Alexander Auer, Franz Tödtling

Driving factors and spatial scales for cluster development - The case of environmental technologies in Upper Austria

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Alexander Auer[1], Franz Tödtling[2]

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Email: Alexander.Auer1@wu.ac.at, Franz.Toedtling@wu.ac.at,

[1], [2]Institute for Multi-Level Governance and Development, Vienna University of Economics and Business, Welthandelsplatz 1, 1020 Vienna, Austria.

The environmental technology industry is considered generally as a growing industry driven by urging climate-, energy- and waste problems, regulations and increasing environmental consciousness, among others. Upper Austria often referred to as an industrial region features a heterogeneous group of environmental technology firms that are outperforming other regions in Austria in terms of firm numbers and employees in this sector. Following the main theoretical approaches on cluster life cycles and cluster evolution this paper examines factors on firm and cluster level on different spatial scales that have affected the emergence and evolution of individual environmental technology enterprises and its cluster in Upper Austria. The aim of the paper is to get a profound understanding of the relevance of these factors and to evaluate their development over time. The paper uses primary data from 30 face-to-face firm interviews with managerial staff.

Preliminary results suggest that factors relevant for the development of Upper Austrian environmental technology firms geographically shift and change over. Location factors that caused firms to settle in Upper Austria show a rather strong connectivity of the company founder to the region. Hence, personal factors and partners in the region are more relevant compared to other factors. At a later stage, factors such as skilled labour and networks become more important on regional level whereas other factors such as demand, regulations and public support initiatives are more relevant on national and international levels. From an evolutionary perspective factors such as demand and corporate partners become nationally and internationally more important over time, others that are mostly associated with knowledge transfer remain on the regional scale. Overall, we find tendencies of growth and geographically enlarged interaction scales of the Upper Austrian environmental technology cluster as well as a certain persistence of related ties to the regional and national innovation system.

1) Introduction

Environmental technologies are considered to contribute to several socio-economic and political challenges (Weber, 2005). With the growing societal awareness and the need for environmental protection firms, institutions and regulatory authorities have been actively pushing technology and markets into new fields. New industries emerged and traditional industries shifted to more efficient and less resource-intensive products and processes. The manifold applicability of environmental technologies turned the industry important for various other sectors and led to a strong diversification among environmental technology related firms. Thus, environmental technologies cover a great variety of products and processes all manifested in the existence of a heterogeneous group of subsectors.

In the past, environmental technologies were mostly associated with end-of-pipe "clean-up" technologies whereas today the focus is more on process and system technologies (Weber, 2005) brought on by the integration of ICTs, biotechnology, nanotechnology or material sciences. "Environmental technologies are thus of a cross-cutting nature that can be applied at any stage of the production-consumption chain" (Weber, 2005).

The cluster life cycle approach by Menzel and Fornahl (2009) awards firms a major role in shifting the cluster through a set of stages such as emergence, growth, sustainment and transformation (Menzel and Fornahl, 2009). Evolutionary concepts underline the uncertainty of cluster change and attribute such changes to an interplay of firms, individuals and the institutional framework (Trippl et al., 2013).

Our analysis of the environmental technology cluster in Upper Austria will draw on primary data to provide an account for its evolution over time. The aim of the paper is to get a profound understanding of factors that are relevant for cluster development. This paper not only examines the relevance of particular factors that are put forward by cluster life cycle and evolutionary approaches. It also investigates how the importance of these factors changes over time and between regional, national and international levels. We use the example of the environmental technology cluster in Upper Austria, a cluster that has emerged since the 1970s and that has seen a period of strong growth since the 1990s (Tödtling et al., 2013). The paper addresses the following research questions:

- What are key factors relevant for cluster development at different spatial scales?
- How do these factors change over time in the course of cluster development?

The remainder of this paper is structured as follows. Section 2 provides the conceptual framework, summarizing the main factors that are characterising individual cluster stages and relevant for cluster change. Section 3 describes the methods and data used and section 4 presents findings from the environmental technology cluster in Upper Austria. Here, the cluster is specified and its main characteristics are explored. In section 5 factors that have been relevant for cluster change in Upper Austria are investigated. The paper concludes with the main findings and links back to the conceptual framework.

2) Cluster life cycles and cluster evolution

Cluster evolution theory mainly deals with the emergence and the development of clusters. Evolutionary approaches emphasize the unpredictability of future cluster trajectories but stress that they are constrained by the past (Trippl et al., 2013). On the one hand cluster emergence is dependent on the co-location of interconnected firms and institutions that share

technological proximity, easier access to internal and external information and a common technological understanding and trust (Maskell, 2001). On the other hand cluster development depends on the diversity of knowledge in a cluster and the absorptive capacity of its member firms (Menzel and Fornahl, 2009).

Menzel and Fornahl (2009) as well as Bergman (2009) propose the concept of cluster life cycles, a concept that is derived from product- and industry life cycle approaches. The authors expect clusters to move through a set of stages (emergence, growth, sustainment and transformation) all of which feature different factors that are relevant for cluster development. They, thus, offer a more structured approach and assume that every cluster will go through some sort of "aging" process (Trippl et al., 2013). In this context Audretsch and Feldman (1996, 271) state that "what may serve as an agglomerating influence in triggering innovative activity to spatially cluster during the introduction and growth stages of the industry life cycle, may later result in a congestion effect, leading to greater dispersion in innovative activity".

In the following frame we present arguments from the cluster lifecycle approach (Menzel and Fornahl 2009, Bergman 2009) that are complemented by statements from the evolutionary view (e.g. Martin and Sunley 2006) in an attempt to characterise different cluster phases and to point out key factors of cluster change.

Emerging clusters are usually difficult to identify because potential firms that might be part of a cluster are scattered and the spatial and thematic boundaries are not yet defined (Menzel and Fornahl, 2009). Martin and Sunley (2006) and Maskell and Malmberg (2007) highlight the role of chance events for the emergence of clusters. Emerging clusters are often based on pre-existing structures. Firms that were following particular technological paths in formerly booming industries might branch into new but related fields. Or, start-up companies might spin-off from existing firms. The thematic orientation of the cluster, thus, is shaped by the existing economic structure, the entrepreneurial environment and policies of the region (Menzel and Fornahl, 2009). Also, pre-existing firm routines and a similar cognitive framework provide a basis for social networking (Pouder and St. John, 1996; Frenken and Boschma, 2007), The decline of old industrial areas and the existence of universities and other research organisations gives rise to a large pool of local skilled labour (Bresnahan et al., 2005; Ter Wal and Boschma, 2011). Thus, the initial costs for hiring new employees are lower and so they positively contribute to the likelihood of spin-off activities, the absorptive capacity and innovation capabilities of the region (Ter Wal and Boschma, 2011; Cohen and Levinthal, 1990). The personal commitment of entrepreneurs and the availability of venture capital, above all, are decisive for start-up formation and spin-off activities from globally active firms (Martin and Sunley, 2006). In addition, new strategies of political authorities on higher geographical levels might influence the thematic focus of the cluster (Martin and Sunley, 2006).

Growing clusters have managed to overcome a phase of strong uncertainty (Ter Wal and Boschma, 2011). The setting has turned into a viable business environment with supportive institutions and cluster organisations (Menzel and Fornahl, 2009). Skilled labour from the region gets increasing attention as firms grow and new firms are founded. It is essential for knowledge dissemination within the cluster provided that the local labour stays mobile and becomes increasingly specialised (Boschma and Lambooy, 1999; Frenken and Boschma, 2007). Tendencies of decreasing firm heterogeneity and knowledge diversity are usually countervailed by the cluster's access to external knowledge through global pipelines and the formation of local firm networks or "local buzz" (Bathelt et al., 2004). Also, firms that are located in a growing cluster are usually confronted with increasing demand (Boschma and Lambooy, 1999) and increasing competition due to spin-off and imitation activities (Maskell

and Malmberg, 2007). As a result, firms and products become more diversified and the cluster pushes into related fields. In the words of Menzel and Fornahl (2009) the cluster enlarges its spatial and thematic boundaries. Altogether, a growing cluster requires a steady access to dissimilar knowledge in order to maintain high diversity. The gradual reduction of diversity, however, might be a first sign of cluster maturity.

Sustaining clusters are characterised by a relatively stable state (Tödtling et al., 2013). There is a focus on the application of knowledge and technologies, i.e. upgrading and modification of products and less on the exploration of knowledge and on radical innovations (Martin and Sunley, 2011). At this point the cluster shows symptoms of maturity (Ter Wal and Boschma, 2011). The number of market entrants will decline because other technological paths promise new market opportunities. New technologies are therefore mostly used for incremental changes of their product portfolio (Menzel and Fornahl, 2009; Asheim and Coenen, 2005). As a consequence, the importance of university collaborations declines (Pouder and St. John, 1996). Furthermore, the sustainment phase of the cluster life cycle approach is dominated by a strong rigidification and growing inflexibility of cluster structures (Martin and Sunley, 2006). The low resilience and adaptability of cluster firms (Martin and Sunley, 2011) which results from high cluster interconnectedness and cognitive bias of the focal firms causes new firms to bypass the cluster. Networks are becoming dense and stable (Menzel and Fornahl, 2009). In this context Martin and Sunley (2006, 2011) refer to the high interconnectedness among cluster firms as being the reason for its inability to adapt to changes or shocks in the external environment. Staber and Sautter (2010) propose the development of a collective identity of cluster firms that must show its highest peculiarity in the sustainment phase. All of these factors might hamper further development, for example in terms of firm entries or venture capital (Pouder and St. John, 1996) so the cluster might finally decline or renew itself by entering a new growth phase.

Declining clusters are regarded as seedbeds for new industries (Ter Wal and Boschma, 2011). Employees in the cluster are usually highly specialised and communicate in homogeneous and rigid networks (Menzel and Fornahl, 2009). Maskell and Malmberg (2007) put forward an overspecialisation of cluster firms which feature reduced variety and a narrow knowledge base. As transforming clusters have usually undergone a phase of stagnation or decline they are characterised by inflexible institutional structures and a reduced heterogeneity of cluster firms. Thus, according to Ter Wal and Boschma (2011) the cluster is dependent on exogenous shocks such as the introduction of radical innovations. These innovative firms do not necessarily have to be located in the existing cluster. In fact, their location is dependent on chance factors (ibid.). Others emphasise the importance of large firms with distinctive supply chain networks, financial resources (Lazerson and Lorenzoni, 1999) or the proximity to research institutions and human capital as key actors and influencing factors for transformation.

Summing up, literature on emerging clusters emphasizes the role of pre-existing economic, political and institutional structures and the role of pioneering firms in particular regions. Firms are considered to be attracted by the proximity to higher educational institutes and a pool of well-educated labour. The vibrancy of an emerging cluster, above all, is reliant on personal commitment of entrepreneurs and their access to venture capital. Growing clusters on the other hand are increasingly affected by demand and competition due to high spin-off and imitation activities. In this stage, firms focus on the exploitation of the cluster's skilled labour and draw on supportive institutions. Additionally, cluster firms need to access external knowledge or form networks. With regard to sustaining clusters the predominance of incremental innovations point to an increasing maturity of the cluster. Also, the number of market entrants and the number of collaborations with higher education institutes decline.

Cluster structures and networks become rigid and the cognitive bias of actors prevent the cluster from adapting to changes. Declining clusters exhibit rigid and homogeneous networks slowing down the innovation process. Cluster transformation and renewal requires radical innovations, a change of the institutional setup, and networks, financial resources, proximity to research institutions and a pool of skilled labour. These factors obviously resemble factors that have been decisive for cluster emergence.

The differentiation between descriptive factors of particular cluster stages and factors which actually drive cluster change is yet to be explored. The following sections should put this ambiguity in perspective and analyse the main factors that are relevant for cluster change.

Table 1: Factors and characteristics by cluster stage

	Emergence Phase	Growth Phase	Sustainment Phase	Transformation Phase and Renewal
Business-, institutional- and social environment	- Prior industry structure - Entrepreneurial environment	- Demand increase - Supportive institutions and cluster organisations	- Growing inflexibility of institutional structures - Cognitive bias of actors	- Change of entrepreneurial and political environment - Change of cognitive framework and firm routines
Labour	- Pool of skilled local labour - Labour mobility	- Employment increase and firm growth	- Increasing homogeneity of qualifications and labor skills	- Change of qualifications and skills
Knowledge and innovation	- Diverse but related knowledge - Heterogenous but converging cognitive frames	- Increasing similarity of cognitive framework - Access to external knowledge	- Less university cooperation - Incremental innovations	- New combinations of knowledge bases - Radical innovation
Networks	- Social networking of entrepreneurs	- Multiscalar network growth	- Stable and dense networks - increasing rigidification	- Network restructuring
Firms / entrepreneurs / venture capital	- Pioneering firms - Venture capital	- Spin-offs - Investments - Diversity of firms and products	- Fewer and larger firms	- Restructuring of firms - Buy outs and spinoffs - Venture capital - Policy support

Own draft based on Menzel and Fornahl (2009) and other evolutionary literature; for the transformation phase we focus on factors relevant for renewal

3) Methodology and data description

Whereas the existence and macro-performance of a cluster can be analysed with quantitative data in terms of firm size or employees, qualitative data is required to explore the dynamics and factors which are responsible for cluster change. Therefore, Menzel and Fornahl (2009) suggest that empirical work would require both quantitative and qualitative research. We use Porter's (1990) cluster definition that refers to geographic concentrations of interconnected companies and institutions in a particular field. Lehtinen et al. (2006) applied his approach to the environmental industry in the Finnish region of Oulu. Based on data collected from WIFO (1998, 2000, 2005, 2008) we have found that the region Upper Austria exhibits patterns of clustering with regard to the environmental technologies as well (Tödtling et al., 2013). The Upper Austrian region also hosts two cluster organisations (Eco-energy Cluster Upper Austria and Environmental Technology Cluster Upper Austria) that have more than 300 members in the region. Among them, we identified 112 potential interview candidates in firms that were active in the environmental technologies field.

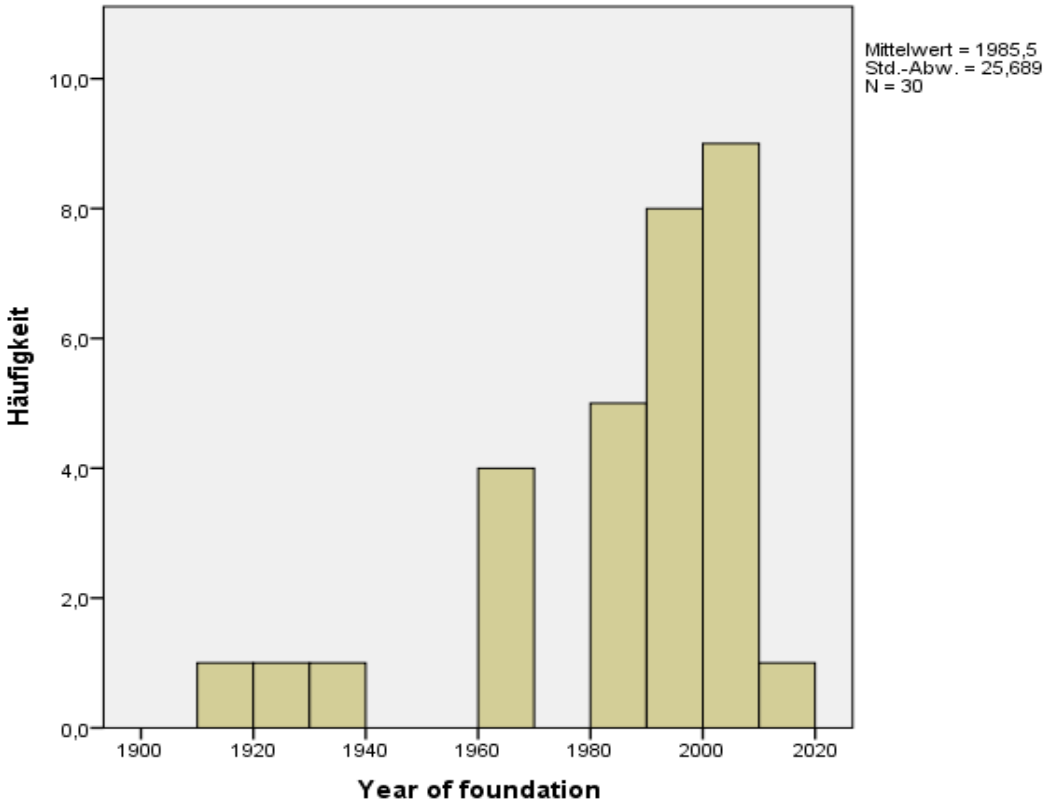
Data were collected via semi-structured interviews with representatives of a selection of Upper Austrian firms from members of the Environmental Technology Cluster Upper Austria and the Eco-Energy Cluster Upper Austria. There are certain restrictions due to occasional subjective and biased answers. However, since individual firm results were compared to related answers about the cluster we were able to check the plausibility of answers.

A total of 30 semi structured interviews were conducted either with company founders or with executives especially in the case of larger firms. Interviews were carried out face-to-face or by phone and lasted between one and two hours. For simplification and easier comparison the factors under investigation were rated on a five-fold Likert scale, whereby the value of "one" represents the most important factors and the value of "five" least important ones. We use qualitative findings as a further background for exploring the context and key factors of development of the environmental technology cluster in Upper Austria.

4) The environmental technology cluster in Upper Austria

Environmental technology firms in Upper Austria have evolved in the 1960s and 1970s in reaction to local resistance to environmental pollution and driven by increasing environmental regulations and directives destined to reduce emissions or wastewater (Pirgmaier, 2011). The regulatory framework was for the most part implemented on national and EU level. It spurred increasing demand for various environmental technology products leading to a technological heterogeneity among firms. After emerging firms had reached a critical mass, the rise of oil and energy prizes in the 1980s and the increasing scarcity of natural resources caused the industry in Upper Austria to enter a distinct growth phase (Tödtling et al., 2013).

Figure 1: Year of foundation of sample firms



From the sample of firms interviewed only few were established before 1960. However, their number took off between 1980 and 2010. This is in line with the larger data set analysed in (Tödtling et al., 2013). Higher environmental awareness, new regulations and visible public support has opened up new markets and investment opportunities since the 1980s. As an interviewee put it: "(...) the environmental thought needed to meet profit expectations". Since the 1990s the number of start-ups increased more strongly. Opportunities and client needs changed as new technologies such as IT or network based technologies emerged, stimulating innovation also in this sector. Thus, the thematic boundaries of the cluster expanded in order to satisfy the rising demand. The figure above indicates that our firm sample is biased towards rather young companies.

Environmental technology firms in Upper Austria can be found in different industries and fields (Tödtling et al., 2013). Most of the firms operate in the field of machinery and equipment manufacturing. More recently, technologies in the field of chemicals, IT, electronics, optics and civil engineering have grown in importance. This reflects the technological legacy and path dependence of the region. In a region that was known for its traditional industries such as steel, vehicles and engineering firms were branching into related fields of environmental technologies (Tödtling et al. 2013).

Table 2: Subsectors of cluster firms (n = 30, multiple entries possible)

	MCT	Air	Energy	Water	Waste	Project&Consulting	Other
Frequency	4	4	9	6	4	8	7
Percentage (%)	13,3	13,3	30	20	13,3	26,7	23,3

As regards environmental technology areas of our sample we find that some medium and larger firms do business in more than one environmental technology area. The table above, thus, presents data of multiple entries by firms. Based on a study of the Austrian WIFO institute we divided the firm sample into the following technology fields: MCT (Measuring and Controlling Technology), air, energy, water, waste, project & consulting services and other activities such as IT services. According to some of the interviewees the success of individual sub-sectors is – besides market conditions - very dependent on subsidies and policy support. In particular, energy related companies or firms that are operating in projects or consulting face higher growth rates whereas firms in other subsectors decline.

Table 3: Size of firms 2010-2013 (n = 30)

	Frequency 2010	Frequency 2013	Change
Micro firms (n = 9)	12	9	-3
Small firms (n = 3)	2	3	1
Medium firms (n = 7)	5	7	2
Large firms (n = 11)	11	11	0

Our sample is composed of a relatively high proportion of large firms. They open national and international markets for smaller firms and therefore play an important role for selling goods produced by micro firms (0 – 9 employees) and small firms (10 – 19 employees) in more distant markets. The decline of micro firms between 2010 and 2013 arises from the fact that some of these firms have grown into the small and medium sized groups.

Table 4: Firm Revenues per Recipient Group categorised by Company Size 2013 (n = 30)

Company Size Categories	Revenue from Firms (%)	Revenue from Consumers (%)	Revenue from Public Sector (%)	Revenue from Othesr (%)
Micro Firms (n = 9)	84,44	11,44	2,44	1,67
Small Firms (n = 3)	90,00	0,00	10,00	0,00
Medium Firms (n = 7)	76,29	0,00	22,29	1,43
Large Firms (n = 11)	65,82	10,00	20,09	4,09
Total (n = 30)	76,27	7,10	14,30	2,33

Our environmental technology sample firms sell their products mostly to other firms (76% of sales), far ahead of sales to the public sector (14%) comprising municipalities or hospitals. Sales to consumers are marginal and mostly associated with energy efficiency and energy generation of households. The table also reveals that larger firms tend to sell relatively more of their products to the public sector because they often maintain extensive relations with representatives of the regional public sector.

Table 5: Geographical dispersion of sales per company size 2013 (n = 29)

Company Size Categories	Regional Level (%)	National Level (%)	EU level (%)	Global Level (%)
Micro Firms (n = 8)	26,88	69,38	3,75	0,00
Small Firms (n = 3)	10,00	51,67	31,67	6,67
Medium Firms (n = 7)	13,57	48,57	29,29	8,57
Large Firms (n = 11)	37,09	26,54	31,27	5,09
Total (n = 29)	25,79	46,28	23,24	4,69

The majority of sample firms have their markets predominantly on national level whereas one quarter of the firms' activities covers the region. The relatively high proportion of national and EU market sales conforms to findings from Tödtling et al. (2013) for a more representative firm sample which award national and EU markets the highest importance but also identify increasing saturation of these markets. Global markets, however, are so far less targeted by our firm sample although previous analyses have uncovered increasing sales on global markets (Tödtling et al., 2013). Interestingly, the table above reveals that smaller firms tend to sell their products and services rather on the national level whereas larger firms predominantly do so in the region. A reason for this unexpected finding might be the fact that smaller environmental technology firms often focus on non-location-bound web and IT activities whereas larger companies rather concentrate on traditional and long term customer relationships as well as on the public sector which are usually more territorially-bound.

Table 6: Self-reported phase of company development and perceived cluster phase (n = 30)

	Freq. Companies	Freq. Cluster
Emergence Phase	3	0
Growth Phase	10	14
Sustainment Phase	9	9
Transformation Phase	8	6
Total	30	29

The table above indicates the self-reported phase of firm development and perceived cluster phase. One of the key findings that was also confirmed by qualitative analysis is that the environmental technology sector in Upper Austria is currently moving towards saturation, i.e. somewhere between growth and sustainment phase. The transformation phase is mostly referred to as an internal restructuring or reorientation process towards related environmental technology products. For example, two of our interviewees claimed that their take-overs by foreign groups were coupled with less in-house R&D investments and a restructuring of the internal reporting system. Another interviewee stated: "My company is working in many different fields and dependent on demand from various sectors. Some of these sectors are declining others are growing (...) eventually it is hard to say which phase we are currently going through". If we compare the self-reported stages for the firms in our sample with that of the cluster we find that relatively more firms consider themselves either in an emerging phase or in a transformation phase, whereas the overall cluster is more often seen to be in the growth and in the sustainment phase. This divergence indicates that the overall cluster can be

perceived as growing or sustaining even if the own firm is regarded as emerging or under transformation.

The growth and evolution of the environmental technology cluster has also led to an intensification of networks. The emergence of new firms over the last 25 years has increased the number of potential and actual partners for innovation networking in the region and beyond. According to Menzel and Fornahl (2009) the continuous emergence of new cluster participants as well as the link to external partners and the related inflow of external knowledge help to avoid potential lock-in (Martin and Sunley, 2006, Tödtling et al 2009, Tödtlig et al 2013). In the Upper Austrian case firms get access to external knowledge especially through vertical linkages (i.e. clients and suppliers). In addition, two cluster organisations (Eco-energy Cluster Upper Austria and Environmental Technology Cluster Upper Austria) are key focal points for fostering linkages between knowledge organizations and firms (Cooke, 2008). Also, these cluster organisations promote firm branching into related industries (Tödtling et al., 2011). However, according to some of the firms interviewed, both initiatives have only a limited impact on firm development.

Table 7: Innovation-relevant network partners for Environmental Technology firms (n = 30)

	Regional.	National	EU	Global	Total
Suppliers	8	5	6	2	21
Client	5	9	3	3	20
Firm of same sector	1	5	-	2	8
Firm of different sector	6	-	1	-	7
University	15	17	1	1	34
Public agency	18	21	1	2	42
Total	53	57	12	10	132

The table above raises the question of why environmental technology firms prefer collaborations with regional and national universities and public agencies over cooperation with suppliers or clients. This pattern might be due to the following factors as our interviewees reveal. Firstly, universities are highly important for pre-market product development and therefore are often accessed by emergent firms. This is in line with Menzel and Fornahl's (2009) assumption that a strong regional scientific base is an important pre-condition for cluster emergence. Secondly, the high relevance of public agencies for the creation of innovation arises from the high importance of regulations and directives in this industry which are implemented by public authorities in the form of environment related certifications, quality inspections and so on. Supportive institutions and a particular policy environment are also relevant for cluster emergence and growth (Menzel and Fornahl, 2009). Thirdly, the innovation-relevant collaborations with a firm's suppliers or clients demonstrate the importance of incremental innovations and product adaptations in day-to-day business as firms grow bigger, also referring to the environmental technology cluster's synthetic knowledge base (Menzel and Fornahl, 2009; Asheim and Coenen, 2005).

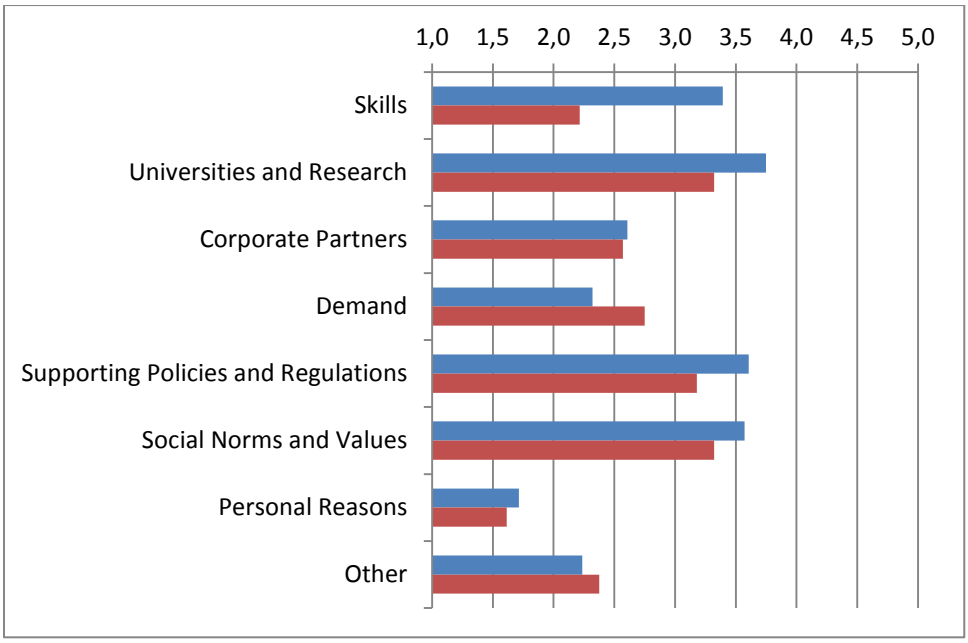
5) Factors relevant for cluster development

A cluster's capability to be innovative arises from heterogeneity among member firms, the diversity of knowledge and the firm's absorptive capacity to exploit external knowledge

(Martin and Sunley, 2006; Menzel and Fornahl, 2009). Authors such as Nelson and Winter (1982), and Dupuy (1997) emphasise the role of government policies and regulations on the promotion of technological and firm innovations whereas Porter and van der Linde (1995) and Porter (1998) stress the incentivating role of competition.

In this section we explore the role of different factors for cluster development that have been elaborated in our conceptual framework. In the firm interviews we have asked for operational factors (such as demand and proximity to other firms), knowledge related factors (such as skills, universities and research and networks) and regulatory factors (such as regulations and directives) on regional, national and international level were selected for the semi-standardised questionnaire. We have explored factors for locating the company in the region and for staying there as well as factors relevant for the development of the respective company and the overall cluster on different spatial levels.

Figure 2: Factors relevant for company foundation and for staying in the region (n = 30)



(Blue bar equals mean value for Establishment; Red bar equals mean value for Staying); Values on a scale from 1 (very important) – 5 (unimportant)

Obviously personal factors such as growing up in the region, strong family ties or the fact that the company already existed and was passed over from one generation to the next were important *factors for founding the company in Upper Austria*. Some of the firms put forward the good infrastructure and Upper Austria's high reputation as an industrial location. Also the availability of other companies as potential business partners in the region and regional demand were important drivers for company establishment. Interestingly, at the time of firm establishment founders regarded the availability of skilled workers and the proximity to universities and research organisations as rather unimportant. This contrasts to theoretical findings that an adequate scientific base and pool of skilled labour are essential for cluster emergence (Menzel and Fornahl, 2009).

Factors important for remaining in the region are still shaped by personal factors, but increasingly objective factors get more important such as the availability of skilled labour, universities & research as well as supporting policies (see also Menzel and Fornahl, 2009). One of the reasons for the higher importance of local skilled labour might be a firm's growth which is often coupled with an increase in the number of required skills and employees. However as some of the interviewees state there is a current shortage of qualified labour in Upper Austria. A fact that can be attributed to the cluster's growth (including start-ups) and a higher demand for qualified workers (Pouder and St. John, 1996).

Table 8: Comparing factors on company and cluster levels by geographical levels and over time (n = 30)

		Mean Value					
		Company		Cluster		Company	Cluster
		Previously	Presently	Previously	Presently	Change	Change
Skills	Regional	1,9	1,6	1,6	1,3	-0,3	-0,3
	National	2,7	2,2	2,2	1,6	-0,5	-0,5
	International	3,6	3,1	2,7	2,2	-0,6	-0,5
Universities and Research	Regional	3,3	2,9	2,2	2,2	-0,4	-0,1
	National	3,2	2,7	2,4	2,1	-0,5	-0,3
	International	3,8	3,6	3,2	2,6	-0,2	-0,6
Demand	Regional	2,3	2,6	2,3	2,4	0,3	0,1
	National	2,0	1,9	1,8	1,9	-0,1	0,0
	International	3,1	2,5	2,5	1,9	-0,6	-0,6
Corporate Partners	Regional	2,2	2,5	2,2	2,3	0,3	0,1
	National	2,5	2,5	2,4	2,4	0,0	0,0
	International	3,2	2,8	2,8	2,3	-0,4	-0,5
Financial Capital	Regional	3,2	3,5	2,5	2,5	0,3	0,0
	National	3,5	3,4	2,7	2,6	-0,1	-0,1
	International	4,2	4,0	3,2	2,7	-0,3	-0,5
Networks	Regional	2,6	2,2	2,2	1,8	-0,4	-0,4
	National	2,7	2,4	2,5	2,1	-0,2	-0,4
	International	3,5	3,0	2,9	2,2	-0,5	-0,7
Subsidies	Regional	2,8	3,0	2,0	2,2	0,2	0,2
	National	2,4	2,6	1,8	2,1	0,2	0,3
	International	3,6	3,1	2,6	2,3	-0,5	-0,4
Regulations	Regional	3,7	3,6	2,8	2,9	-0,1	0,1
	National	2,9	2,8	2,3	2,4	-0,1	0,2
	International	3,0	2,3	2,6	2,1	-0,6	-0,5
Directives	Regional	3,7	3,6	3,0	3,0	-0,1	0,0
	National	3,0	2,9	2,3	2,4	-0,1	0,0
	International	3,0	2,4	2,7	2,2	-0,6	-0,5
Others	Regional	2,4	2,0	2,7	2,3	-0,4	-0,3
	National	2,2	2,2	3,0	2,0	0,0	-1,0
	International	3,0	2,3	3,0	2,3	-0,7	-0,8

Values on a scale from 1 (very important) – 5 (unimportant)

As regards *factors relevant for company development* in the environmental technology sector in Upper Austria we can observe that skills available in the region, demand (on national and regional levels), other firms (on regional level) and national subsidies have been regarded as important. Over time the following changes can be observed. From the regional factors, the availability of skilled labour and network participation became more important, a finding that is typical for firms in a growing cluster (Menzel and Fornahl, 2009). There is also a persisting role of regional knowledge sourcing. It conforms to Bathelt et al.'s (2004) notion of "local buzz" which emphasises the advantages of face-to-face contacts and personal information sharing. In contrast, operational factors such as regional demand or other firms lost ground to the national and international levels. This can be interpreted as an operational shift from the region to the national and international markets for products and components.

As concerns factors at national level demand has been most important over time and clearly is more relevant than demand on regional level. Universities and research institutes are also accessed increasingly on the national level corresponding to the high relevance of a cluster's scientific base in cluster literature (e.g. Menzel and Fornahl, 2009; Trippl and Tödtling, 2008, Audretsch et al., 2006) However, as the factor universities and research on national level features a relatively low mean value compared to other factors these findings are in line with knowledge base theory given the fact that environmental technologies are regarded as sectors with a synthetic knowledge base. One interviewee stated: "(...) although we were formerly engaged in university cooperation, today, I would rather prefer business partners over scientific research institutes or universities. In fact, firms tend to be more reliable because they depend on the fulfilment of contracts". As there are still many university-industry links which are not considered to be important for firm development it can be assumed that companies are often engaged in short term research contracts. Also, the availability of skilled labour and network participation have gained importance on national level, but receive still more attention in the region. Despite lower relevance of national subsidies we find, thus, a certain shift of relevant factors from the regional to the national level.

Although factors on international level have previously exhibited little influence on the development of environmental technology firms in Upper Austria, their importance has generally and in the case of regulations and directives even strongly increased, indicating a shift from national to international legislation and regulations.

Interestingly, *cluster related factors* clearly differ by more positive values, awarding various factors more influence on the development of the cluster life cycle than on individual firms. There might be two reasons for that. First, individual firms might have biased views on relevant factors. Second, the cluster and its members might be situated in a different stage of the life cycle than the companies under investigation. As qualitative findings reveal, the cluster is currently affected by a strong upswing of energy related technologies mediated by uncertainties of crude oil availability. Thus, the strong diversity of the environmental technology industry (Weber, 2005), the continuous rise of new and the decline of old subsectors makes it difficult to draw general conclusions.

The tables below add to a more differentiated understanding of development factors by focussing on the importance of *factors for different categories of firms*. We have distinguished by age of companies (indicated by foundation year) and perceived cluster phase. As regards age, companies were categorised into three time periods of foundation.

Table 9: Importance of company factors by year of foundation (Presently) (n = 30)

Presently		-1990 (n=12)	1990-2000 (n=8)	2000+ (n=10)
Skills	Regional	1,4	1,8	1,7
	National	2,1	2,1	2,4
	International	3,0	2,6	3,6
Universities and Research	Regional	3,1	2,8	2,9
	National	2,9	2,5	2,6
	International	3,6	3,1	4,0
Demand	Regional	2,4	2,8	2,6
	National	2,0	2,0	1,7
	International	1,8	2,6	3,2
Firms	Regional	2,3	2,4	2,7
	National	2,8	2,4	2,3
	International	2,4	2,5	3,7
Financial Capital	Regional	3,4	3,4	3,7
	National	3,4	3,5	3,3
	International	4,0	3,9	4,0
Networks	Regional	2,4	2,0	2,1
	National	2,8	2,3	2,2
	International	2,8	3,3	2,9
Subsidies	Regional	3,7	2,9	2,4
	National	3,2	2,5	2,0
	International	3,1	3,1	3,0
Regulations	Regional	3,5	4,0	3,3
	National	3,1	1,9	3,2
	International	2,5	1,8	2,7
Directives	Regional	3,7	4,3	3,1
	National	3,4	2,0	3,1
	International	2,4	2,1	2,7

Values on a scale from 1 (very important) – 5 (unimportant)

Older companies (i.e. those founded before 1990) regard skills at the regional and national levels of key importance. Obviously, these firms have relied to a high extent on qualifications they can draw from the regional and also the Austrian labour market and the tacit knowledge that goes along with mobile labour (e.g. Ter Wal and Boschma, 2011; Frenken and Boschma, 2007). The second major factor has been the pull of demand, in this case from international and the national markets. Older companies, thus, are tied to the region via labour flows and to the market for goods & services at higher spatial scales.

For companies founded between 1990 and 2000 knowledge related factors such as skilled labour and networks are considered most important on the regional level. In addition universities and research institutes have on national level some relevance. Compared to firms that were founded before 1990 they sell their goods & services rather nationally, a level where they also interact with other firms. This age group of firms, furthermore, indicates that they heavily rely on national and international regulations and directives that have become more common since the 1990s. This contrasts with older firms as well as younger firms for which regulations seem to be less relevant.

Companies founded after 2000 seem to rely on the region as regards skills and networks, and on the country as regards demand and subsidies. The region, thus, is an important space to draw skills and knowledge that is often codified, whereas Austria as a country is important for them as regards demand for their products & services as well as financial and other political support that helps them to get the firm going. It is interesting to observe, that younger firms seem to penetrate the national market right from the beginning which might be supported

through larger firm networks. The relatively low importance of regulations and directives for this younger firm group might be attributed to the stronger engagement of these companies in service oriented and IT related activities.

The table below shows the self-reported life cycle phase of company development. One of the key findings is that a high share of environmental technology firms in Upper Austria is currently located on the verge of saturation, i.e. somewhere between growth and sustainment phase (for more details see section 4).

Table 10: Importance of company factors by life cycle phase (Presently) (n = 30)

Presently		Emergence (n=3)	Growth (n=10)	Sustainment (n=9)	Transformation (n=8)
Skills	Regional	2,3	1,8	1,2	1,5
	National	3,0	2,4	2,4	1,4
	International	5,0	3,8	2,2	2,5
Universities and Research	Regional	3,0	2,6	2,9	3,4
	National	1,7	2,8	2,9	2,8
	International	5,0	3,4	3,2	3,6
Demand	Regional	2,7	2,7	2,3	2,6
	National	1,3	1,9	2,1	1,9
	International	5,0	2,1	2,3	2,1
Firms	Regional	2,3	2,8	1,9	2,8
	National	1,7	2,7	2,6	2,6
	International	5,0	2,4	2,7	2,6
Financial Capital	Regional	4,3	3,9	2,9	3,3
	National	4,0	3,2	3,4	3,3
	International	5,0	3,6	4,2	3,7
Networks	Regional	2,0	2,3	2,2	2,1
	National	3,0	2,4	2,8	1,9
	International	5,0	2,4	2,9	2,9
Subsidies	Regional	3,7	2,7	2,7	3,6
	National	3,0	2,2	2,6	3,0
	International	5,0	2,8	2,9	2,9
Regulations	Regional	4,0	3,6	3,3	3,6
	National	4,0	2,7	2,7	2,6
	International	4,3	1,9	2,7	1,8
Directives	Regional	3,7	3,6	3,9	3,4
	National	3,7	3,0	2,9	2,6
	International	4,3	2,1	2,8	1,6

Values on a scale from 1 (very important) – 5 (unimportant)

In the emergence phase firms pay no attention to international factors. Firms are mostly occupied with getting their business to run. Therefore we find relevance of national demand and other firms on regional and national level. Firms seem to be relatively well connected to universities and research organisations on national level (Menzel and Fornahl, 2009). Some of our interviewees state that university collaborations are crucial for developing their initial product. Knowledge exchange in the form of recruiting skills, networks participation gets increasing attention on regional level (Ter Wal and Boschma, 2011). Financial capital has not contributed to firm development, a finding which conforms to our interviewees' perception that capital is difficult to access. It is basically due to its scarcity or even a state of non-existence and the strong role of national subsidies in the emergence phase. As one of our interviewees stated: "(...) founding the company was all about the financial support program. Without it, there would be no publicity, no technical innovations, no risk, (...) no firm".

In the growth phase international regulations and directives have an increasing impact on company development. We see less use of university and research links but more orientation

towards international markets and international firm collaboration. This might be due to the fact that most interviewees associate the growth phase with their own internationalisation efforts. Theoretical findings confirm the relevance of rising demand and access to external (national and international) knowledge (Bathelt et al., 2004).

In the sustainment phase environmental technology firms regard regional factors such as demand, other firms and networks as more relevant than in the growth phase. Their importance on national and international level decreases at the same time. Maturing firms draw skilled labour increasingly internationally whereas firms in the growth phase still mostly source from the region and the country.

The transformation phase is dominated by a need for skilled labour sourced from regional, national levels, although as stated by the interviewees this period is characterised in some firms by hiring freezes or layoffs owing to company restructuring. A transformation process might require the allocation of information and knowledge which brings us to the increasing importance of regional and national network participation. Ter Wal and Boschma (2011) as well as Martin and Sunley (2006) put forward the importance of network restructuring in this phase in order to promote radical innovations. Moreover, international regulations and directives are of high importance suggesting that firms will adopt new environmental technology in anticipation of a change in environmental regulations (Dupuy, 1997).

6) Conclusion

The environmental technology cluster in Upper Austria is composed of a heterogeneous group of firms which have evolved in the 1960s and 1970s due to increasing environmental awareness and increasing regulations destined to reduce the environmental burden (Pirgmaier, 2011). Whereas the cluster emergence was marked by the formation of only a few firms mostly descending from related fields, the cluster moved into a growth phase at the beginning of the 1980s with a strong upswing in company foundations especially since the 1990s. Since 2000, two cluster organisations have been established in order to promote collaboration in local networks, especially among different types of firms and with knowledge organisations.

This paper seeks to explore in particular factors that are affecting cluster change, using the example of the environmental technology cluster in Upper Austria. In particular, we address the issues of how these factors shift geographically and how their influence changes over time. The reviewed literature on evolutionary and cluster life cycle theories primarily focuses on firm characteristics, firm capabilities and firm interconnections in a cluster (Trippl et al., 2013). At the same time it investigates the relevance of factors that are influencing cluster change. The empirical analysis of this paper addresses these issues and, thus, tries to contribute to a more dynamic perspective in cluster research.

Factors that are relevant for a cluster to emerge are usually hard to grasp because emerging clusters are difficult to locate. However, cluster literature mentions some regional pre-conditions that make its formation more likely. Among them are the existence of a particular entrepreneurial and political environment, a pool of skilled labour, a strong scientific base and venture capital. Our findings from the environmental technology cluster in Upper Austria have revealed that these factors are indeed important during the early stages of company development but not all are regarded as crucial for company foundation. Our interviewees have pointed out that personal factors have been most important followed by regional demand and pre-existing contacts to potential business partners. Later on, skilled labour, universities and other research organisations attract more attention as they learn about new opportunities

to access cluster internal or external knowledge. We conclude that the role of entrepreneurs and their personal social networks during cluster emergence are still underestimated by cluster literature. Our findings furthermore indicate that universities and research organisations play an important role during the emergence phase of some companies while in later stages their relevance seems to decrease.

Factors relevant for cluster growth are also shifting by spatial scale as firms are expanding their activities as the cluster is growing. Theoretical contributions highlight an important role of the region as regards skilled labour and network formation. Also, the high relevance of external knowledge inflows, demand increases and the availability of venture capital all embedded in a supportive institutional framework are mentioned. Empirical findings from Upper Austria show that the access to knowledge through network participation and the recruitment of skilled labour mostly happen in the region. Higher education institutes are most relevant in the region and the country and decrease in importance the more mature a company gets. Operational factors such as demand and corporate business partners shift from the region to national levels. On international level growing environmental technology firms increasingly pay attention to the regulatory framework.

Factors that go along with a move of the cluster towards a sustainment phase are a decreasing importance of university links and a narrowing of cognitive frames of actors involved. Furthermore, theoretical findings emphasize characteristics such as a growing inflexibility of cluster structures, a prevalence of incremental innovations, stable and dense networks and a decline in the number of firms. Empirical findings from the environmental technology cluster in Upper Austria reveal that sustaining firms reorient towards the region (with regard to demand, other firms and networks) and focus on incremental innovations by rather slowly adapting to customer needs. This also comprises the employment of already existing technology rather than inventing new one. Another factor important during this phase is regional but increasingly also international sourced skilled labour.

Factors that are held responsible for a cluster to decline are too homogeneous cognitive frames and rigid networks and institutions. For a cluster to transform and to renew itself, thus, a region requires a change of networks and cognitive frames. Other factors relevant for cluster renewal are access to new or recombined knowledge, enhanced innovation and entrepreneurship. Empirical results emphasize the role of skills and networks on regional and national levels, national and international markets as well as international regulations and directives.

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Multilevel Governance and Development
Wirtschaftsuniversität Wien
Institutsvorstand : ao.Univ.Prof. Dr. Gunther Maier
Welthandelsplatz 1
A-1020 Wien, Austria
Tel.: +43-1-31336/4777 Fax: +43-1-31336/705 E-Mail: mlgd@wu.ac.at
http://www.wu.ac.at/mlgd