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Evolution of regional clusters in nanotechnology.
Empirical findings from Germany.

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Abstract

This article aims at establishing a wider understanding of the evolution of spatial clusters. It will be argued that the potential to generate regional growth is dependent on the way a cluster emerges. Two models of cluster formation will be distinguished in detail – start-up clusters and unrelated spatial concentrations. In its sectoral orientation the study is focused on nanotechnology, a key(technology)-industry said to contribute to new growth spurts in the industrialised world. By analysing the evolution of regional clusters in the Saarland and in Berlin-Brandenburg it will be shown that both types of cluster formation can be found in nanotechnology, demanding different modes of policy intervention.

1 Introduction

Regional clusters – i. e. “non-random agglomerations of firms with similar or highly complementary capabilities” (MASKELL and LORENZEN, 2004, p. 1002) – have gained much in importance in social sciences in the last years. According to many authors they have a positive impact on regional development as they strengthen the productivity of companies, enhance their innovation capability and stimulate the foundation of new firms (PORTER, 1998a; COOKE, 2001). While up to now emphasis has mostly been put on the function and effectiveness of successful clusters (e. g. Silicon Valley, Route 128) there are at least two facets of cluster research that have hardly been dealt with so far: On the one hand there are only a few theoretical contributions with reference to regional cluster policies. This is surprising in so far as there are a lot of different strategies to create and sustain clusters on a regional scale in nearly all industrialised countries (HOSPERS and BEUGELSDIJK, 2002; RAINES, 2002).

On the other hand there is a wide conceptual disregard of the processes that lead to an initial spatial concentration of economic activities. A better understanding of the early development stages, however, could prevent regional politics from failure when trying to establish clusters (ORSENIGO, 2001; Feldman and Francis, 2004). Only recently different authors (BAPTISTA and Swann, 1999; BRESHI and MALERBA, 2001; FELDMAN, 2001; Leibovitz, 2001; BRENNER, 2003; MENZEL, 2005) have made the formation of regional clusters the starting point for further research. By addressing the relation between the processes of evolution and the growth potential of regional clusters this study aims at contributing to close this research gap, too. In particular it is focused on nanotechnology, a nascent field of technology with a presumably great influence on future market developments. Quite contrary to the existing ex-post analytical studies (MENZEL, 2005) it thus concentrates on emerging clusters or so-called protoclusters. The most important advantage of this approach is the possibility to recourse to knowledge of central actors that might not be available at a later date. Moreover it can be assumed that their knowledge related to relevant events and contexts is going to fade or will be eventually superposed by other factors. Hence both aspects should allow a comparatively authentic analysis of the formation of clusters. Finally it is possible to identify erraneous trends that might lead to a premature ending of cluster formation. In contrast to that studies written retrospectively, unavoidably focus on such clusters as have passed a successful development.

2 Theoretical considerations

2.1 Cluster dimensions

Starting from the fundamental works by PORTER (1990, 1998a) who attached great importance to spatial proximity for the competitiveness and innovativeness of firms, many authors regard clusters as centres of regional growth (for example PORTER, 1998a; COOKE, 2001; TICHY, 2001). This view, however, is problematic as it neglects the fact that there are different stages of cluster development and diverse cluster configurations that need not necessarily come along with positive impacts (e. g. the Ruhr area) (MARTIN and SUNLEY, 2003; BATHELT, 2005; for cyclical approaches of cluster development see PORTER, 1998a; SWANN, 1998; KLINK and de LANGEN, 2001; FORNAHL and MENZEL, 2003; TRIPPL, 2004). Each cluster therefore should be carefully analysed before assessing its actual regional implications and deriving political recommendations.

As an adequate instrument to characterize regional clusters and their growth potential, the multidimensional approach recently developed by MASKELL (2000), MALMBERG and MASKELL (2001) and BATHELT (2004a, 2004b) can be applied. According to BATHELT (2004a, 2004b) a cluster is characterised by five different dimensions only ensuring a growth when developing simultaneously.

The **horizontal cluster dimension** often neglected in empirical studies (MASKELL, 2001), comprises companies competing with each other. Although exchange or trustful co-operation between them are seldom there are some advantages resulting from their co-localisation: The firms gain the possibility to monitor each other continuously and intensively. Due to the similarity of their business segments and the knowledge bases they are able to pick up successful solutions and add their own ideas. As a consequence, incremental product and process innovations will occur (BATHELT, 2004a, 2004b, 2005; BATHELT and ZENG, 2005).

The **vertical cluster dimension** relates to companies with complementary products and/or competencies. A spatial concentration of specialised firms implies a high demand for specific inputs. This again acts as an incentive for suppliers and service providers to locate close-by. In the long run a concentration of companies emerges that covers different segments of the supply chain. The firms can benefit from low transport and transactions costs as well as from the realisation of economies of scale. Furthermore the spatial proximity allows technological spillovers and processes of interactive learning. Both aspects ceteris paribus imply competitive advantages for the companies inside the cluster compared to those outside.

The **institutional cluster dimension** comprises the system of norms and rules deep-rooted in formal and informal institutions. Recent work in economic geography has shown that especially the latter play an important role in the formation and the functionality of regional clusters (BATHELT, 2005). The evolution and change of such "untraded interdependencies" (STORPER, 1997, p. 5) rely on social practices that require the presence of actors. Clusters defined by the co-presence of different actors with similar experiences promote the development of a distinct institutional structure in particular: So it is likely that a common language, corresponding schemes of interpretation and similar attitudes towards technologies will eventually evolve. This in turn facilitates what is called local buzz, i. e. the communication and the transfer of knowledge between the actors.

Last but not least the **external cluster dimension** covers the linkages of firms inside the cluster to companies outside. This dimension is of great relevance as cluster connections that are too narrow, too exclusive or too rigid are able to threaten the existence of a cluster in the long run (so-called lock-in). External linkages, referred to as trans-local pipelines, however, help the local actors to gain access to new technologies and different forms of organisation that can be applied inside the cluster. The consequence is: the higher the number of companies in touch with the outside world the stronger the density of information inside the cluster. This enables the cluster companies to profit for their innovation processes (BATHELT et al., 2004).

Finally, a cluster only exists if the respective actors perceive it as a unit that is sufficiently distinct from the environment and if they act accordingly so that the cluster becomes evident to outsiders as well. The coherence between the local actors required in this context does not exist a priori but is rather a result of everyday interactions. The latter can be stabilized by certain technologies as companies make the same experiences and develop a similar understanding for common problems. According to actor network theoretical considerations, the actors' ability to involve others in collective action is allowed for in the so-called **power dimension** of a cluster (BATHELT, 2004a; BATHELT and BOGGS, 2003).

2.2 Models of cluster evolution

The potential of a cluster to generate regional growth differs due to variations in the five dimensions mentioned above. It is argued here, that these differences are determined by the way a cluster emerges. In detail two models of cluster evolution will be distinguished, depending on whether the development of technology clusters can be traced back to start-ups (from one incubator) or by learning processes. Relocations, on the contrary, only play a minor role for different reasons: Firstly companies of an emerging industry have innovative and specific demands on their location that normally are not yet met at any location but have to be produced by the companies themselves. Secondly, due to the high locational freedom of new branches there is no plausible reason for them to choose a location within a cluster, especially as it does not, in its early stage of development, differ significantly from other locations (STORPER and WALKER, 1989; FORNAHL and MENZEL, 2003).

Model A: Start-Up Cluster

As different authors (ENRIGHT, 2001; BRENNER, 2003; STERNBERG, 2003) state, regional clusters often evolve from an initial concentration of newly founded firms with the founding processes mainly influenced by aspects like incitements by research facility resp. the founders' individual visions of getting ahead. In many cases the origin of such start-up-clusters (STERNBERG, 2003) can be traced back to one focal research facility. If so, the common institutional background of the founders in all probability leads to a similar understanding of technological issues. This in turn facilitates the creation of a basis for inter-firm communication and cooperation as well as the formation of a cluster coherence. Gradually incubator networks (MENZEL, 2005) may arise. Regional politics will recognize the evolving structures and support the cluster growth by setting up a specific infrastructure (e. g. specialised training centres) (PORTER, 1998a). Furthermore, relocations of suppliers are probable due to economies of scale arising from similar demands of the local firms, thus extending the vertical cluster dimension. In general, the initial conditions of these clusters suggest a considerable growth potential of the sector in question.

Model B: Unrelated spatial concentration

The contrasting model of cluster evolution concerns agglomerations of companies that have simultaneously developed along a certain technological trajectory. Besides there also may be several start-ups rooted in different research facilities. In these 'clusters'[1] neither the applied methods nor the products nor a common past of the employees act as connecting elements but the mere activity in a certain field of technology often put forward by political support programmes (e. g. biotechnology). The missing links between the firms do not only obstruct communication but also imply a weak rivalry between them, cutting off a stimulating competition. Due to the absence of technological and commercial similarities, the formation of a local buzz resp. a cluster coherence arising from it is hampered (BATHELT et al., 2004). As a consequence, the cluster will not or only insufficiently be perceived by political actors so that the provision of cluster specific institutions probably will not take place. For the lack of economies of scale an expansion of the vertical dimension seems unlikely so that – on the whole – the growth potential of such clusters appears to be comparatively low.

3 Nanotechnology

3.1 Definition

Although one nanometre by definition equals one millionth millimetre (10^{-9} m) there is no common understanding of what can be subsumed under the term 'nanotechnology' (FLEISCHER, 2002; WGZ-Bank, 2002; LUTHER et al., 2004; for an elaborate discussion on the denotation see DECKER et al., 2004). Some authors use the expression when referring to structures with dimensions smaller than 100 nm; others point out that besides the geometrical aspects there have to be new optical, electronical, magnetical, catalytical or mechanical qualities caused by the smallness of the structures in order to speak of nanotechnology (BACHMANN, 1998; BMBF, 2004a). Following the last argument, the term refers to the "creation, investigation and application of structures, molecular materials, internal interfaces or surfaces

[1] For that reason the term of an unrelated concentration rather seems more adequate than the notion of a cluster, which usually implies an interrelatedness of the companies (PADMORE and GIBSON, 1998; ISAKSEN, 2001).

with at least one critical dimension or with manufacturing tolerances of (typically) less than 100 nanometres. The decisive factor is that the very nanoscale of the system components results in new functionalities and properties for improving products or developing new products and applications”[2] (BMBF, 2004a, p. 6). Thus defined, nanotechnology can be understood as an enabling technology covering different fields of technology and influencing the development of different industries. Especially in the coming years, numerous innovations that can hardly be imagined as yet are expected to conquer the markets (BMBF, 2004a). For that reason nanotechnology is believed to make a substantial contribution to the stabilization of the employment markets as well as to the transfer of economic growth to certain segments of national economies (HENN, 2003).

3.2 Classification of companies

In consideration of the comparatively wide definition of nanotechnology differentiation on two different levels of companies involved into commercialising nanotechnology is proposed. At first all firms with reference to nanotechnological value-adding will be referred to as **nanotechnology-related** firms with the respective value chain divided into five steps (DG-Bank and GZ-Bank, 2001): At its beginning the development of methods and devices takes place (1). With their help it is possible to carry out research and development (R&D) resp. analytical tests (2) which again can be seen as necessary precondition for the production of nanoscaled structures (3). Finally the latter are distributed to the end-consumer (4) or enter further processing (5).

Secondly firms being an element of the second step of the value added process (R&D, analytics) will be classified as **nanotechnology companies**. One subcategory comprises the so-called core nanotechnological companies characterized by an exclusive focus on nanotechnological activities. These firms, notably small and medium enterprises (SME), are said to have an important function for the knowledge transfer into the economy (BMBF, 2004a).

4 Database and methodology

Due to the lack of official statistics and empirical research concerning spatial aspects of nanotechnology (HENN, 2003), the study is based on primary data collected during the years 2003 and 2004. Standardized questionnaires were used in order to get a general idea of the spatial distribution and the choice of location of German nanotechnology companies. On the whole 215 (=25,6 %) out of 840 (=100,0 %) selected companies stated to carry out R&D in the field of nanotechnology resp. to put forth products based on nanotechnology. Another 178 (=21,2 %) firms declared not to make use of nanotechnological techniques. The remaining enterprises were neither available (33 companies; 3,9 %) or did not answer (414 companies; 49,3 %). The questionnaires were followed by a CATI[3]-survey addressing those companies that had not answered up to that date. Combining both methods, 314 nanotechnology companies could be identified.

Furthermore 36 interviews were conducted with entrepreneurs and managers in order to gain information about their relevance structures and their motivations to start a firm resp. to implement nanotechnological activities in the manufacturing process. Finally eight experts from

[2] This definition is also used by the Federal Ministry of Education and Research which coordinates the support in the field of nanotechnology by order of the Federal Government of Germany.

[3] CATI=Computer assisted telephoning interview

the business environment were interviewed, aiming at getting insights in those structures and processes supposed to have an influence on the emergence of nanotechnological activities in certain regions but staying beyond the individual experience of founders or managers.

5 Spatial distribution of commercial activities related to nanotechnology

The results of the combined questionnaire/CATI-survey show that the German nanotechnology companies are not evenly spaced. Instead they appear to cluster in a few locations. Regarding the types of regions (Table 1) more than two thirds of the firms can be found in densely populated areas.

Table 1: Locations of nanotechnology companies

Type of region	Share
Densely populated areas	67.9 %
Urbanized areas	27.9 %
Rural areas	4.1 %

Source: Own Survey (N=314).

About one third have chosen a location in urbanized areas while less than five percent have established themselves in rural areas. It can be assumed that the large share of companies in metropolitan areas is primarily due to universities and specialised research institutes acting as incubators. Furthermore there are likely to be numerous private R&D-departments that have implemented nanotechnological activities recently (e. g. by co-operating with a local research facility) or focussed on structures that had gradually decreased due to technical progress.

Looking at map 1 (p. 7) it becomes obvious that Berlin and Munich are the two cities with the largest number of nanotechnology companies. Moreover there appear to be regional clusters in the southern part of Saxony, the middle of Germany (“Mitteldeutschland”), in the Stuttgart region, the Saarland and the Rhine-Main resp. Rhine-Neckar area. Contrary to that only a few firms can be found in the northern parts of Germany as well as in northern Hesse and Thuringia. The identification of regional clusters on the basis of absolute numbers, however, is problematic: Spatially concentrated firms are more likely to be found in regions with a wider extension and/or many inhabitants (STERNBERG and LITZENBERGER, 2003). Considering even these two variables, HENN (2006) showed that relative clusters can be proved.

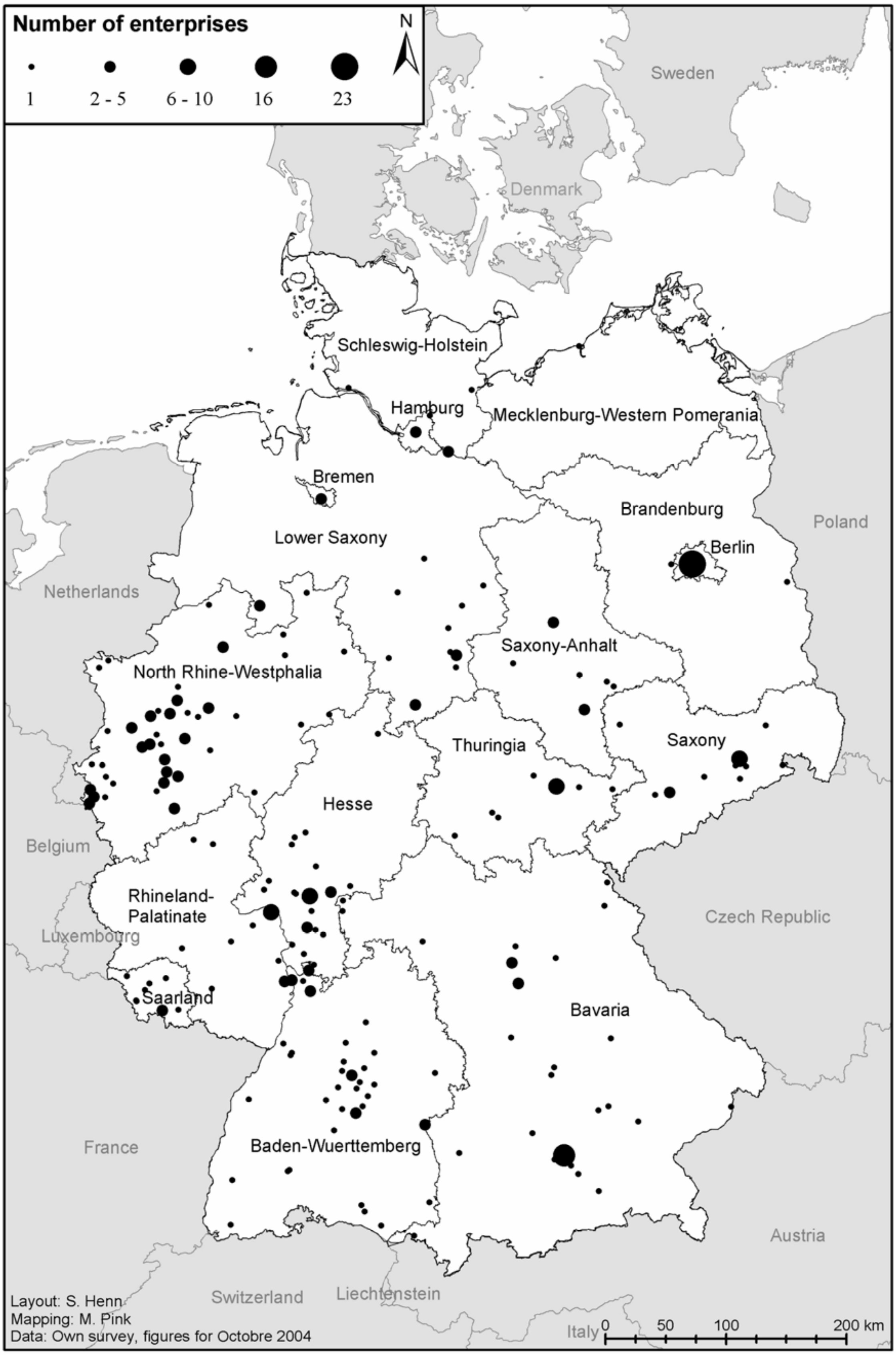
In traditional approaches of industrial geography the spatial distribution of companies is taken as a result of regional disparities in the endowment of location factors. For this reason representatives of core nanotechnological companies were asked to evaluate the role and the actual occurrence of different factors.

The results show (Table 2, p. 8) that a distinct majority of the companies attached value to the availability of qualified workforce, the research infrastructure and the proximity to research institutions. Given the knowledge intensity of nanotechnological activities, these results had been expected. The large share of firms stating regional promotion programmes, the general financing conditions and the availability of venture capital to be of great importance did not surprise either as these factors reflect the high demand for capital resulting from R&D-activities.[4] Finally the fact that the companies neither purchase nor produce goods that cause high transportation costs explains why the spatial proximity to both primary market and sup-

[4] The fact that the availability of venture capital is not as important as both of the other factors should not be contributed to a comparatively small need but rather to provisos to make use of it (DTA, 1998).

pliers is just secondary. On the contrary, the factor ‘proximity to research infrastructure’ plays an important role, pointing at the high demand for equipment and the exchange of information with research institutes.

Map 1: Distribution of nanotechnology companies in Germany



Source: Combined CATI/Questionnaire-survey (N=315).

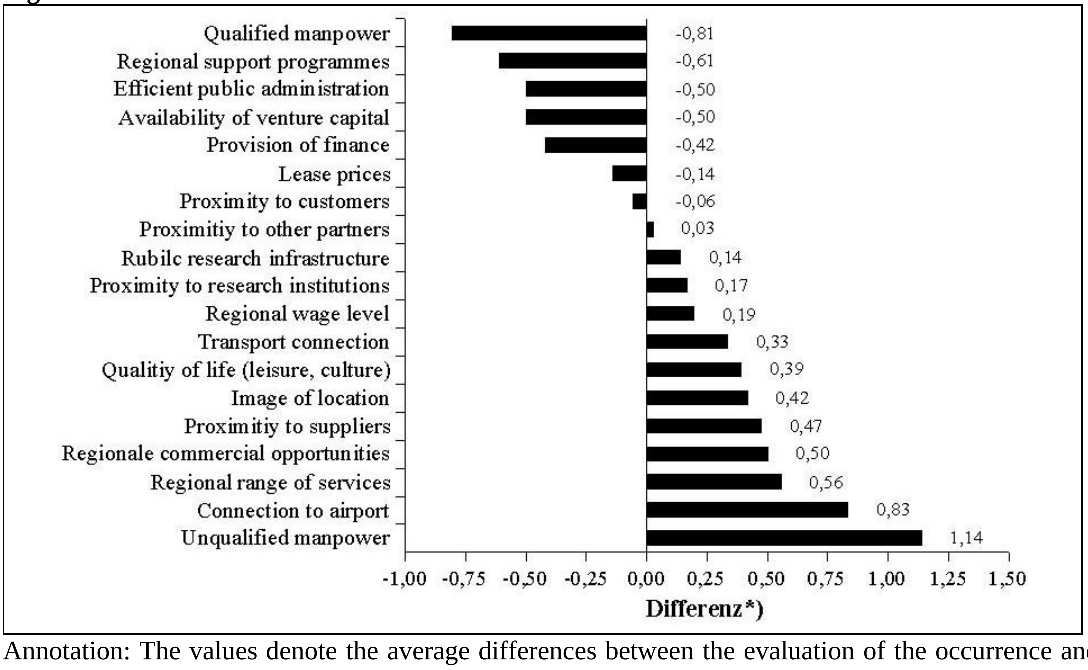
Table 2: Relevance of location factors for core nanotechnology companies

Location factor	Share[a)]
Availability of qualified workforce	70.7 %
Public research infrastructure	65.9 %
Proximity to research institutions	65.9 %
Regional support programmes	63.4 %
General financing conditions	48.8 %
Lease prices	46.3 %
Quality of life (leisure, culture)	43.9 %
Availability of venture capital	39.0 %
Efficient public administration	36.6 %
Image of location	36.6 %
Regional wage level	22.0 %
Consulting Services	22.0 %
Proximity to suppliers	19.5 %
Proximity to customers	17.1 %
Proximity to other partners	17,1 %
Transport connections	0.0 %

a) Share of core nanotechnology companies stating the respective factor to be important or very important.
Source: Own Survey (N=41; n/a=9).

When considering the differences between the evaluation of the factors and their actual relevance (Figure 1), the locations apparently offer good conditions in terms of research infrastructure, regional wage level, transport connection, and soft factors like culture or leisure facilities resp. the image of the location. Nevertheless considering the factors ‘regional support programmes’, ‘availability of venture capital’ and ‘common financing possibilities’, it becomes obvious that the companies face problems when trying to gain access to capital. On the one hand this can be attributed to the fact that most of the firms can be treated as young technology firms naturally in need of capital (BMBF, 2004c), on the other hand the tense situation of the German venture capital market still implies a general lack of venture capital for technology-based start-ups (KLAGGE, 2003, 2004; WELTER and LAGEMANN, 2003; ENGELHARDT, 2004).

Fig. 1: Differences between the relevance and the actual occurrence of location factors



Annotation: The values denote the average differences between the evaluation of the occurrence and the actual relevance of the factors on a Likert-scale ranging from 1 to 5. Positive scores imply that the occurrence of the location factor at an average is rated higher than its relevance for the company. Source: Own survey (N=36; n/a=14).

The results also point at a significant scarcity of qualified workforce, thus uncovering an inconsistency of the traditional approach: Though this factor is regarded as most important it appears to be least developed. The view based on the location factors is further questioned by the fact that personal aspects in many cases had been decisive for the choice of location (Table 3). In the first instance the proximity to the founders' residence resp. their workplaces was crucial (Table 4). Moreover contacts already established during university studies as well as other personal networks played an important role. In addition the results show that many entrepreneurs had been living in the region that later became the location of their enterprises. In such cases it can be assumed that the founders had a good information level concerning the region so that a choice of location in the narrow sense has not taken place. These thoughts are supported by the fact that almost half of them had never looked for any alternative (Table 5).

Table 3: The influence of subjective factors on the choice of location for founders of core nanotechnology companies

Role of subjective factors	Share[a)]
Primarily decisive	26.0 %
Of importance, but not primarily decisive	40.0 %
Irrelevant	34.0 %

a) Share of core nanotechnology companies.
Source: Own Survey (N=50).

Table 4: Types of personal ties

Motives	Share[a)]
Residence of founder/family	84.8 %
Former job location	39.4 %
Personal networks	27.3 %
Location of studies	21.7 %
Other reasons	9.1 %

a) Share of those companies stating that personal aspects were decisive or important for their choice of location (multiple answers possible). Source: Own survey (N=33).

Table 5: Number of checked location alternatives (cities, countries)

Alternatives	Share
0	46.9 %
1	12.2 %
2	22.4 %
3	8.2 %
4	4.1 %
5	2.0 %
More than 5	4.1 %
Total	100.0 %

Source: Own survey (N=49; n/a=1).

Following this line of reasoning a static consideration is not sufficient to explain the emergence of regional clusters. It is rather essential to take up an evolutionary point of view, understanding cluster formation as a historic process influenced by many small events. This will be done in the following when dealing with the formation of nanotechnology clusters in the Saarland and in Berlin-Brandenburg.[5]

[5] The special consideration of these two regions primarily aimed at capturing the influence of different fields of technologies and institutional frameworks.

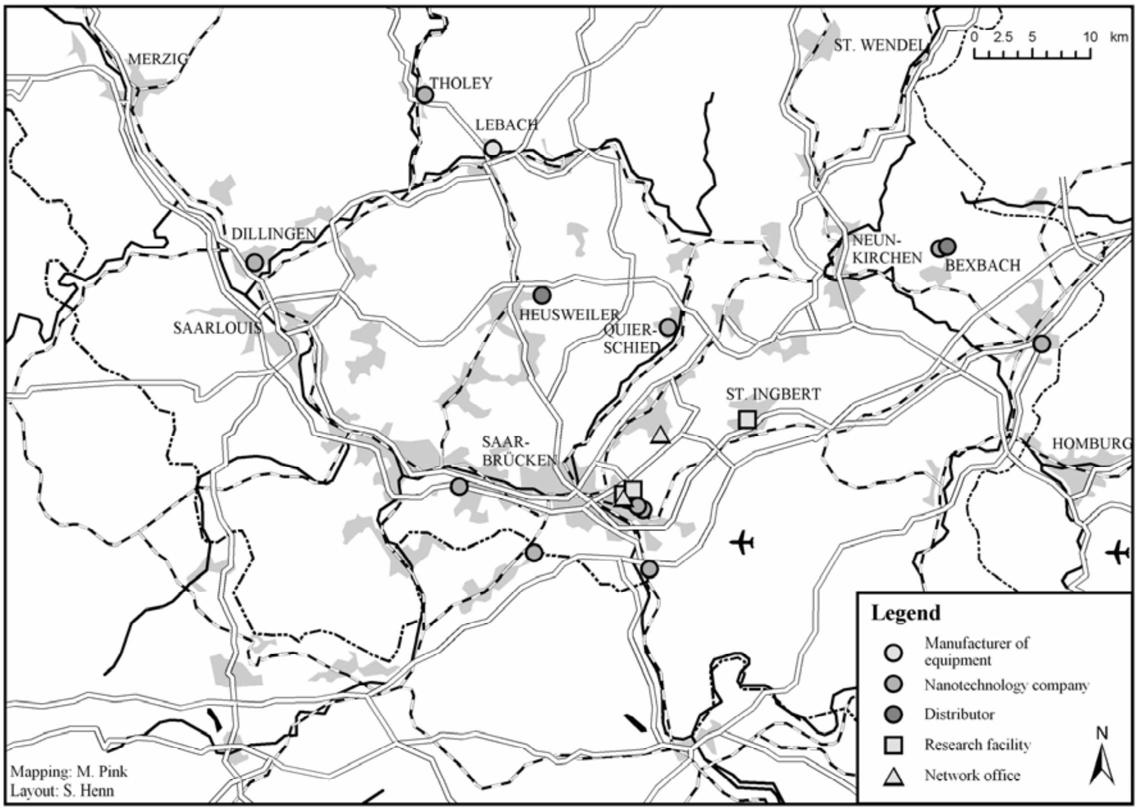
6 Cluster dynamics in selected regions

6.1 The chemical-nanotechnology cluster in the Saarland

6.1.1 Structure and evolution

In the Saarland a striking concentration of nanotechnology-related firms evolved during the last few years (map 2): Apart from 10 core nanotechnology companies a manufacturer of equipment for making nanoparticles as well as another two start-ups distributing nanotechnology-based components belong to the cluster. Furthermore, though not carrying out R&D in nanotechnology, companies from different industries use nanotechnology-based products in their manufacturing processes aiming at process or product innovations.[6] With the exception of the last type of company, the emerging cluster is characterised by SME with a total of about 200 employees.

Map 2: The nanotechnology cluster in the Saarland



Source: Own survey.

When considering the foundation processes of the core nanotechnology companies[7], the Leibniz Institute of New Materials (INM) stands out as a focal point. It is one of numerous research facilities created by the state government in the 1980s with the aim to overcome the structural changes laid upon Germany's smallest federal state by the demise of the local heavy industry (DEUTSCHER BUNDESTAG, 2000; BMBF, 2004b). The institute has currently

6 Unfortunately there are substantial difficulties as for an empirical registration of these companies so that an exact number cannot be stated here.

7 For two reasons the focus will be on the core nanotechnology companies in the following: On the one hand the relation to nanotechnology of both distributors and further processing companies results from the existence of these firms. On the other hand the supplier of equipment should be regarded as a special case for it is the only firm that – originally coming from catalyse techniques – gradually has developed into this field of technology (learning processes).

about 200 employees and represents the world's most important centre of chemical nanotechnology holding about 100 patents in different fields (Interview S18; INM GmbH, 2004, 2005a). Contrary to traditional research structures it favours a linkage between vertical and horizontal interdisciplinarity: This means that expertise from different disciplines is combined in such a way that research results will be pushed forward to the marketable end-product by drawing on materials sciences as well as on mechanical resp. chemical engineering, plant construction and industrial engineering. As a consequence the institute is not limited to basic research but also makes a substantial contribution to the transfer of knowledge into the economy and its subsequent commercialization (Interview S13; FRISCH, 2002).

As early as 1994 the first spin-off rooting in the INM was established. Throughout the years 1999-2003 another nine companies followed. Six of them directly spun off from the institute. The founders of the remaining firms, who formerly also had been working for the INM, were employed by other enterprises resp. were un- or self-employed in the meantime. Due to the fact that the relevant knowledge for their businesses originates from the INM, these companies can be classified as spin-offs, too (Interviews S1, S3, S4, S7, S13).

In general the founding processes had been triggered by three aspects: (1) First of all the INM-technology allows incremental product innovations within a large spectrum of potential applications. As a consequence founding a firm with reference to this kind of technology seemed promising in terms of economic variables (Interviews S4, S5). (2) The transaction costs for the foundations were comparatively low due to the fact that the technology is based on simple means that usually do not require expensive investments. In addition some of the founders could benefit from their former function as heads of department in the INM: As such they had some understanding of patent practices and were able to gain initial experience in personnel and project management. Above all they got in touch with customers and other cooperation partners of the institute delivering information about market developments and technological gaps within the technology transfer activities (Interviews S2, S13). (3) The simultaneous cancellation of regular employments, however, also points to the influence of negative push factors. In fact one interview partner said that some of his colleagues actually had "flown" (Interview S4) from the INM. In different talks this behaviour was ascribed to the personality of some staff members but also to an uncooperative atmosphere in the institute widely repressing personal initiative. These aspects also explain why there was no intensive cooperation between most of the INM-spin-offs and their incubator at the time of the study (Interviews S1, S2, S4, S5, S6, S7). The decisive reasons for their choice of location were of rather subjective nature: All the founders were born in the Saarland resp. had been living there for long. As a consequence personal and professional networks had evolved tying the founders to the region. As there was no further sound reason for moving away, so strictly speaking, for most of the entrepreneurs the question of choosing a location did never occur (Interviews S1, S2, S3, S7, S8).

6.1.2 Growth potential

The fact that the cluster owes its existence predominantly to spin-offs from one research facility has influenced its growth potential as will be shown by accessing the different cluster dimensions:

The core nanotechnology companies basically focus on different business segments (i. e. nanotechnology for fire protection, nanobiotechnological, nanoceramics) reflecting the individual subjects of their founders' diploma and/or doctoral theses resp. their workscopes in the

INM. There is, however, a certain competition in the field of surface technology (Interviews S2, S3). Though direct forms of cooperation only play a minor role in this domain, the firms benefit from their co-localisation: For instance, in one interview it was pointed out that a customer hinted at complementary developments in a different company providing an opportunity for further collaboration. In a second case a customer helped the founder to gain samples from his competitors allowing him to proceed technologically (Interview S4). Such a variation of products and processes is not only facilitated by the common technological background but also by the distinct nature of the technology: Under certain conditions the very knowledge of the inputs allows recourse on the respective production process so that imitations are likely to occur. Coatings of glass, at first developed by one single company and later offered by another two firms, may serve as an example for learning processes that help to increase the competitive capacity of the local firms (Interview S6).

On the other hand the vertical dimension of the protocluster has only poorly developed as yet. So far there are just two foundations that can be attributed to the existence of the spin-offs. One reason surely was the likelihood of obtaining information about the emerging technology sector (e. g. from the local media) that is induced by the local buzz. Furthermore the potential spatial proximity to the nanotechnology companies announced rapid communication flows which also might have been an influencing factor (Interview S8). Concerning the cluster growth along the vertical dimension, however, processes of internal learning appear to be more relevant than firm foundations: According to an estimation of the local nanotechnology network, 500 plants in the region can be classified as potential users of nanotechnological components (Interviews S1, S12). Anyway, this number should not hide the fact that up to now only a very small share of customers of the core nanotechnology companies is localised in the Saarland: In most of these companies more than 90 % of the sales actually account for regions outside the state. The coordination of such a nation- or worldwide client base is only possible as the technological development does not require a permanent contact with the clients. In some cases, the companies rather confine themselves to producing some critical components while external service providers are responsible for the remaining manufacturing steps (Interviews S4, S7). At the same time regional linkages to suppliers appear to be almost negligible. Chemicals needed for the production processes as well as production equipment that is more or less standardized (stirrer, scales etc.) are being acquired from outwards (Interviews S2, S4). Regarding the comparatively small amounts of input factors it even seems questionable whether relocations due to economies of scale will occur in the near future.

The interactions within the different up- and downstream linkages allow new knowledge to enter the cluster, resulting in an increase of the innovative capacity of the local firms. Aside from these classical types of translocal pipelines two companies built up other forms of external linkages that play a vital role for the competitiveness of the companies and the subsequent growth of the cluster: One firm is engaged in two joint ventures, both acting as clients. In so doing, it gains the possibility to refine the technologies according to special needs which in turn improves its competitiveness. Another Saarland-based company has opened a subsidiary in Eastern Germany primarily responsible for the up-scaling. As there is an intensive interaction between the two locations, different views and deviant experiences with the technology brought in by the employees recruited at the new location, reach the headquarters, stimulating further developments (Interviews S11, S20).

When dealing with the external cluster dimension, however, it is inadequate to make reference only to the companies. It can rather be assumed that linkages of research facilities are able to pump external knowledge into the cluster as well. In this context the INM again is of particular importance due to the mentioned technological similarities. It not only has a strategic partnership with a Swiss concern and a Japanese research facility but also stays in close contact with other actors from around the world (Interview S13). In addition the institute acts as a central organizer of exhibitions and conferences. Such meetings provide to the firms important information about new technology trends and potential applications. Furthermore they favour the development of direct contacts to customers which is of great importance to SME in nanotechnology, an aspect due to a lack of sales channels (MISCHLER, 2003).

The potential of generating a dynamic interaction between the local buzz and the translocal pipelines, however, remains restricted as there is a certain mistrust within the local community: Many talks pointed at frictions between single companies and the INM that mostly originate in personal aspects and differences concerning the interpretation of patent regulations (Interviews S1, S13, S15). The linkages between the firms are also characterised by a certain tension. As the talks suggest it seems reasonable in this context to differentiate between firms based on venture capital (VC) and non VC- financed companies. According to one interview this “society of class distinction” (Interview S5) is primarily based on personal aspects. Nevertheless it yields effects on inter-firm cooperation and thus on the development of the spatial concentration as a whole: Due to similar experiences collected by the founders of the non VC-financed companies when setting up their firms, a kind of appreciation for each other’s problems has developed resulting in the willingness to pass on customers (Interview S7). This kind of solidarity, however, is not granted to the other group of firms: The latter is rather being blamed for having raised expectations that could not be lived up to so that the reputation of nanotechnology has been damaged (Interviews S1, S5, S6). The VC-based firms, on the other hand, assume resentments and distance themselves from the others. Besides they argue that differences in the stages of development would hamper a wider cooperation (Interview S20). Nonetheless, the similarity of the applied technologies basically enables a common understanding and communication between the actors allowing a specific cluster awareness to form.

As a reaction to the emerging structures different formal institutions have developed aiming at stimulating a further growth of the cluster. In 2003 the competence centre (CC) Nanobionet was created by the state of Saarland with subsidies from the European Union. It follows the task to match cooperation partners, to do patent inquiries, to provide advice as to apply for funds, and to find qualified contact persons for different classes of problems. There are another two offices of nanotechnology related networks (CC Nanobiotech, CC Nanochem) created during a nationwide competition by the Federal Ministry for Research and Education (BMBF) in 1998. Although they primarily do not focus on the region, they too can act as contact points for local firms carrying out nanotechnological activities or being interested in this field of technology in general. Moreover they participate in creating regional institutions related to technology specific questions (like support programmes) and thus have an influence on the cluster development.

The field of further education is characterised by cluster related structures as well: For example, at the local university, two laboratories were created where pupils can conduct nanotechnology-related experiments under the supervision of a scientist. Furthermore two kits have been developed for the local schools containing different components for nanocoating and nanoparticle-based experiments.

As the pupils learn, so do their teachers: several lectures and test series with relation to nanotechnology are being carried out to give them an understanding for this field of technology. As a whole, the mentioned measures contribute to a sensitization regarding nanotechnology which again can reduce provisos and initiate a kind of technological enthusiasm, both providing the grounds for a reproduction of the cluster.

Special attention is paid to the emerging technology by the local university which made nanobiotechnology one of three main thematic fields determining its future profile. In addition it has implemented micro- and nanostructures as nanotechnology-related course of studies. It can be assumed that its alumni will shape the local employment market and probably act as potential entrepreneurs (Interviews S1, S12).

The education of laboratory assistants, however, is presently based on training on the job. Regarding a potential scarcity of specialised workers in the future several measures are being discussed among the responsible governmental authorities as how to react adequately to the growing demand (MALLMANN, 2005).

Finally the cluster firms can benefit from new forms of financial support: A few years ago already, nanotechnology became one element of the investment portfolio of a local medium-size investor, thus enabling the foundation of three companies (Interview S16). Moreover, special guidelines for the support of life-science and nanotechnology have been adopted by the department of trade and industry, and only recently a special fund was created for companies willing to carry out feasibility studies (NANOBIONET, 2005).

6.1.3 Intermediate Result

The evolution of the nanotechnology sector in the Saarland clearly corresponds to model A: As could be shown, certain factors promoting future cluster growth have been developed as a reaction to initial start-up-processes. This set-up of institutions presupposes the perception of the emerging structures which in particular was favoured as the foundation processes took place within only a few years and were characterised by the motivation to commercialise the same technology.

It may serve as an indicator for further developments that five companies taking part in the survey pointed out that they plan to hire a total of 94 workers till 2007.[8] Besides the growth of existing companies, other spin-offs from the INM and the university are supposed to occur. Last but not least, incubator networks resulting from repeated spin-outs from existing companies may arise.

The positive developments achieved during the last years, however, should not imply that there is no scope for further reactions. Rather it seems essential to reduce the mistrust between the INM and the spin-offs in order to stimulate the local buzz. In this context it should be attempted to facilitate the access to the institute by easing regulations. Moreover future spin-offs could be promoted by creating an entrepreneurial atmosphere in the INM. In this context so there is the possibility of implementing part-time-models or set up guarantees for coming back when the respective start-up fails. Eventually, aiming at avoiding future conflicts between the institute and the spin-offs, free information sessions related to intellectual property should take place in planned intervals. Finally, due to the fact that the financing of the federal

[8] At the time of the study the considered companies had about 100 employees so that a doubling of staff numbers seems probable till 2007.

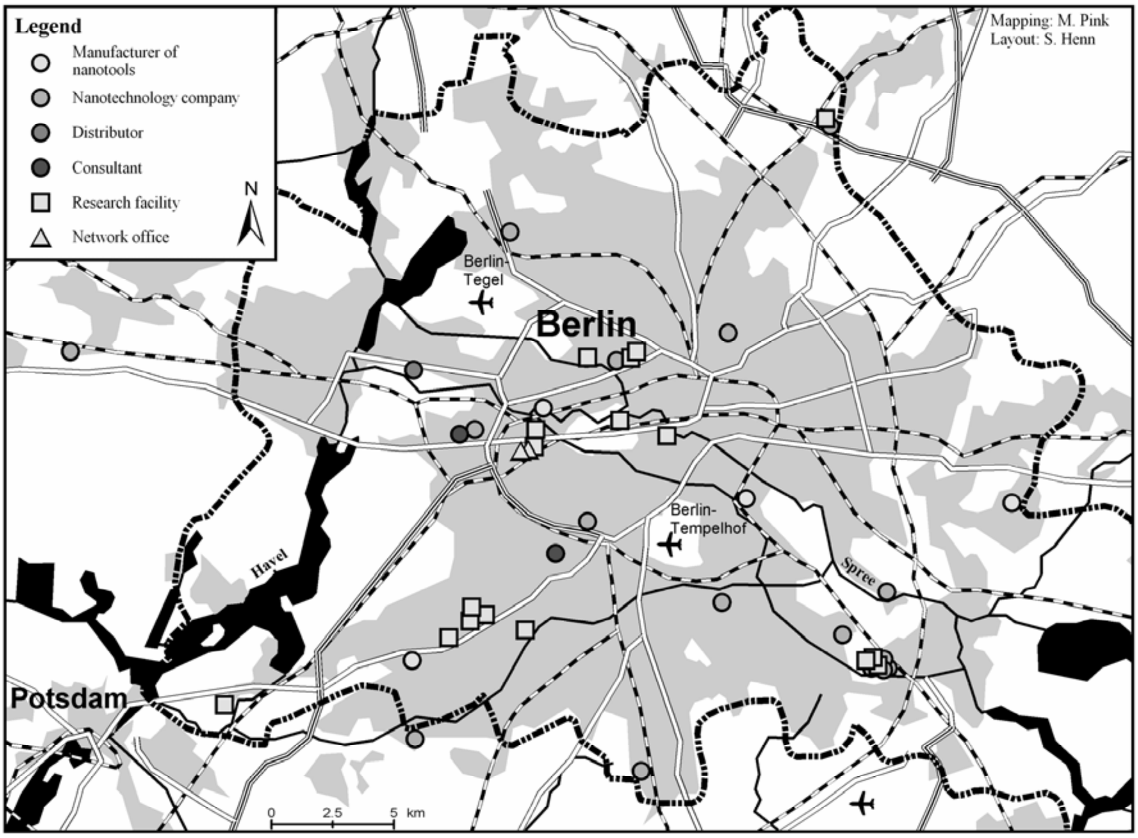
networks expires in 2006, it has to be considered whether a continuation of the networks is possible by adapting special funds by the Saarland.

6.2 The cluster in Berlin-Brandenburg

6.2.1 Structure and evolution

In Berlin-Brandenburg, a spatial concentration of firms with activities in different fields of nanotechnology has evolved over the years (map 3).

Map 3: Actors in nanotechnology in Berlin-Brandenburg



Source: Own survey.

Altogether, five groups of companies can be distinguished: Firstly there are six plants developing nanotools, i. e. devices for analysing nanoscaled structures. Secondly sixteen nanotechnology companies can be found. While some of them deal with nanomaterials and ultraprecise surface technology there is a clear emphasis on nanobiotechnology. According to the distinction made above, some of these firms can be classified as core nanotechnological companies. Thirdly one enterprise focuses on the distribution of products based on chemical nanotechnology. Last but not least another two firms offer consulting services related to nanotechnology. Finally there are miscellaneous companies that do not produce nanotechnology based components but make use of them in their manufacturing processes.[9] Apart from them, the cluster firms, mostly SME, have more than 10 000 co-workers.[10]

[9] However, as to the reasons mentioned above, their number cannot be stated here.
[10] It should be mentioned, however, that one single company has more than 6.000 employees.

With regard to the formation of the spatial concentration three different mechanisms can be distinguished:

Apart from one firm all core nanotechnology companies are **spin-offs** from different research facilities located in the region. Their foundation was mainly due to commercial opportunities and technological visions. In at least one case the founders' wish of being self-employed played an important role (Interview B3), while in another case the foundation was predominantly an outcome of the individual threat of getting unemployed (Interview B12). In terms of site selection many companies are dependent on the spatial proximity to their incubators because of the access to devices and facilities they cannot afford (Interview B5). Further, the proximity to the incubator ensures the continuation of proven routines as it was stated in one interview (Interview B3). But even for those firms not reliant on their incubators, a location in the considered region usually was chosen along with the founding-decision decisively based on subjective factors (social networks, proximity to residence) (Interviews B15, B16).

Besides the foundation of new firms, **learning processes** in existing companies accounted for the commercial nanotechnological activities in the region. Often the latter are taken into account just as a part of temporary projects. This holds true for big companies with separate R&D-departments but also for SME and is favoured by the fact that high investments need not be necessary for taking up nanotechnological activities (Interviews B2, B17, B18, B19).
Finally one **dislocation** of a core nanotechnology company contributed to the agglomeration so far, the decisive cause being social relations rather than location problems (Interview B20).

6.2.2 Growth potential

Except for the nanobiotechnology companies that – at first glance – produce similar products (nanoscaled drug-delivery systems), all other firms are characterised by large differences in regard to their product range. As a result they do not compete with each other. A closer analysis shows that even in nanobiotechnology in most of the cases there is no rivalry among the firms because of different types of nanoparticles made for different purposes and thus affording a different kind of knowledge. The competitors of nanotechnology firms, however, need not necessarily be active in nanotechnology either for the application of conventional technologies (e. g. classical biotechnology) could basically cause the required or similar effects as well. However, considering the high specificity of the problems, the companies even do not face a strong competition throughout the world (Interviews B4, B5, B10, B11). As a consequence a horizontal cluster dimension has not yet developed.

Linkages between the different segments of the value added chain, reflecting the vertical dimension of a cluster, remain quite sparse, too. The fact that there seem to be numerous up- and downstream companies should not be contributed to the existing concentration of nanotechnology companies but is owed to independent foundation and learning processes. The founders of the two consulting companies, for example, had gained experiences in the field of nanotechnology during their former profession. When their careers faced changes they decided to become self-employed. They had been living in Berlin for a couple of years, creating complex social networks so that there was no reason to move to another location (Interviews B1, B24). Looking at start-ups in the field of nanotools resp. at the distributing firm yields similar results (Interviews B6, B7, B8, B9).

In the majority of cases, the interviewees did not know the mentioned up- or downstream firms. This suggests that the companies refer to different parts of nanotechnology-related value chains that do not overlap.

Supplier relations to other firms located in the region do not appear to be important either. For example, some nanobiotechnology companies are dependent on chemicals and other raw materials which usually are purchased by catalogue from outside. In one case it even was pointed out that the company usually draws on the suppliers of its customers in order to develop under future manufacturing conditions and thus to guarantee the best possible reproduction of the processes (Interview B10). Relations to regional customers only play a minor role as well. One important cause for this is that, for historic reasons, there are only a few companies in relevant branches in Berlin-Brandenburg (Interviews B3, B10, B15). Besides customer-relationships on a national or international scale many companies have developed other types of linkages that permit the inflow of new knowledge into the region, whether these are international agreements on licences and patents, co-operations with research facilities outside the region, the affiliation to a foreign concern or the engagement of a management member at a foreign university. Partly the firms can further benefit from local fairs and symposia which focus on nanotechnology. In this context the NanoMed, an international fair on nanomedicine initiated in 1999 by scientists of a Berlin based clinic, stands out. Companies active in nanobiotechnology there gain the possibility to socialize with external partners offering opportunities for further collaboration (Interview B10).

Information delivered through the translocal pipelines cannot, however, contribute to a cluster growth due to a lack of local buzz: Though the employees of the nanotechnology companies often know each other or have some information about the respective activities the contacts between the firms more or less remain restricted to knowing each other. Only in exceptional cases they imply more intensive interactions between the companies. This low intensity of the local buzz has different reasons: Firstly in many cases there is a lack of identification with activities in nanotechnology because the actors are not exclusively dealing in this field but only carry out temporary projects. In case of universities and research facilities the evolutionary development towards decreasing structures has led to a lack of consciousness of being active in nanotechnology (Interview B14). Secondarily the inter-firm communication is hampered by activities in different fields of nanotechnology (Interview B10). Thirdly there is a certain mistrust between companies primarily due to personal aspects (Interview B21). On the whole the missing communication between the companies has resulted in the fact that the agglomeration has not yet become ‘visible’ as a cluster (Interviews B4, B6).

As a consequence a consistent institutional framework could not develop: For example there is no programme of studies that explicitly focuses on nanotechnology (Interview B4). Instead it is being dealt with, if at all, as a part of conventional subjects (physics, chemistry, etc.). Very rarely nanotechnology has entered further education. So it constitutes one element of the optional subject nanobiotechnology offered by a local academy for further education (Interview B21) but also is central to the centre for nanophotonics opened by one university in 2004. There employees of firms active in nanooptics have the possibility to gain information concerning different techniques for producing nanooptoelectronic components (TU Berlin, 2005). Moreover some companies offer internships for students resp. further training (e. g. exercises in the field of atomic force microscopes) for interested parties and educational institutions (Interviews B2, B4, B6). Altogether, the different measures do not appear homogeneous but rather patchy.

Different firms also pointed out that there was no common contact point in nanotechnology. In fact, the competence center for the application of nanostructures in optoelectronics (CC Nanop) founded by the BMBF in 1998 comprises different academic groups from around Germany but only has a weak regional basis though its headquarters is in Berlin (Interview B25). But even the centre for biomedical nanotechnology (CBN) comprising a research group of the Charité as well as one spin-off has not been able to realise its aims due to a lack of personnel and financial support (Interview B4). However, recent developments suggest change: In 2004 representatives of the local biotechnology network founded an association of common interest with reference to nanobiotechnology, realising that previously applications related to similar subjects had been submitted by different local firms suggesting that they work on the same fields. Inquiries, however, showed that the firms did not know each other or that a co-operation between them had not taken place for several reasons so that the implementation of regular informal meeting seemed an adequate measure to strengthen the contacts (Interview B21).

6.2.3 Intermediate Result

As the evolution of the spatial concentration of nanotechnology-related firms cannot be traced back to a single research institute, model B seems adequate to explain the formation of the spatial concentration of nanotechnology companies in Berlin-Brandenburg.

Spin-off processes from different organizations as well as learning processes in different fields of technology have resulted in technological gaps between the firms thus obstructing the formation of a cluster awareness. As a consequence the nanotechnology-related activities are only insufficiently perceived by political actors implying a lack of regional support institutions. Due to the lack of different cluster dimensions it even seems probable for the future that nanotechnology will not be supported as such but only as an element of other fields.

Nevertheless it seems possible to sustain a cluster in nanobiotechnology (esp. drug-delivery systems) for there are several firms and research facilities with similar activities in this field. An important measure in this respect is the implementation of a central actor able to identify and to link different firms. In order to build up trust between the spin-offs it is further recommended to set-up a center for nanobiotechnology that could function as a business incubator providing a certain infrastructure for further firms spinning off from different institutions. Such a meeting-point would favour contacts between the firms thus forming the basis for future collaboration. A quick reaction, however, seems essential as five out of 14 companies, taking part in the survey, pointed out that they cannot rule out potential relocation.

7 Conclusion

In detail the results of this work show that two forms of evolution of spatial concentrations in nanotechnology should be distinguished, each demanding its own political recommendations:
At first there are nanotechnology clusters that predominantly owe their existence to spin-off-processes from focal organisations. Due to technological similarities they are likely to be characterised by a broad horizontal dimension. Further, they have a comparatively high growth potential as regional actors easily will perceive them and accordingly build up cluster-specific institutions. As a consequence the emerging clusters might also be perceived as outstanding regional competence centres from an international point of view. Regarding the vertical cluster dimension it can be assumed that the cluster firms probably will demand only

small amounts of input so that there is no incentive for contractors to collocate. Due to the fact that the firms usually serve the global market there is no plausible reason why customers should relocate close by either. The consequence is that learning processes in existing companies seem to be of more importance for the growth of the vertical dimension pointing at the necessity to transfer products and techniques based on nanotechnology in local companies. Whether this is possible, however, depends last but not least on the nature of the technology and its potential fields of application.

In the long term, these start-up-clusters face a disadvantage due to their technological one-sidedness as they are likely to run the risk of disregarding new technologies developed outside, thus endangering their competitiveness as a whole. In order to avoid this it seems important to develop the external cluster dimension quite early, for example by organising business delegations or events like international trade fairs and symposia related to the respective technology. Additionally, effective marketing strategies like joint trade fair stands or a common brand or logo implemented by a kind of cluster management could help to draw the external actors' attention to the cluster (RAINES, 2002). But even connecting-elements like joint purchasing networks could meet the needs of the firms. Moreover, these clusters can be supported by facilitating spin-off processes out of the focal institution by setting-up certain incentives (informative meetings, presentations of success stories, comeback guarantees etc.). On the other hand it can be assumed that the founders of the companies know each other due to their common past so that taking measures with the aim to establish contacts between them only plays a minor role. All in all, start-up-clusters in nanotechnology appear to be a rare phenomenon for their evolution relies on technologies capable of generating numerous start-ups.

The second model of cluster evolution implies that nanotechnology develops simultaneously and independently in different organisations over the years. Considering the heterogeneity of nanotechnology and the different modes of how nanotechnology companies evolve it can be assumed as a rule that these clusters are characterised by a weak horizontal dimension, resulting in considerable difficulties in terms of inter-firm communication. Supporting a growth of these agglomerations seems difficult as there probably is no essential coherence between the firms. Furthermore there is only a limited interest in getting to know each other because of large technological gaps that have to be bridged pushing the company too far from its core competence. One interview partner put this issue in his own words: „Nano is not the same as nano. We do microelectronics – what should I do with a firm coating washbasins? There are not many similarities. What do the companies have in common? They have in common that they deal with nanoscaled structures" (Interview D6). However, what appears as a disadvantage in the short run, might become advantageous in the future: Under certain circumstances these unrelated agglomerations will manage to bring together actors from quite different fields of technologies (so for example nanobiotechnology and nanoelectronics) thus generating highly innovative developments. For that reason it seems important to design guidelines for future developments based on the identification of the current activities in the field of nanotechnology and potential fields of cooperation.

On the whole the study implies that the notion of nanotechnology clusters should be used carefully, always taking into consideration that spatial concentrations of nanotechnology firms considerably differ in their evolution, their inner structure and hence in their potential to generate regional growth.

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