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Cluster Performance reconsidered: Structure, Linkages and Paths in the German Biotechnology Industry, 1996-2003

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Abstract

This paper addresses the evolution of biotechnology clusters in Germany between 1996 and 2003, paying particular attention to their respective composition in terms of venture capital, basic science institutions and biotechnology firms. Drawing upon the significance of co-location of "money and ideas", the literature stressing the importance of a cluster's openness and external linkages, and the path dependency debate, the paper aims to analyse how certain cluster characteristics correspond with its overall performance. After identifying different cluster types, we investigate their internal and external interconnectivity in comparative manner and draw on changes in cluster composition. Our results indicate that the structure, i.e. to which group the cluster belongs, and the openness towards external knowledge flows deliver merely unsystematic indications with regard to a cluster's overall success. Its ability to change composition towards a more balanced ratio of science and capital over time, on the other hand, turns out as a key explanatory factor. Hence, the dynamic perspective proves effective illuminating cluster growth and performance, where our explorative findings provide a promising avenue for further evolutionary research.

JEL-Classification: O18, O32, L22

Keywords: Cluster evolution, dynamic perspective, basic science, venture capital, biotechnology, Germany

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1 INTRODUCTION

There is a rather long and well established tradition to regard ‘clusters’, ‘industrial districts’ or ‘regional innovation systems’ as favoured locations for the production of goods, services and knowledge (e.g. (Audretsch/Feldman (1996); Bresnahan et al. (2001)). Here, one camp has been arguing that firms, industries and knowledge are becoming more and more footloose and economic activities progressively take place regardless of physical distance. In such a ‘weightless economy’ (Quah (1997); Coyle (1997)), geography is treated more or less as historical relict (Ohmae (1990); Cairncross (1997)).

A counter-movement follows a radically different line of thinking. According to this view, spatial proximity enhances the competitiveness of firms by facilitating the types of interrelations and interactions that keep organisations in place and foster processes of learning and innovation by means of face-to-face contacts, ‘local buzz’, localised capabilities and the like (e.g. Maskell/Malmberg (1999); Storper/Venables (2004)). In this line of reasoning, proximity acts as a basic governance mechanism in that it reduces transaction costs by establishing helpful local codes and a common language. Similarly, Morgan (2004) warned before accepting views regarding the supposed death of geography, as knowledge creation still depends on localised interaction to a large extent. Thus, a specific geographical configuration of economic activity is seen as playing a crucial role in determining the future prospects of firms and industries.

Many of the characteristics of the knowledge-intensive sectors point in the direction of this line of argument. According to Leamer/Storper (2001), these sectors – while permitting a decentralisation of certain routine activities – contribute to reinforce urban concentration and agglomeration. Economic success in the knowledge-intensive services often hinges on the creation of networks, on social interaction, locally based tacit knowledge and personal contacts – factors whose genesis is significantly facilitated by geographical closeness (compare in more detail Zademach (2005)). As spatial expression of this phenomenon, the emergence of strong clustering effects, such as the concentration of high-technology industries in Silicon Valley, the Boston or the Cambridge area, are found all around the globe. However, discussions about the cluster phenomenon concentrate only on a handful of famous clusters. Several locations that start off with favourable conditions did not takeoff but sunk into oblivion. The concentration on the few successful clusters has many researchers and policy analysts led to a kind of recipe approach: Take a university, locate some investors around, initiate entrepreneurship lessons and the cluster economies will start off.

This paper addresses the mechanisms pushing regions to extraordinary performance. Building on Powell et al's (2002) work on the biotechnology industry in the US in which they addressed the relationship between science institutions, venture capital (VC) and biotechnology firms and identified the significance of 'co-location of money and ideas', the case of the biotechnology industry in Germany serves as testing ground. The analysis proceeds from a triad of conceptual starting points. In essence, we investigate first the extent to which the clusters composition (i.e. proportion between locally-based science and capital), second their external linkages, and third their evolutionary trajectories correspond to their respective performance levels. By this means, we do not merely emphasize if, but also on how clusters change over time. That is, by looking on several clusters showing a wide heterogeneity of performance, we explore their respective configuration, degree of openness and internal interconnectedness, as well as structural transformation over time.

The remainder of the paper proceeds as follows. The next section draws relevant theoretical considerations from the related literature. Section 3 briefly sketches the characteristics of the human biotechnology industry. Section 4 specifies the methods of the analysis and represents the empirical results. Section 5 concludes.

2 LITERATURE REVIEW AND THEORETICAL CONSIDERATIONS

The literature in business and managerial science highlights that the composition of a cluster (Porter (2000, 254)) i.e its configuration in terms of private firms, public institutions, governmental regulations, access to capital, sectoral specifications etc., is crucial for providing a hotbed for innovative firms (e.g. Feldman (1994)). For nurturing innovative firms, science and capital are two essential factors. Substantiating this statement, Powell et al. (2002) find that these two factors are strongly regionally concentrated in the US hotspots of the biotechnology industry.

Given the – at least theoretically utterly unrestricted – ubiquitity of capital, one might ask for the basic rationales behind the spatial concentration of money and ideas. Here, a first key rationale relates to the fact that in high-technology industries, innovations are the result of accumulation and a special combination of knowledge, namely basic and applied science. Public research institutes not only draw scientists and engineers to a region but also generate knowledge that nearby firms can use. In her case study, Saxenian (1994) reports the importance of knowledge transfer between Stanford University and firms located in Silicon Valley. Jaffe (1989) documents that university research positively impacts patenting by firms in the same region. Feldman/Florida (1994) argue that the clustering of innovations is related to the existence of R&D institutions, universities and firms in a particular region as main centres of knowledge creation. Similarly, Prevezer (1997) finds that the strength of the science base is an effective magnet for the entry of biotechnology firms in the USA (compare similarly Audretsch/Stephan (1996); Zucker et al. (1998)).

A second key aspect is the availability of VC with its rather well established role for the development of high-technology regions. The private equity market has become a major source of financing of start-up firms and has grown, at least until the economic downturn at the beginning of the 21st century, at an explosive rate. Empirically, Powell et al. (2002, 304) found a strong pattern of spatial concentration in biotechnology and VC and state "… that without venture capital and regional agglomeration, the industry would not exist in the form that it does today". The role of locally-based capital might appear astonishing at first sight since capital, particularly if compared to knowledge, is highly fungible (Clark/Wójcik (2005)). Yet most VC or risk capital investors do not only transfer the money; in addition they provide advice and contacts and influence management decisions; being able to combine the investment process with such influence is one of the distinctive features of venture and private equity capital. As problems of asymmetric information, agency and uncertainty are a function of physical distance (Porteous (1995)), close geographical proximity between firms seeking and institutions providing finance reduces costs and efforts of monitoring and consulting. Thus a spatially rather concentrated distribution of innovations and "smart money" may be seen distinctly advantageous compared to more dispersed systems (Casamatta (2003)).

Following the argument of Bathelt et al. (2004), the co-location of money and ideas can, however, not be regarded the bare source of a regional innovation system's economic and innovative success. Instead, the role of external sources in stimulating growth within a cluster has to be taken into account, too. In other words, besides local "noise" (Grabher (2002)) fed by the interconnection of local actors, 'pipes' pumping knowledge from other areas of the nation and the world into the cluster are expected to matter for cluster success. The openness of the cluster is of particular importance when the market for the innovation is global. Ties to market actors worldwide keep the cluster up to date and provide relations to current and potential collaborators in research and commercialisation (Bresnahan et al. (2001); Zeller (2001)).

However, getting access to external information and partners over pipes requires most often accepting high uncertainty and undertaking significant investment. Here, some institutions (e.g. government and investors) can play a decisive role, first by taking the role of boundary spanners that build the bridge between clusters and non-local actors over which information flows to the cluster, and second by bringing experience from operating in other parts of the world in the cluster. Apart from providing money VC firms play a hands-on role in the running of the young companies and present relevant sources of management expertise. Though it is generally acknowledged that these processes of monitoring, advising and managing are much more easily accomplished when the young firm is located nearby, the mere focus on the local arena runs also the distinct risk of lock-in effects (e.g. Grabher (1993)). To avoid such lock-ins, "consciously open network relations for the influx of external information as well as maintaining a certain amount of distrust with respect to traditional solutions are important" (Bathelt et al. (2004, 42)). The same mechanism holds for the firm level; Several studies show that biotechnology firms involved in an intense collaboration network are bringing products to the market faster (Rothaermel/Deeds (2004)), attract more capital (Stuart et al. 1999) and are more likely to restructure in times of change (Häussler (2005a)).

Third and lastly, we regard clusters as moving targets with its composition and interconnectivity evolving over time. Past cluster studies – at least those addressing multiple clusters in comparing manner – have rarely considered the dynamics and trajectories of clusters being relevant for their performance. However, the dynamic lens is gaining momentum with the accelerated pace of technological innovations and increased competition. Changes in the composition of clusters can be understood as an evolutionary path; paths thereby show the development of cluster characteristics such as growth in number of firms, performance (e.g. patents, products), and structure (e.g. science and capital) over certain time spans. Based on the assumption that these paths are not fully dependent on former positions, the actors in a cluster or third parties (e.g. government) have the ability to influence the paths.

The composition of clusters over time may either remain stable, or show the trend towards greater divergence respectively convergence. In this regard, several scholars provide convincing arguments – e.g. imitation is inherent in human nature, people exchange ideas, learn from each other and may be influenced by the same advisors – which favour a convergence hypothesis (DiMaggio/Powell (1983)). This hypothesis has however hardly ever been tested for cluster evolution. To our best knowledge, the mere closely related study is Owen-Smith/Powell's (2006) comparative investigation of the Boston and Bay area clusters. By examining three types of ties – those between biotechnology firms, between biotechnology firms and investors, and between biotechnology firms and public research organisations – the authors show that the clusters network structure shows strong differences in 1994 but resembles in the year 1999. Broad similarities between clusters today "…can be outcome of divergent patterns of development" (p. 3). However, the authors focus only on two very successful clusters. Hence, no general conclusion between evolutionary paths and cluster performance can be derived.

3 Human biotechnology industry as testing ground

The biotechnology industry was born when recombinant DNA technology and molecular genetics opened a path-breaking method of research. In this industry, it is widely recognized that firms tend to agglomerate due to the following rationales for spatial clustering. First, the biotechnology industry exemplifies many of the characteristics of science-based sectors. Firms must be at the forefront of science to be successful market actors. Thus, biotechnology firms are often linked to universities and public research institutes that conduct basic and applied science. Second, biotechnology is likely to profit from localisation economies because much of its knowledge is tacit and uncodifiable (Aharonson/Feldman (2004, 3)). Third, the R&D process, by its very nature, is highly uncertain and complex (Häussler (2005b)). On average, during the ten to fifteen years it takes to develop a drug to market, the 10,000 compounds that enter the process are distilled down to one single marketable drug. Fourth, biotechnology firms are dependent on the capital market. Developing pharmaceutical products is highly capital intensive; on average, costs to develop a new drug amount to $802 Mio. (DiMasi et al. (2003)). Thus, the availability of capital is an important ingredient for developing a hotbed for biotechnology firms.

In Germany, there was hardly any sign of a biotechnology industry when Interferon™, the first drug developed by a biotechnology firm, entered the market in 1986. The amendment of the Genetic Engineering Act in 1993 significantly improved the administrative and legal environment for biotechnological research, raising hope for a biotechnology industry in Germany. The initial spark was the BioRegio competition in 1995, launched by the German Federal Ministry of Education and Research, which aimed to boost the foundations of biotechnology firms around its winner regions. Entrepreneurs in life sciences have been motivated by public policy and enormous government subsidies to form ventures around those regions.

The German biotechnology regions provide an excellent environment for investigating the structure and evolutionary paths of clusters. The observation period of this study starts in 1996 in order to capture the effect of the BioRegio competition, the early steps of biotechnology firm foundation in Germany, and to track the development of biotechnology firms, science institutions and investors in biotechnology.

4 Specification of analysis and empirical results

Before focus is shifted to the empirical results and the examination of the extent to which the given theoretical approaches help to explain the performance of German biotech clusters, the following section briefly describes the database and reflects on the methods applied.

4.1 Data, methods and cluster identification

As key source for our investigation serves a compilation of the annual BioCom listing of (1) biotechnology firms, (2) public institutes researching biotechnology, and (3) investors in biotechnology operating in Germany between 1996 and 2003.[1] Further directories, e.g. Dechema or the Dufa-Index were used to complement the database. Separately, we compiled data on risk/venture capitalists investing in biotechnology firms by dint of information provided by the magazines “Venture Capital”, “Going Public” and “Transcript”, the Venture Economics database, the VC Facts database as

[1] *BioCom is the largest and most historical independently operating directory for biotechnology in Germany.*

well as company press releases and announcements from the German Private Equity and Venture Capital Association.[2]

Concerning the identification of biotech clusters, the literature provides a variety of different approaches. They all offer more or less identical results, so that the 'hot spots' of German biotech are rather well established (e.g. Ernst & Young (2001); BioCom (2004, 13)). On basis of our data record, this is once more substantiated: In the present study, clusters were identified using the relative Euclidean distances between biotechnology firms, research institutes and VC investors in biotechnology. Applying a two step-approach, the raw cluster data were first visually selected from a map and then analytically refined. Each firm's, each research institute's, and each VC investor's postal address was therefore converted into latitude and longitude measurements. Subsequently, the objects were mapped with help of MapInfo (a software package offering a tool to identify clusters depending on a selectable radius); clusters were specified as concentration of an overall minimum of 40 objects, with the individual lower thresholds for firms, research institutes and investors being 20, 10 and 2, respectively.[3] A clear leap in the quadratic distances from the cluster objects to the cluster centre determines the borders of the clusters.

For each year during the period of investigation, this means brought forward nine clusters, in which a significant share of German biotechnology activities takes place in spatially concentrated manner.[4] All nine regions are compact areas with radii ranging from 16.9 km (Hanover) to 60.7 km (Ruhr area). Beside these two, Hamburg, Berlin, Göttingen, the Rhine/Main area, Heidelberg as well as Stuttgart and Munich come to the fore as the key nodes in German biotechnology. They all explicitly define themselves as a biotech region; that is the applied mode of cluster selection let to results that coincide with the 'real world'. The identification and interplay of the cluster participants is expressed, e.g. in a regional logo, own webpage with regional firm profiles as well as events, regional newsletter, regularly local meetings. In all of the nine clusters one institution is representing the region, as well as fostering and bundling the regional activities, like Bio-M and BIOPRO for Munich and Stuttgart respectively.

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[2] *Concerning the VC data, BioCom proved less helpful as source of information as it encompasses a number of investors that in actual fact did never invest in biotechnology, but other sectors. For the objective of this study, it is however rational to include only VC investors that have at least once provided capital to a biotech firm.*

[3] *For a similar mean of cluster demarcation, see Aharonson et al. (2004).*

[4] *Göttingen fulfils the given classification requirements only from 1999 onwards.*

Notwithstanding these common characteristics, the evolution of the nine identified clusters varies significantly over time. Figures 1 and 2 indicate their differing levels of performance measured by the growth of the number of biotechnology firms located in each of the identified regions. Figure 1 depicts firm growth in absolute terms, Figure 2 with reference to an index (setting 1996 to 100).[5]

[Fig.1 and 2 about here]

In both figures, Munich and the Ruhr area appear as 'out performers', accompanied by Berlin showing in absolute terms the highest number of firms over the whole period of observation. Göttingen, Hanover, Hamburg and the Rhine/Main area around Frankfurt display below average number of firms. In order to examine how the just given performance heterogeneity may be explained with reference to the theoretical considerations, the investigation comprises three steps. The first one of them classifies the different clusters according to their composition. Here, the number of biotech firms is confronted with the number of investors on the one hand side and the number of basic science institutions on the other. By this means, we identify three different general cluster types: the well balanced ones, the basic science-driven ones, and finally the VC-/investor-dominated ones.

The second step addresses a cluster's openness and interconnection with the other clusters, but also with firms located outside these key nodes. For this purpose we use the amount of VC cash-flows and the number of VC investors that flew within and between the cluster objects, i.e. 'intra- vs. intercluster' VC flows. In addition, this step of analysis also covers the flows of public money and governmental subsidies which have to be regarded important impulse transmitters with significant impact on a cluster's genesis and evolution.

In the third step the cluster's evolutionary trajectories are investigated by means of an index that allows exemplifying how a clusters composition has changed over the period of investigation. The composition comprises two variables: number of risk

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[5] *We are, naturally, conscious that the sheer number of biotech firms represents a rather limited indicator to measure a clusters overall performance. Therefore, we have controlled for the number of employees per firm in all clusters on the one hand, and the varying main fields of activity (e.g. mainly product firms vs. supplier and service firms) on the other. So far, significant deviations compared to the chosen indicator could not be observed. Nonetheless, we consider this an important field for future investigation.*

capital investors and number of basic research institutes. The *C*luster *C*omposition *I*ndex *CC-I* is calculated according to the following formula:

$$CC-I = \frac{\sum BS_{i,t} \ / \sum VC_{i,t}}{\sum BS_{Ger,t} \ / \sum VC_{Ger,t}}$$

BS thereby depicts the absolute number of basic science institutions and *VC* the number of risk capital investors respectively venture capitalists; *t* denotes the year of investigation; *i* stands for the included clusters; and *Ger*, finally, corresponds to the whole of Germany, i.e. the respective national total.[6] Regarding the direction of change, we differentiate between clusters shifting towards a more balanced a structure, and clusters moving towards a structure that strengthens their specific idiosyncrasies. The former direction points to ‘convergence’, the latter to ‘divergence’.

4.2 Empirical results I: Structure and openness

For the nine identified clusters, Figure 3 shows the total number of research institutes as proxy for level of basic science on the abscissa, the total of VC investors as measure for the amount of locally available risk capital on the ordinate, and the number of biotechnology firms via the size of the respective ‘bubble’ with the total number in parentheses. The plot suggests a distinct degree of heterogeneity in the composition of clusters; some of them, however, are obviously featured by rather similar characteristics. As the most important locations of biotech production in Germany (compare also Figure 1, again), Munich and the Ruhr area display the greatest quantity of both science and capital. Likewise, the indexed rate of the firm growth (Figure 2) is highest in these two locations. In comparison, Hamburg, Hanover, Stuttgart, Heidelberg, and Göttingen reveal rather small numbers of research institutes and investors. The Rhine/Main area, locating the financial centre Frankfurt, represents the second largest concentration of investors, but shows the smallest number of science institutions. The direct opposite is true for the capital city of Berlin which is featured by a large number of science institutes but relatively few investors.

[Fig. 3 about here]

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[6] *Via the standardisation by the national average, the index controls for the overall proportion of investors and basic science institutions in the German biotechnology sector and thus masters the extent to which a cluster is relatively seen either dominated by ‘ideas’ or ‘money’. An index below one indicates that the cluster hosts a larger proportion of investors compared to the national average, an index greater than one that the cluster houses relatively more science institutions.*

The exercise of depicting the cluster's composition in absolute terms gives a first idea of the varying types – rather 'finance-driven' vs. more 'science-dominated' vs. 'well-balanced' clusters – which can be distinguished in the German biotechnology landscape. Concerning this matter, the Rhine/Main area around Frankfurt clearly represents the money-led player. Berlin, and to a lesser extent Göttingen as well as Stuttgart as the borderline case compose the contrasting group of the 'science-driven' ones (albeit in the case of the latter two, the crucial factor is rather a low number of investors than an extraordinary high number of science institutions). The remaining clusters Munich, the Ruhr area, Hamburg, Heidelberg and Hanover are – at least at the end of the period of investigation – best captured as 'well-balanced' in terms of their financial and scientific fabrics.

When we contrast the varying cluster types with their performance, one dominant cluster type to be particularly successful can not be identified. The 'well-balanced' and the 'science-dominated' clusters provide above as well as below average performers alike. Similarly, Hanover, Göttingen, and the Rhine/Main area prove all a rather dissatisfying performance, though they display entirely differing structural compositions. When we focus only on the three top performing clusters – Munich, Berlin, and the Ruhr area – we find that Munich and the Ruhr area belong to the 'well-balanced' type but step out within this group by showing a particularly large number of research institutes and investors. The rather unbalanced Berlin area hosts a large number of research institutes but locates only few investors. As first intermediate result, it thus has to be stated that no cluster type becomes apparent as clearly superior, and that a cluster's general composition adds only little to explain its economic success.

In light of this finding, it is now turned to the debate stressing the importance of interconnectivity and external linkages. As far data availability allows, Table 1 reports the mean number of collaborations with non profit organisations (i.e., universities, and research organisation) and for profit firms for all biotechnology firms located in our nine clusters.[7] This distinction reveals information on the science versus technology orientation of the firms in the clusters. Companies that intensely collaborate with for profit firms are presumably more commercialisation oriented, whereas firms intensely collaborating with academic or non academic research organisations are more science

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[7] *Note that only about half of the biotechnology firms in the BioCom yearbooks list their collaborations.*

intense and yet more distant from selling their invention. This exercise reveals different levels of interconnectivity as well as distinct patterns of specialisation.

[Table 1 about here]

Among the group of the intense collaborators are firms located in the three outperforming clusters – Munich, Berlin, Ruhr area – and in the rather low performing Hamburg cluster. Hamburg is catching attention as the cluster with the largest number of for profit firms presumably explained by a relative large proportion of service firms. In contrast, Heidelberg with the largest number of pure product development firms shows the largest number of collaborations with non profit organisations but a rather low number of collaborations with firms. Conspicuously, besides their high overall interconnectivity, not one of the outperforming clusters is showing a strong specialisation in either science- or technology-dominated collaborations. As data availability does unfortunately not allow to control for the locational dimension of collaboration, i.e. whether the partner is located within or outside the cluster, no systematic conclusion concerning the inter- and intracluster connectivity can be drawn.

The risk capital inflow within and to a cluster is the second aspect of interconnectivity we shed light on. For the nine identified clusters as well as the remaining part of the country, i.e. the cluster outsiders, Table 2 provides an accordant overview that distinguishes between VC cash flows on the one hand side and the number of deals on the other. First, the table shows that in absolute terms, regardless if from in- or outside, the greatest amount of 'smart money' flew in and to Munich. Over the period of investigation, more than €1.1 billion have been invested here in 415 single deals. In proportion to the total national VC flows between clusters (column 5) and those coming from outside of that cluster (column 6), these investments account both in terms of total cash flows as well as number of transactions for close to 50%. That is, nearly half of all intra-cluster financed projects in the German biotechnology industry are heading for Munich. Other areas that succeed in attracting money – though to a smaller extent – are the Ruhr area, Berlin, and Heidelberg, attracting 14%, 13% and 11% respectively from all outside VC flows, i.e. the total national amount of VC less the capital circulated within the clusters themselves (column 6). Each of the remaining clusters attracts only below 2% of total outside flows.

[Table 2 about here]

These findings underline the extraordinary role played by the Bavarian capital city and certainly add to explain the take off of its biotech industry. Yet apart from this insight, the external linkages to investors seem to be less indicative in predicting cluster success: In particular if the intra-cluster flows (column 2) are compared with the outside-cluster flows (column 3), the ones showing a relatively high proportion of external flows are not necessarily the out performers. For example, Hanover and Heidelberg display the same intra- to outside-cluster flows ratio of about one to three as Munich; and the low performer Göttingen attracts among the greatest relative proportion of outside flows, namely nearly six times the amount spent within the cluster[8].

In order to shed some further light on this aspect, Figure 4 displays the accumulated cash flows of VC funding within and between the nine identified German biotech clusters in dynamic perspective. The two maps distinguish between the time span 1996 to 2000, i.e. from the beginning of our observations up to the crash of the New Economy, and the period 2001 to 2003.[9]

[Figure 4 about here]

Three important findings emerge from the temporally differentiated analysis. First, notwithstanding the overall cooling down of VC dynamism, the total amount of investments during the second given period exceeds that of the first one. The key driver of this development is a significant increase of the mean amount to be invested (investments between 1996 and 2000 averaged €1.88 million, from 2001 onwards €2.65 million), a development which in essence is due to the growing maturity of the receptors, shifting, if successful, from their initial seed and start-up stages towards a more capital intense expansion stage. Second, it can be observed that not only the overall level of VC investments has increased, but also the number of linkages between the clusters. With the exception of Hamburg which's involvement into the interregional VC network remained almost entirely unchanged, all clusters multiplied their links to external sources of money (and managerial knowledge) on the one hand and their investments into proximately located firms on the other. Most notably, this is the case in

[8] *To some extent, Göttingen's underperformance concerning this matter can also be attributed to limited data availability.*

[9] *The rationale for taking these two spans of time is rather straightforward and intuitive: While the 1990s saw an extremely dynamic development of public equity markets in Germany including the establishment of the Neue Markt in 1997, the burst of the New Economy bubble in 2000-01 has significantly slowed down this dynamic development.*

Berlin and Stuttgart with an increase of six to eleven and two to seven external links respectively. With regard to the share of intra-regional investments, third and finally, a pretty variegated picture comes into view. While the majority of our clusters show a relatively stable proportion of capital invested within them, internal funding died down in Hamburg and the Rhine/Main area; Heidelberg in contrast features above-average growth concerning this matter.

Taken together, the result of the VC flows mapping exercise is rather ambiguous if matched with the performance of our clusters: Though all of the three outperforming clusters – Munich, Berlin, and the Ruhr area – are intensifying their links to provide finance to and receive capital from other clusters, their respective configuration is relatively dissimilar with Berlin stepping out as one of the receiver clusters whereas Munich finds itself within a tight financing net. That is, internal interconnection as well as external linkages both can doubtlessly be regarded important general cluster features adding to their overall success, but add merely little to explain their differing performance levels.

Turning, finally, to public money and governmental grants (compare Table A1 in the appendix) which, apart from triggering significant economic stimuli, are also to be seen as important extra-cluster linkages and potential sources of new ideas and knowledge. Again and barely astonishing, Munich, Berlin and the Ruhr area receive by far the greatest slice of the cake. This has however to be put into perspective of the number of firms in these localities taken as a whole. Accounting for this as well as for the overall rather minor level of coverage – take e.g. the 24 million Euro governmental means in comparison to the 1.1 billion Euros of VC flowing into Munich –, again, only a small and fairly unsystematic piece can be fit into the puzzle that might explain the detected variance of cluster performance.

In sum, it hitherto can be stated that both a cluster's general composition and its openness respectively its degree of external interconnectivity in terms of collaborations and financial flows provide a certain, but not yet entirely convincing contribution to explain their differing levels of performance; no comprehensible statement is possible, how and to which extent a certain relation or degree of interaction contributes to a cluster's competitiveness. For this reason, the following section turns to the evolutionary paths and individual trajectories of each cluster and investigates the extent to which a cluster's adjustment abilities correspond to its success.

4.3 Empirical results II: Convergence and adaptability

Addressing the convergence hypothesis, the third and final analytical step reveals changes and movements in each cluster's composition over time. In order to quantify the extent to which both the level and the direction of change are related to a cluster's performance, Table 4 lists the relative cluster composition index for 1996 and 2003 as the initial and the endpoint in the investigation, i.e. the proportion of investors to basic science institutions standardised by the national average.[10] The last column of Table 4 depicts the change in the composition from 1996 to 2003.

With a change of 55% the Munich area has undertaken the strongest structural change in cluster composition, followed by the Ruhr area with 31%, Rhine/Main area with 13% and Berlin with 12%. If the listed cluster types are now contrasted with their respective performance, we find that three of the four most dynamic clusters are the ones breeding the largest number of biotechnology firms. Thus, the intensity of change serves as rather suggestive indicator for the relationship between dynamics and success but does not hold for the Rhine/Main area.

[Table 4 about here]

The direction of change represents a second important aspect in this evolutionary investigation. With reference to the results of the cluster composition index, Figure 5 tracks the 'movements' of the cluster between 1996 and 2003 in respect of their respective configuration, thus clarifying their varying evolutionary paths: While the clusters Hamburg, Heidelberg, Hanover, and Stuttgart with a rather well balanced composition of 'money and ideas' in 1996 remain relatively constant, the other five clusters move either towards a more balanced structure (this is the case in Munich, the Ruhr area and Berlin), or reinforce their financial or scientific dominance (Rhine/Main and Göttingen).

By connecting these paths with cluster performance, the Rhine/Main area and Göttingen suggest that a movement strengthening the orientation of a cluster proves to be negatively related to cluster performance. The clusters that start off with a well balanced composition and more or less kept it are found to be the middle field players. The outperforming ones, in contrast, are those three that move from dominant

[10] *With an increase of 2.8%, the national average remained almost stable. In 1996, research institutes in biotech outreached biotech investors with a factor of 4.24.*

compositions towards less slanted fabrics. Starting off with investor dominance, Munich and the Ruhr area turn to a more balanced structure. Remarkably, both clusters undertook the most dynamic structural shift and show the highest relative firm growth compared to the other clusters. The German capital Berlin locating the largest number of biotech firms over the whole period moved from its science orientation in 1996 to a less biased composition.

[Figure 5 about here]

The exercise of tracking the starting position and movement of clusters appears to provide powerful insights in explaining cluster performance. Clusters that started off with a dominant orientation and dynamically managed to change toward a more balanced proportion of capital and science are outperforming their counterparts. Hence, the dynamic analysis offers a rather convincing explanation for the success of clusters.

5 CONCLUSIONS

This paper addresses the evolution of nine biotechnology clusters in Germany between 1996 and 2003. In essence, three different approaches were tested in respect of their explanatory power concerning the detected heterogeneity of performance: First, a cluster's composition in terms of the extent to which it hosts science and capital; second, its degree of openness respectively its external linkages to institutions located outside the cluster; and third, its trajectories and ability to adapt its configuration over time.

Though we witnessed interplay of varying factors as well as a critical mass precondition in all cases and are surely aware that an overall recipe to explain different levels of cluster evolution cannot exist, our analysis suggests some strong regularities. In this manner, the first two ways of reasoning proved yet some but not convincing help to further the understanding of cluster performance. Our analysis shows that it is not clearly possible to attribute a certain cluster type to a certain performance level. The analysis of interconnectivity provides ambiguous results. Regarding interorganisational collaboration as one means of interconnectivity, we find that clusters in which firms are intensely cooperating with for profit as well as non profit firms tend to be more successful. In terms of financing flows within and between clusters – as another means of interconnectivity – the general interconnection proves to be an important factor for cluster success but no evidence can be reported regarding the characteristics of involvement (e.g. receiving versus equally receiving and giving). That is, external linkages – without denying their general significance for cluster performance – do not help to systematically explain the differing success of clusters in breeding high-technology firms neither.

The dynamic perspective in contrast, i.e. the view addressing the extent to which clusters were able to change their composition over time towards a less slanted structure during the period of investigation, showed off as the key criteria for success. Regardless of their starting point – science dominated or money led – those clusters which managed to move to a more balanced fabric were the outperforming ones. That is, after a cluster has taken off and managed to establish itself in the global competition of innovative locations, the crucial task is to get it moving towards a balanced portfolio of science and capital. This directs to the important but complex task to investigate the factors setting clusters in motion and vehicles of incessant movement; our primary, explorative indications may provide an avenue for future research on this issue.

But the presented findings also have immediate implications for politics, business management and social science. In political and managerial terms, the constant and ongoing evaluation, intervention and direction of cluster composition appear as straightforward challenge. The turnover and renewal of cluster composition maintain the clusters as successful hotbeds for innovative firms. Regarding the scientific community, the results substantiate the role of a dynamic approach tracking evolutionary paths when considering firm and cluster performance. Hence, future research should focus on the extent to which organisations, institutions and regions are willing to rethink themselves and to 'move' in that they undertake corresponding structural adjustments. While we do not claim to have identified and conceptualised the multilayered mechanisms underlying such movements or have answered the causality question (i.e. to what extent external and internal interconnections of firms impact on cluster configuration and vice versa) in comprehensive manner, our hope is that this paper stimulates further explorations in order to understand the on-going creative ferment in clusters as social entities. Succeeding evolutionary and comparative studies which inter alia apply a more differentiated performance measure – such as firm turnover or productivity, for instance – might offer fruitful contributions and further deepen our knowledge on the interplay of finance, innovation, and space.

APPENDIX

[A1 about here]

REFERENCES

Aharonson, Barak, Joel Baum and Maryann P. Feldman (2004), Industrial clustering and the returns to inventive activity: Canadian biotechnology firms, 1991-2000, DRUID Working Paper No. 04-03.

Audretsch, David and Paula E. Stephan (1996), Company-scientist locational links: The case of biotechnology, *American Economic Review* 86, 641-652.

Audretsch, David and Maryann P. Feldman, (1996), R&D spillovers and the geography of innovation and production, *American Economic Review* 86, 630-640.

Bathelt, Harald, Anders Malmberg, and Peter Maskell (2004), Clusters and knowledge: Local buzz, global pipelines and the process of knowledge creation, *Progress in Human Geography* 28, 31-56.

BioCom (2004), *BioTechnologie – Das Jahr- und Adressbuch*, Berlin: BioCom AG. (also for the years 1995-2003)

Bundesministerium für Bildung und Forschung (2004), Förderdatenbank von BMBF / BMWA.

Bresnahan, Timothy, Alfonso Gambardella, and Annalee Saxenian (2001), 'Old economy' inputs for 'new economy' outcomes: Cluster formation in the new Silicon Valley, *Industrial and Corporate Change* 10, 835-860.

Casamatta, Catherine (2003), Financing and advising: Optimal financial contracts with venture capitalists, *The Journal of Finance* 58, 2059-2085.

Cairncross, Frances (1997), *The death of distance*, London: Orion.

Coyle, Diane (1997), *The weightless world. Strategies form managing the digital economy*, London: Capstone.

Clark, Gordon L. and Dariusz Wójcik (2005), Path dependence and financial markets: The economic geography of the German model, 1997–2003, *Environment and Planning A* 30, 1769-1791.

DiMaggio, Paul J. and Walter W. Powell (1983), The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields, *American Sociological Review* 48, 174-190.

DiMasi, Joseph, Ronald Hansen, and Henry Grabowski (2003), The price of innovation: new estimates of drug development costs, *Journal of Health Economics* 22, 151-185.

Ernst & Young (2001), *Biotech in Germany*, Stuttgart: Ernst & Young.

Feldman, Maryann P. (1994), *The geography of innovation*, Boston: Kluwer Academic Publishers.

Feldman, Maryann P. and Richard Florida (1994), The geographic sources of innovation: Technological infrastructure and product innovation in the united states, *Annals of the Association of American Geographers* 84, 210-229.

Grabher, Gernot (1993), *The embedded firm. On the socioeconomics of industrial networks*, London: Routledge.

Häussler, Carolin (2005a), Marrying, selling, and integrating - Firm restructuring in German biotechnology, Working Paper, Munich School of Management..

Häussler, Carolin (2005b), *Inter-firm collaboration: Valuation, contracting, and firm restructuring*, Wiesbaden: Gabler.

Jaffe, Adam (1989), Real effects of academic research, *American Economic Review* 79, 957-970.

Klagge, Britta and Ron Martin (2005), Decentralized versus centralized financial systems: is there a case for local capital markets?, *Journal of Economic Geography* 5(4), 387-421.

Leamer, Edward and Michael Storper (2001), The economic geography of the internet age, *Journal of International Business Studies* 32, 641-665.

Morgan, Kevin (2004), The exaggerated death of geography: learning, proximity and territorial systems, *Journal of Economic Geography* 4, 3-21.

Maskell, Peter and Anders Malmberg (1999), Localised learning and industrial competitiveness, *Cambridge Journal of Economics* 23, 167-185.

Ohmae, Kenichi (1990), *The borderless world: Power and strategy in the inter-linked economy*, New York: Harper Business.

Owen-Smith, Jason and Walter W. (2006), Accounting for emergence and novelty in Boston and Bay Area Biotechnology, in Pontus Braunerhjelm and Maryann Feldman (eds.), *Cluster Genesis: The emergence of technology cluster and their implication for government policies*, forthcoming.

Porter, Michael (2000), Locations, clusters, and company strategy, in Gordon Clark, Maryann Feldman P., and Meric Gertler (eds.), *The Oxford Handbook of Economic Geography*, Oxford: Oxford University Press, 253-274.

Porteous, David J., 1995, *The geography of finance: Spatial dimensions of intermediary behaviour*, Aldershot: Avebury.

Powell, Walter W., Kenneth Koput, James Bowie, and Laurel Smith-Doerr (2002), The spatial clustering of science and capital: Accounting for biotech firm-venture capital relationships, *Regional Studies* 36, 291-305.

Prevezer, Martha (1997), The dynamics of industrial clustering in biotechnology, *Small Business Economics* 9, 225-271.

Quah, Danny (1997), Increasingly weightless economies, *Bank of England Quarterly Bulletin* 2, 49-56.

Saxenian, Annalee (1994), *Regional advantage: Culture and competition in Silicon Valley and Route 128*, Cambridge: Cambridge University Press.

Storper, Michael and Anthony Venables (2004), Buzz: The economic force of the city, *Journal of Economic Geography* 4, 351-370.

Stuart, Toby, Ha Hoang, and Ralph Hybels (1999), Interorganizational endorsements and the performance of entrepreneurial ventures, *Administrative Science Quarterly* 44, 315-349.

Zademach, Hans-Martin (2005), *Spatial dynamics in the markets of M&A, Essays on the geographical determination and implications of corporate takeovers and mergers in Germany and Europe* (Wirtschaft und Raum, Band 12), Munich: Herbert Utz.

Zeller, Christian (2001), Clustering biotech: A recipe for success? Spatial patterns of growth of biotechnology in Munich, Rhineland and Hamburg, *Small Business Economics* 17, 123-141.

Zucker, Lynne, Michael Darby, and Marilynn Brewer (1998), Intellectual human capital and the birth of US biotechnology enterprises, *American Economic Review* 88, 290-306.