermore, both in Austria and the study region domestic ownership increased between 1993 and 2007. As regards foreign ownership, a shift from majority holding to total ownership can be identified, but the respective share stayed below 10% in the study region. These findings indicate vital endogenous firms in the region suggesting local technological capabilities and a certain degree of regional embeddedness (Granovetter 1985). This may positively affect networking and knowledge relations of firms in the region and beyond.

| 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

Tab. 5: Firm ownership (in % of firms active in the environmental technology sector)

As regards firm size, Table 6 shows that more than 60% of environmental technology firms both in Austria and the study region are small firms with less than 50 employees. Another 23–24% of firms are of intermediate size (between 50–249). In the observed period from 1993 to 2007, we can observe a shift from small towards intermediate firms for both Austria and the region. The shift from smaller firms (10–49) to the intermediate segment (50–249) was particularly marked in Upper Austria. Obviously, a number of small firms has expanded their business and are now to be found in the next category. This finding is in line with the high growth rates of employment and sales described before.

| Number of employees (2007) | Austria in % of companies | | | Upper Austria 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

Tab. 6: Firm size (employment-size classes in %)

The majority of Austrian and Upper Austrian environmental technology firms are active in a market with less than five competitors (i.e. in an oligopoly), indicating a focus on highly specialised niche markets (see Tab. 7). However, the share of such companies has decreased since 1993 for both Austrian and Upper Austrian firms. The level of competition obviously increased in this period as many firms were entering the market. This is also reflected in an increasing share of companies that are in a market with many competitors rising from 12.1% to 20.3% in Austria and from 9.5% to 23.1% in Upper Austria. This finding is basically in line with the industry life cycle hypothesis (Klepper 1997). Overall, both in Austria and the region firms appear to be confronted with an intensified competition since the 1990s.

| 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

Tab. 7: Market structure (% of firms)

Table 8 shows the product classes of Austrian and Upper Austrian environmental technology firms, indicating the pattern of product specialisation and technological variety in the local and national environmental industry. According to the data, most of the environmental technology firms in both Austria and Upper Austria have their products in the field of machinery and equipment, and especially 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 the region are here particularly evident. Furthermore, Upper Austria features a specialisation in the fields of chemicals and chemical products, computer, electronic and optical products and civil engineering, areas that have more recently grown in the region. Although regional firms are relatively more active in these fields, they represent only small shares of the regional environment technology sector. Another important area is the manufacturing of electrical equipment, but here Austria shows a higher specialisation in comparison.

| Product classes (manufacturing) | | Austria 2007 | Upper Austria 2007 | Share of Upper Austria in % of Austrian total |
|---|---|---|---|---|
| | | in % of companies | | |
| 20 | Chemicals and chemical products | 3.8 | 6.3 | 38.5 |
| 22 | Rubber and plastic products | 1.7 | 0.0 | 0.0 |
| 23 | Other non-metallic mineral products (Glass products, refractory products…) | 2.3 | 0.0 | 0.0 |
| 25 | Fabricated metal products, except machinery and equipment | 2.6 | 0.0 | 0.0 |
| 26 | Computer, electronic and optical products | 8.4 | 12.7 | 34.5 |
| 27 | Electrical equipment | 15.1 | 12.7 | 19.2 |
| 28 Machinery and equipment | | | | |
| 2811 | Engines and turbines, except aircraft, vehicle and cycle engines | 2.6 | 0.0 | 0.0 |
| 2813 | Other pumps and compressors | 5.2 | 5.1 | 22.2 |
| 2821 | Ovens, furnaces and furnace burners | 11.6 | 16.5 | 32.5 |
| 2825 | Non-domestic cooling and ventilation equipment | 10.1 | 11.4 | 25.7 |
| 2829 | Other general-purpose machinery | 12.8 | 19.0 | 34.1 |
| 2830 | Agricultural and forestry machinery | 1.7 | 0.0 | 0.0 |
| 2892 | Machinery for mining, quarrying and construction | 1.2 | 0.0 | 0.0 |
| 2899 | Other special-purpose machinery | 4.4 | 5.1 | 26.7 |
| 33 | Repair and installation of machinery and equipment | 6.7 | 0.0 | 0.0 |
| 38 | Waste collection, treatment and disposal activities; materials recovery | 1.2 | 0.0 | 0.0 |
| 41 | Construction of buildings | 2.0 | 0.0 | 0.0 |
| 42 | Civil engineering | 1.5 | 5.1 | 80.0 |
| | Other NACE codes | 5.2 | 6.3 | 27.8 |
| Total | | 100.0 | 100.0 | 22.9 |

Source: Special sample from WIFO Environmental Technology Industry surveys

Tab. 8: Product classes (NACE codes; % of companies)

### 4.3 Investments and exports

Changes in investments and export markets are further indicators of cluster performance and growth (Porter 2008). In both the region and the country, we find a slowing-down of growth in the period 1997–2007, since investment ratios decreased, as shown in Table 9. However, while in Upper Austria the investment ratio went down only slightly to 4.7%, it decreased in all of Austria from a high 8.2% in 1997 to a low 3.1% in 2007.

| | 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

Tab. 9: Investment and export ratios (in % of total turnover)

As regards export markets, Table 9 shows that the export ratios in 2007, both regionally and nationwide, were very high at 75.2% and 71.5%, respectively. In 1997, the Upper Austrian firms had, in fact, a much lower export ratio compared to Austria as a whole, whereas in 2007 they were superior. High levels of exports are indicative of several aspects of company performance such as technological capabilities and a high product quality. Both the big jump in export rates and the overtaking of the national level are indicative of the high level of competitiveness of the Upper Austrian firms in 2007.

Table 10 shows the geography of markets. We find that domestic and EU markets are the most important ones. The results, however, also indicate a decrease in the relative importance of these markets from 1997 to 2007. As domestic and EU markets became more saturated, both the Austrian and Upper Austrian environmental technology firms had to find new foreign markets for their environmental products and services. To some extent, they were 'going global'. For the Austrian sector, a strong increase of 12%-points in the share of South East Asian markets is evident. For Upper Austrian firms, China and 'other' countries (e.g. in Latin America) have increased in importance during this period.

Overall, the region's environmental technology firms had benefited from sales to domestic clients in an earlier phase. Over the study period, they seem to have become more competitive and were able to expand to international markets.

| Export markets | Austria | | | Upper Austria | | |
|---|---|---|---|---|---|---|
| | 1997 | 2007 | Change (%) | 1997 | 2007 | Change in %-points |
| 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

Tab. 10: Geography of markets (in %)

### 4.4 Innovation and R&D

The competitiveness of firms and the opening up of new markets is often linked to R&D and innovation. Both indicators are also relevant from an industry or cluster life-cycle perspective (Klepper 1997; Menzel & Fornahl 2009). High R&D and innovation intensities are expected for early stages of the cycle, and lower ones for more mature stages (Maier, Tödtling & Trippl 2012). Table 11 shows the R&D intensity of firms (R&D expenses in % of turnover) by firm size for Austria in total and the study region.

| 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

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

We find some surprising results: Firstly, in 2007 Upper Austrian environmental technology firms have in all size classes lower R&D intensities than firms in Austria. Secondly, R&D intensities in Upper Austria have decreased between 2003 and 2007 in most size classes and in the aggregate (from 4.2 to 2.4%). Since R&D expenses cover only inputs to the innovation process, we will also look at (product) innovations introduced by the firms. In this case, the data cover a longer period (1993 to 2007).

| **Types of innovation** | **Austria** | | | **Upper Austria** | | |
|---|---|---|---|---|---|---|
| | **1993** | **2007** | **Change in %-points** | **1993** | **2007** | **Change in %-points** |
| Product new to the Austrian market | 83.5 | 78.7 | –4.8 | 90.0 | 78.0 | –12.0 |
| Product new to the international market | 60.9 | 68.4 | 7.5 | 83.3 | 61.0 | –22.3 |

Source: Special sample from WIFO Environmental Technology Industry surveys

Tab. 12: Product innovations (in % of responding companies)

Table 12 presents the shares of firms that have introduced products that are new to the Austrian and international markets. We find a decline in the share of firms for both types of product innovations for Upper Austria, whereas an increase for products new to the international market in the case of Austria in total can be observed. These findings indicate an unexpected low innovation performance of the firms in Upper Austria in 2007 in comparison to all of Austria. This might be due to several reasons:

1) Upper Austrian environmental technology firms might be more often in the growth or even maturity phase of the cycle than firms in the rest of Austria. In these later phases the emphasis is said to be more on production, sales and market growth, e.g. through productivity increases, scale economies and new distribution channels, than on R&D and innovation. This, in fact, would be in line with product and industry life-cycle arguments (Klepper 1997).
2) The findings might also reflect the fact that the Upper Austrian RIS lacks technical universities and R&D organisations (Tödtling & Kaufmann 2006; Tödtling et al. 2011) and that the regional business environment does not support R&D-based innovation, e.g. if compared to the regions of Styria or Vienna.
3) Firms in Upper Austria seem to rely to a higher extent on a synthetic knowledge base and a DUI mode of innovation than on R&D and analytical knowledge (Asheim et al. 2011). This implies a focus on new combinations of knowledge and technologies and on incremental innovations that are based on tacit knowledge and qualified labour.

We should take into account, however, that we are interpreting only the relative differences and changes in comparison to Austria and that the level of innovation is still rather high in the study region, since more than 60% of firms have reported to have introduced products new to the international market in 2007. Still, the finding of relatively lower and decreasing innovativeness of environmental technology firms in Upper Austria requires further investigation and has been taken up in a firm survey carried out in a second step. Preliminary findings support our results above and suggest that the application and modification of technologies is more important than the creation of radical innovations.

Finally, the innovativeness of firms does not exclusively depend on the level of internal R&D expenditures, but also on external knowledge (von Hippel 1986; Freeman 1988; Lundvall 1988, 1992; Gertler & Levitte 2005). Besides the embeddedness in the RIS, the engagement into innovation networks is considered as an important factor for accessing such external knowledge and for enhancing the innovation performance of firms (Tödtling et al. 2006; Tödtling et al. 2013a; see Tab. 13).

| 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 |

Source: Special sample from WIFO Environmental Technology Industry surveys

Tab. 13: Cooperation during the innovation process (in % of responding companies, multiple responses possible)

Table 13 shows that Austrian and Upper Austrian environmental technology firms generate innovations increasingly in collaboration with other companies. For Austria the proportion of companies generating innovations alone decreased from 57% to 48.8% from 1997 to 2007, but this decrease was much stronger in Upper Austria (from 68.8% to 32.8%). In contrast, 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. This finding is in line with results from the recent CRA project, where Upper Austrian ICT companies turned out to be well connected in order to source external knowledge (Tödtling et al. 2013b).

For the Upper Austrian environmental technology firms, in addition, the share of companies that innovate together with their parent company or subsidiary increased from 9.4% in 1997 to 26.2% in 2007. This might be indicative of an increasing number of national or international corporations that are locating in the region or taking over existing companies. These types of interactions are also relevant indicators for cluster links and knowledge sharing. Innovation in the environmental technology sector, thus, has clearly become more interactive in Upper Austria and firms interact more with other firms and within corporate networks. Companies in Upper Austria seem to overcome RIS weaknesses by engaging in inter-firm and corporate networks.

## 5 Conclusions

The development of the environmental technology sector in Upper Austria is strongly based on traditional industries in the region such as mechanical engineering, steel, and chemicals. On the one hand, these industries contributed specific skills and technological capabilities, on the other they generated demand for products and services in order to deal with environmental problems such as pollution of air, soil and water they had caused. This created pressure and opportunities to invest in environmental technologies. Some leading companies such as the steel producer VOEST have been acting as "demanding customers" asking environmental technology firms to come up with innovative and appropriate solutions. In addition, policy had a strong impact on the development of the sector in Austria and the region. There have been environmental laws, regulations and subsidies at the national as well as the European level. Since the 2000s, there were two cluster organisations established in Upper Austria, aiming at supporting firms in the region and beyond.

Although the environmental technology sector in Upper Austria appears to have started later, it grew more strongly since the 1990s in comparison to the national level. There was strong growth of the number of firms, employees and turnover. In 2007, the region turns out to be one of the dominant locations in Austria in this sector. The competitiveness of the firms and the market leadership in certain areas allowed them to export their products to European and global markets. The firms in the environmental technology sector are in general quite innovative, although the R&D intensity in Upper Austria is lower than in Austria. Innovation in the study region seems to follow a DUI ("doing, using and interacting") mode of innovation relying on a synthetic knowledge base (Asheim et al. 2011), reflecting the dominant sectors (machinery, engineering) and relative low public research capacities of the Upper Austrian RIS.

Our data for the study region were available only up until 2007, so the question arises how the Environmental Technology sector has performed since 2008, the year of the major economic crisis. From the most recent study by Köppl et al. (2013), we can see that at the Austrian level this sector has clearly outperformed the rest of manufacturing and the overall economy in the years from 2008 to 2011. We find that sales of the environmental technology sector have increased from 6 to 8.2 billion Euros and exports from 4 to 6 billion Euros enhancing the export share of this sector further from 66% to 73%. Moreover, employment increased in this recent period from about 22,200 to 28,600, and labour productivity by 6.1%. Obviously, international demand for environmental technology products has further grown and Austrian firms were able to compete successfully on these markets. Although there is no regional data available for this latest period, there are good reasons to assume that also the Upper Austrian environmental technology firms were able to participate in this growth, since in particular subsectors well-represented in the region such as energy-related technologies and measurement & control technologies were growing most strongly.

Overall, we find in our study both similarities and differences to the cluster-life-cycle model proposed by Menzel & Fornahl (2009). Whereas the model suggests that the emergence of a cluster is characterised by start-ups and spin-offs, we find in our case rather the evolutionary branching of existing firms into new areas as an important mechanism. The application of their engineering capabilities to new environmental problem areas and demands by those firms, rather than the creation of new technology-based firms and spin-offs has characterised the emergence phase. We find a re-orientation of existing firms towards new but related fields, and new types of products, based on modified technologies. This is much in line with the "related-variety" concept by Frenken et al. (2007) describing the evolutionary emergence of new industries out of existing ones. Furthermore, instead of exhibiting all the characteristics of the stages, we see a less clear-cut picture. Some characteristics are sector-specific, such as regulatory pressure at regional and higher levels, which were relevant as factors of emergence, but less emphasised by the CLC model. However, the argument by Menzel & Fornahl (2009) that technological heterogeneity is a defining characteristic of cluster emergence can be confirmed by our results. The Upper Austrian region has a considerable degree of technological heterogeneity and sectoral diversity, which is a significant enabler for the development of environmental technologies. The growth of this sector in Upper Austria has been made possible by the convergence and bridging of diverse technologies and industries, the expansion of firms into those new product areas, as well as a supportive institutional setting in the region for this new type of industry.

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