

*An Identification of Local Industrial Clusters in
Germany*

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ABSTRACT. This paper presents a method that allows local industrial clusters to be identified and applies this method to Germany. The method is applied to all 3-digit manufacturing industries in Germany. The results are used in two ways. First, they provide some information about which industries are clustering and which are not. Second, a complete list of all local clusters that existed in Germany in 2001 and are identified by this method is given. The spatial distribution of these local clusters in Germany is discussed in the light of other studies on Germany.

KEYWORDS: local industrial clusters, industry study, spatial agglomeration, empirical methodology.

JEL classification: C12, L60, R12

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1. Introduction

Local clusters and industrial districts have been studied intensively in the recent economic literature. These studies mainly aim to identify the prerequisites for the development of such local systems and the specific characteristics that are responsible for their economic success. It is usually implicitly assumed that local clusters and industrial districts can be clearly identified. This means that it is assumed that local systems can be classified into two categories according to their economic situation: successful regions, labelled local clusters or industrial districts, and regions lagging behind.

In the literature on case studies there is not usually much discussion about the identification of local clusters. Those who conduct the case studies implicitly, and usually rightly so, assume that they have correctly identified the local cluster that they are studying. There are other approaches that try to identify all local clusters within a country (see Sforzi 1990, Isaksen 1996, Paniccia 1998 and Braunerhjelm & Carlsson 1999). In these approaches a threshold level of the number of firms or employees in a region is arbitrarily defined, usually in relation to the size of the region. All regions in which the number of firms or employees in an industry exceeds this threshold value are said to contain a local cluster. In most of the approaches additional conditions are formulated. The most elaborated approach has been developed for Italy (see Sforzi 1990 and Sforzi, Openshaw & Wymer 1997). However, even in this case, the condition on the size of the industrial agglomeration is little discussed. Furthermore, the same condition is applied to all industries.

What is missing is a theoretical or empirical explanation for the threshold level that is used. There are several theoretical works that analyse what the spatial distribution of firms should look like if there is the phenomenon of clustering (see, e.g., Ellison & Glaeser 1997 and 1999, Dumais, Ellison & Glaeser 2002 and Bottazzi, Fagiolo & Dosi 2002; a discussion of the different approaches is given in Brenner 2003b). However, these studies only aim to show that firms are not randomly distributed in space and therefore agglomeration forces are present. They do not aim to identify the locations of agglomerations.

This paper provides a methodology to identify empirically the threshold in the number of firms that separates those regions containing a local cluster in a certain industry from those that do not. The methodology used here is based on a theoretical model of clustering (see Brenner 2001) and some methodological considerations (see Brenner 2003b). It allows predictions to be made about the shape of the distribution of firms among regions. Through fitting the parameters of this distribution

function, two results are obtained. First, it can be tested whether local clusters exist in a certain industry or whether the spatial distribution of firms can be explained without assuming clustering forces. This corresponds to the approaches on the spatial distribution of firms in the literature (see Ellison & Glaeser 1997). Second, the threshold for the number of firms in local clusters can be calculated on the basis of the parameters of the distribution function. This means that the threshold is obtained empirically and for each industry separately. This value can then be used to identify existing local clusters.

The methodology is then applied to Germany. It is applied on the level of administrative districts and conducted for each 3-digit manufacturing industry separately. The results are used in two ways. First, they answer the question of whether clustering exists in the different manufacturing industries in Germany. Second, the location of clusters in the different industries in Germany can be identified. This provides a picture of clustering in Germany.

The paper proceeds as follows. In Section 2 the theoretical framework is outlined and predictions for the distribution of firms among regions are presented. The methodology to test these predictions is developed in Section 3. In Section 4 this methodology is applied to Germany and the results are discussed. Section 5 concludes.

2. Theory and predictions

In order to identify whether industries show clustering in space, a model is needed that describes both a situation with clustering and a situation without clustering. This model can then be used to make two predictions about the spatial distribution of firms, one for the situation with clustering and one for the situation without clustering. Finally, the adequateness of the two predictions can be compared. There are several such models in the literature (see Ellison & Glaeser 1997, Brenner 2001, Bottazzi, Fagiolo & Dosi 2002 and Dumais, Ellison & Glaeser 2002). Here the model by Brenner (2001) is used. It is beyond the scope of this paper to describe the whole model or how the predictions are derived, hence, only some intuitive arguments are given. For further details the reader is referred to Brenner 2001, 2003a and 2003b.

2.1. BASIC ASSUMPTIONS

The theoretical considerations that are used here to predict the firm distribution among regions is based on two fundamental assumptions. The first assumption

separates those industries in which local clusters exist from those industries without local clusters. It is assumed that industries with local clusters are characterised by local self-augmenting processes that, in some regions, lead to much higher economic activity, and therefore to a much higher number of firms than in other regions (a theoretical analysis of this can be found in Brenner 2001). Let us denote the probability that a randomly chosen region of size s contains f firms by $P(f|s)$ and call it the ‘firm distribution among regions’. Then, the above assumption leads to the predictions that $P(f|s)$ is bimodal. This means that there are many regions with a small number of firms but also quite a number of regions with a high number of firms. Between these cases there are numbers of firms that are rarely observed (see Figure 1 for an example of such a distribution). Industries in which no local clusters exist are characterised by a unimodal firm distribution $P(f|s)$.

The second assumption concerns the functional form of the firm distribution $P(f|s)$. In the literature the functional form of the firm distribution is deduced from theoretical considerations about the stochastic process of firm location (see, e.g., Ellison & Glaeser 1997, Bottazzi, Fagiolo & Dosi 2002 and Dumais, Ellison & Glaeser 2002). Here it is assumed that, in addition to the stochasticity of firm locations, the attractiveness of regions is influenced by many factors that cannot be explicitly considered in an approach such as the one used here. Examples are the human capital available in the region, cultural factors, and the geographic attractiveness. The only factor that is explicitly considered, as in most other studies, is the size of the regions, s . Therefore, the firm distribution is denoted by $P(f|s)$, which means that for each size, a different distribution is assumed. The other factors have to be treated as stochastic influences as well. Usually we do not even know the distribution of these factors among regions. For some factors the functional form of the distribution can be at least estimated on the basis of empirical data (see Brenner 2003b). However, it is argued here that the final decision about the functional form of the firm distribution has to be made on the basis of empirical data. In Brenner (2003b) three different functional forms are tested: an exponentially decreasing function, a Binominal distribution, and a Boltzmann distribution[†]. The Binominal and the Boltzmann distribution have quite similar shapes. Therefore, only one of these two distributions is used here. The Boltzmann distribution has been found to describe the highest percentage of the empirical distribution (see

[†] The exact form that is used there is obtained in physics under certain conditions for the more general Boltzmann distribution. For simplicity it is called Boltzmann distribution here.

Brenner 2003b). Therefore, a mixture of an exponentially decreasing function and a Boltzmann distribution is used here for $P(f|s)$.

2.2. PREDICTIONS FOR THE INDUSTRIAL FIRM-DISTRIBUTION AMONG REGIONS

Combining the two assumptions that have been outlined above, it is possible to formulate mathematical predictions for the industrial firm-distribution among regions. First, the prediction for an industry without local clusters is formulated. In this case, the firm-distribution should follow the distribution of the factors that influence the attractiveness of regions plus the stochastic fluctuations caused by the location decision of firms. Above it is argued that it is impossible to deduce the functional form of the resulting distribution theoretically. Therefore, a mixture of an exponentially decreasing function and a Boltzmann distribution is used which has been found to describe the empirical situation quite well (see Brenner 2003b). This means that the firm-distribution among regions is predicted by

$$P_n(f|s) = (1 - \xi_3(s)) \cdot \xi_1(s)^f + \xi_3(s) \cdot f \cdot \xi_2(s)^f \quad (2.1)$$

for industries with no local clusters. $\xi_1(s)$, $\xi_2(s)$ and $\xi_3(s)$ are parameters that depend on the size of the considered region, s . The first term on the right-hand side of Equation (2.1) is an exponentially decreasing function. The second term is a Boltzmann distribution. The distribution (2.1) is called the natural distribution.

The second case in which local clusters occur is characterised by the fact that some regions might contain a much higher number of firms than the others. The theory predicts that there is a gap between the number of firms in those regions that contain an industrial clusters and those regions that do not contain such a cluster. Mathematically such a situation can be described by the following distribution:

$$P_c(f|s) = (1 - \xi_3(s) - \xi_6(s)) \cdot \xi_1(s)^f + \xi_3(s) \cdot f \cdot \xi_2(s)^f + \begin{cases} \xi_6(s) \cdot [f - \xi_4(s)] \cdot \xi_5(s)^{[f - \xi_4(s)]} & \text{if } f > \xi_4(s) \\ 0 & \text{if } f \leq \xi_4(s) \end{cases} \quad (2.2)$$

where $\xi_1(s)$, $\xi_2(s)$, $\xi_3(s)$, $\xi_4(s)$, $\xi_5(s)$ and $\xi_6(s)$ are the parameters of the function. This distribution is called the cluster distribution. It consists of the same two distributions as the natural distribution. In addition a further Boltzmann-like distribution is added that takes values greater than zero only for high firm numbers f . All industries that contain local clusters should be better described by the cluster

distribution. This will be tested for all manufacturing industries and some service industries below.

However, testing the predictions for the distribution of firms does not allow statements to be made about the existence of local clusters. Brenner (2003a) defines local industrial clusters as spatial agglomerations of the firms in an industry in which the firms benefit from their co-location. Here only the existence of spatial agglomerations of firms is checked. There might be other reasons for the existence of such agglomerations, such as natural resources or urban externalities. However, different reasons for industrial agglomerations might cause the mathematical shape of the firm distribution to be different. Here the adequateness of the particular shape that is predicted by the above theory of local industrial clusters is tested. Still other reasons for industrial agglomerations might cause the same mathematical shape of the firm distribution but this is at least less likely. Nevertheless, it cannot be excluded that the method that is used here identifies local agglomerations that are not caused by clustering forces but by other factors.

2.3. INFLUENCE OF THE SIZE OF REGIONS

In the approach that is taken here the size of regions is considered explicitly. This implies that the firm-distribution, $P(f|s)$, is different for regions of different sizes. However, some assumptions about the impact of the size on the firm-distribution are necessary. If $P(f|s_1)$ and $P(f|s_2)$ would be completely independent of each other, the empirical data would provide only us with one data point for each firm-distribution, $P(f|s)$. This would not allow any statements to be made.

The assumption that is used here is that the average expected number of firms in a region increases linearly with the size of the region. This is an assumption that is also used in other works (see, e.g., Ellison & Glaeser 1997). In contrast, the shape of the firm-distribution is assumed to be independent of the size of the region. This means that the average number of firms has to increase linearly with s for each part of the distributions and that the relative shares of the different parts have to remain constant, meaning that $\xi_3(s)$ and $\xi_6(s)$ are independent of s . This is reached by making the following assumptions:

$$\xi_1(s) = \frac{\xi_1 \cdot s}{1 + \xi_1 \cdot s}, \quad (2.3)$$

$$\xi_2(s) = \frac{\xi_2 \cdot s}{2 + \xi_2 \cdot s}, \quad (2.4)$$

$$\xi_3(s) = \xi_3 , \tag{2.5}$$

$$\xi_4(s) = \xi_4 \cdot s , \tag{2.6}$$

$$\xi_5(s) = \frac{\xi_5 \cdot s}{2 + \xi_5 \cdot s} , \tag{2.7}$$

and

$$\xi_6(s) = \xi_6 . \tag{2.8}$$

Through this, a new set of parameters is obtained, namely $xi_1, xi_2, xi_3, xi_4, xi_5$ and xi_6 , which is independent of the size of regions and can be fitted to the empirical data.

3. Empirical data and method of analysis

3.1. EMPIRICAL DATA

The data that are used in this approach have been collected by the German Federal Institute for Labour. The dataset contains the number of firms for each 3-digit industry[†] and each of the 441 administrative districts in Germany for the 30th of June 2001. The study that is conducted here is restricted to the 104 manufacturing industries. The industries are denoted by i ($\in \{1, 2, \dots, 104\}$). Some of the empirical analysis is also conducted for a few service industries that are frequently discussed in the literature. The administrative districts are denoted by r ($\in \{1, 2, \dots, 441\}$). The number of firms in each industry and districts is denoted by $f(i, r)$.

In the approaches that identify local clusters in the literature, the number of firms or employment is usually compared to the ‘natural’ share of the region (see, e.g., Sforzi 1990, Isaksen 1996, Paniccia 1998 and Braunerhjelm & Carlsson 1999). This implies that the number of firms has to be studied in relation to the size of the respective region. This seems to be plausible for the approaches taken in the literature. However, arguments can be put forward in favour of using the absolute number of firms. On the one hand, it is assumed here that the existence of local industrial clusters is caused by local self-augmenting processes. These result from the symbiotic interaction among firms and between firms and local circumstances. The effects of these interactions depend on the number of firms but not on the total size of regions in terms of population or employees. Therefore, the self-augmenting

[†] Industries are classified according to the WZ93-classification, which is the standard classification of industries in Germany at the moment.

processes should occur whenever the absolute number of firms exceeds a certain value. On the other hand, the total number of employees in a region might well determine the number of firms that might be established in a region, once a cluster emerges. The relative number of firms takes this into account.

Therefore, the firm-distribution among regions is studied below considering the size of regions as well as neglecting their size. To this end the size of regions, s , is defined in two ways. First, the size of a region is defined as the share of all employees in Germany that are employed within the region:

$$s(r) = \frac{\sum_{i=1}^{N_i} e(i, r)}{\sum_{r=1}^{440} \sum_{i=1}^{N_i} e(i, r)} \quad (3.1)$$

where $e(i, r, t)$ denotes the number of employees in industry, i , and region, r , at time, t . Second, the size of all regions is set to the same value, namely

$$s(r) = \frac{1}{441} . \quad (3.2)$$

This allows the same mathematical formulations to be used in the empirical study.

3.2. RESTRICTIONS ON THE MODELS

The first two terms of the natural distribution (2.1) and the cluster distribution (2.2) are identical, except for the factor in front of the exponential part. The last term of the cluster distribution is defined in a similar way to the second term with the form of a Boltzmann-like distribution. It is a shifted Boltzmann-like distribution which is zero for all numbers of firms below $\xi_4 \cdot s$ and has the shape of a Boltzmann-like distribution for all numbers of firms above $\xi_4 \cdot s$. Hence, this term represents the clusters that exist.

The parameters, ξ_4 and ξ_6 , are restricted in the analysis below. The shifted Boltzmann-like distribution is designed to describe the local clusters existing in an industry. This implies several characteristics of this part of the distribution. First, it should only describe a few regions. Local clusters have to be the exception. We would not talk about ‘local industrial clusters’ if they occurred in most of the regions. Hence, the share of the regions that contain a cluster has to be small. 10% is assumed to be the maximal share that is accepted. This implies that $\xi_6 \leq 0.1$ has to be satisfied.

Second, only those regions with a high number of firms should be classified as local industrial clusters. Nevertheless, the line between clusters and other regions should be empirically determined. It is represented by the parameter ξ_4 . A value

of $\xi_4 = \bar{f}$, with \bar{f} denoting the total number of firms in the industry under consideration, would imply that all regions containing a number of firms above average would be called clusters. This seems to be inadequate. In the literature a value of $\xi_4 = 3$ is used (see Isaksen 1996). Here, a more complicated restriction is chosen for the parameter ξ_4 .

According to the analysis in Brenner 2001, every region that includes a cluster of the industry under consideration should contain more firms than any region that does not contain such a cluster. This implies that the part of the distribution described by the last term in Equation (2.2) should be separated from the rest of the distribution. In reality such a separation cannot be expected because regions differ with respect to factors other than their attractiveness. Nevertheless, the overlapping of the two parts of the distribution should be small. The amount of overlap is given by the number of regions that contain a number of firms higher than $\xi_4 \cdot s$ according to the first and second part of the cluster distribution. This number is denoted by $n_{cl,n}$ here. It should be small compared to the number of regions that contain industrial clusters. Otherwise, most of the regions containing many firms could be explained without considering the phenomenon of clustering. Therefore, ξ_4 is restricted to those values for which at least $\frac{5}{6}$ of the regions that contain a number of firms higher than $\xi_4 \cdot s$ are explained by the cluster part of distribution (2.2). This is reached by the condition

$$0.2 \cdot \xi_6 > \frac{n_{cl,n}}{N_r} . \tag{3.3}$$

3.3. METHOD TO TEST THE THEORETICAL DISTRIBUTIONS

To fit the two theoretical distributions to reality, the likelihood value is calculated for each parameter set using the data on each industry. The likelihood value is the probability that the empirical situation occurs according to the theoretical distribution. It is given by

$$L_n(i) = \prod_{r=0}^{441} P_n(f(i, r) | s(r)) \tag{3.4}$$

and the analogous equation for the cluster distribution (replacing ‘n’ by ‘c’). The maximum likelihood is the maximal value of $L_n(i)$ and $L_c(i)$, respectively, that can be reached for any parameter set. It is denoted by $\hat{L}_n(i)$ and $\hat{L}_c(i)$, respectively. The respective parameter sets determine those distributions that describe reality best. An example of a fitted natural and cluster distribution is given in Figure 2 with the empirical distribution given in Figure 1.

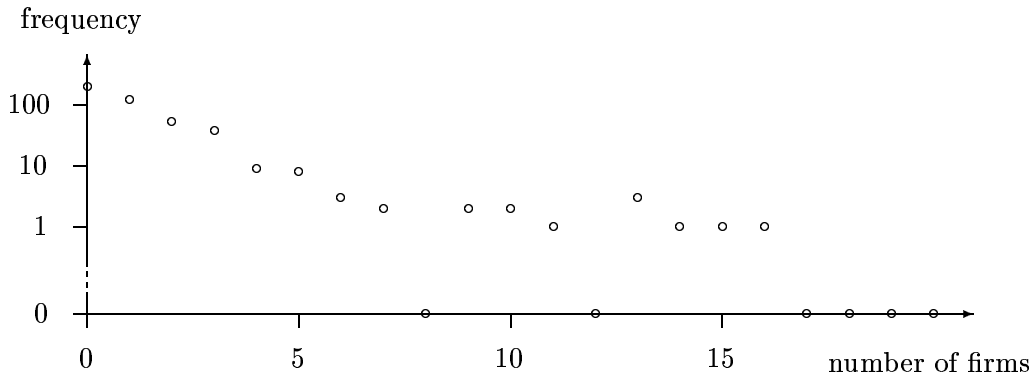


Figure 1: Empirical industrial distribution among regions for office machines.

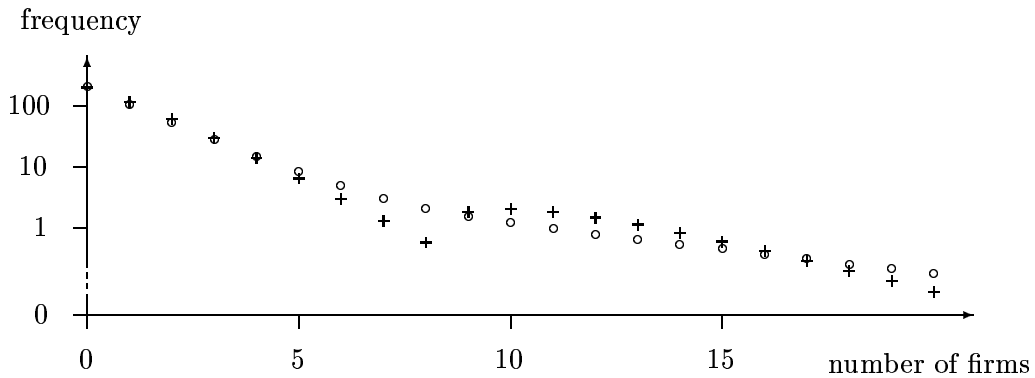


Figure 2: Theoretical industrial distributions among regions that result from fitting the natural distribution (circles) and the cluster distribution (crosses) to the empirical distribution of firms producing office machines.

The aim of the study that is conducted here is to find out whether and in which industries local clusters appear. The additional term in the cluster distribution should describe such clusters. Thus, the cluster distribution should describe the empirical data significantly better than the natural distribution if clusters exist.

The cluster distribution contains 6 parameters, while the natural distribution contains only 3 parameters. Furthermore, the natural distribution is a special case of the cluster distribution. Therefore, the cluster distribution will always fit reality better, so that $\hat{L}_c(i) \geq \hat{L}_n(i)$ is satisfied for all industries.

The likelihood ratio test is used to check whether the cluster distribution describes reality significantly better than the natural distribution. This is done for

each industry separately. To this end, the value

$$\lambda(i) = 2 \ln[\hat{L}_c(i)] - 2 \ln[\hat{L}_n(i)] \quad (3.5)$$

is calculated. $\lambda(i)$ measures this difference in the fitting of the data. Statistical theories tell us that $\lambda(i)$ can be expected to follow a χ^2 -distribution if the additional term in the cluster distribution does not really make the cluster model more adequate than the natural distribution (see Mittelhammer 1995). Whether $\lambda(i)$ falls into this distribution can be tested. Hence, the hypothesis that the cluster distribution is not more adequate than the natural distribution can be tested. If it is rejected, the industry is said to be clustering.

The likelihood ratio test answers the question of which distribution describes the empirical data better. However, it does not answer the question of whether the distributions describe the empirical data adequately. To test the adequacy of the distributions, the distribution that is more adequate in each industry is compared to the empirical distribution.

To test whether the theoretical distribution and the empirical distribution deviate from each other significantly, the Kolmogorov-Smirnov test is used. The Kolmogorov-Smirnov test compares the cumulative distribution function of a theoretical and an empirical distribution. It makes a statement about the maximal distance of these two functions that should occur with a certain probability if the two distributions are identical. Hence, if the distance is too large, the hypothesis that the theoretical and the empirical distribution are identical can be rejected.

3.4. IDENTIFICATION OF LOCAL CLUSTERS

Finally, it is intended here to identify all local clusters in those industries that are found by the approach described so far to show clustering. Above it has been assumed and confirmed that regions containing a local cluster can be described by a Boltzmann-like distribution with a minimal number of ξ_4 (see Equation (2.2)). Hence, ξ_4 can be seen as the critical number of firms that constitute a cluster. It is formulated either in relative or absolute terms (see Equation (2.6), depending on the definition of the size, s , that is used. In the case of relative numbers of firms, s and therefore also ξ_4 differ between regions, while s is the same for all regions in the case of absolute numbers of firms. This means that the critical value, ξ_4 is obtained as a result of fitting the theoretical model to the empirical data. Thus, information is obtained about how large clusters are.

This information is then used to identify the existing clusters in Germany. All

regions in which the number of firms in an industry exceed the critical value ξ_4 are called local industrial clusters here. Two restrictions on the approach have to be mentioned in this context. First, the approach used here is not able to distinguish between different causes of the existence of local clusters. If there are natural causes, such as the availability of necessary resources, for the existence of an agglomeration of firms, this agglomeration will be identified as a cluster here. However, this only happens if the distribution of firms among regions that is caused by the natural circumstances is in line with the predictions obtained through the assumption of local self-augmenting processes. Otherwise the empirical approach that is used here will not confirm the existence of local clusters in the industry under consideration. Second, the two parts of the cluster distribution overlap to some extent in quite a number of cases. This implies that an exact distinction between regions containing a cluster and regions not containing a cluster is not feasible. However, in most cases the overlap concerns less than two regions. Nevertheless, it has to be kept in mind that the method used here might identify some additional clusters.

4. Empirical results

The method that is described above allows each industry to be examined to determine whether local clusters exist, how many firms have to be located in a region to constitute a cluster, and where the clusters are located. The method is applied to all 3-digit industries in Germany. The results are given below. First, some general findings are reported. Then, a list of all identified local clusters in the manufacturing sector in Germany is presented. Finally, these findings are compared with the existing case studies and are discussed from a regional perspective.

4.1. GENERAL RESULTS

According to the German WZ-93 classification there are 20 3-digit industries in the farming and mining sectors, 104 3-digit industries in the manufacturing sector, and 97 3-digit industries in the service sector. For each of these industries the methodology developed above is applied to the absolute and the relative numbers of firms. The test of the theoretical model shows that it can be rejected for none of the industries in the farming and mining sector. It can be rejected for 7 industries in the manufacturing sector, but only with respect to the relative numbers of firms. The distribution of the absolute numbers of firms among regions is adequately described by the theoretical model in all manufacturing industries. In the case of

the service sector, the theoretical distribution is rejected for both, the absolute and the relative, numbers of firms for 19 industries. In addition, for 29 industries the theoretical distribution is rejected for the relative numbers of firms. Hence, the theoretical model fits the service sector quite badly. The reason for this is the fact that the theoretical model considers only stochastic influences and clustering forces. In addition, many service industries are characterised by forces that lead to a uniform distribution in space, caused by the fact that consumers and customers approach only local firms for the respective services. All further analyses are restricted to the manufacturing sector, because this sector is most discussed in the context of clustering and the theoretical model seems to represent the situation in the manufacturing industries adequately.

absolute numbers	relative numbers		
	cluster	natural	rejected
cluster	17	16	3
natural	17	46	4

Table 1: Identification of local clusters in the manufacturing sector.

Table 1 shows that number of manufacturing industries for which local agglomerations are shown to exist. In total local agglomerations are found for at least one of the two numbers of firms – relative and absolute – in 50 of the 104 manufacturing industries. Hence, clustering forces seem to be common but not universal in the manufacturing sector.

In the case of the existence of local agglomerations, ξ_4 can be called the critical value for agglomeration. All regions in which the numbers of firms is higher than ξ_4 times the average value contain an agglomeration according to the approach taken here. It is likely that these agglomerations are local industrial clusters. The values of ξ_4 range from 3 to 87. However, values between 3 and 20 are found most frequently. Values larger than 30 only appear in those cases in which one region contains a very large agglomeration of firms and is identified as the only local cluster. The distribution of the value of ξ_4 that is found in the empirical analysis is shown in Figure 3.

In the literature, e.g., a value of $\xi_4(i) = 3$ is used (see Isaksen 1996). Hence, for a few industries the value that is found here fits the value assumed in the literature quite well. However, for many industries, $\xi_4(i)$ is much higher than it is

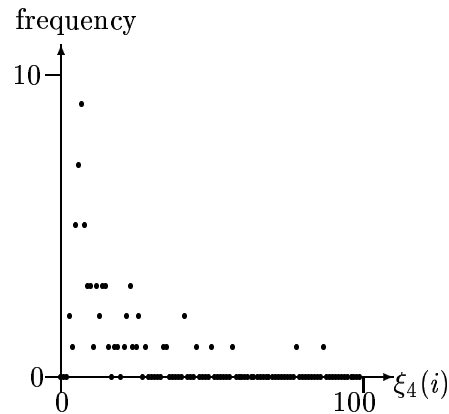


Figure 3: Distribution of the critical value of the number of firms in the case of clustering.

assumed to be in the literature. Hence, the number of local industrial clusters that exists is overestimated in the literature. Furthermore, such a critical value for the identification of local clusters is applied equally to all industries in the literature. The analysis conducted here shows that not all industries contain local clusters and that not for all the same critical values hold.

4.2. LIST OF LOCAL INDUSTRIAL CLUSTERS

For 54 manufacturing industries, the existence of local clusters has been confirmed. In these industries a total of 383 local industrial clusters are identified according to the condition $f(i, r) > \xi_4(i)$. It is impossible to discuss or even depict all of them. However, a complete list of them is given here. The distilling industry is excluded because the number of firms is low so that all small regions that contain at least one firm show up in the list of local clusters. Some service industries are added to this list because they are repeatedly discussed in the literature. The list contains, for each industry that is studied, a list of the names of all administrative districts that satisfy the above condition (439 local clusters altogether).

For the following industries local clusters are found for the relative and the absolute numbers of firms (regions that contain clusters according to both numbers of firms are in bold):

fish processing: Dithmarschen, Nordfriesland, Schleswig-Flensburg, **Cuxhaven**,

- Wittmund, **Bremerhaven (city)**, Wismar (city), Ostvorpommern, Rügen, Schöneberg
- textile weaving:** Borken, Steinfurt, **Hof**
- curtains:** Grafschaft Bentheim, Coesfeld, Vogelsbergkreis, **Reutlingen, Tübingen, Zollernalbkreis, Sigmaringen**, Bayreuth, **Hof**, Wunsiedel i. Fichtelgebirge, Aichach-Friedberg, **Chemnitzer Land, Stollberg**, Zwickauer Land, **Weimarer Land**
- clothing:** Hamburg (city), **Zollernalbkreis**, Munich (city), **Miltenberg**, Berlin (West)
- leather processing:** **Offenbach (city)**, **Offenbach**, **Bad Kreuznach**, Munich (city)
- shoes:** **Pirmasens (city)**, **Pirmasens**
- sawmills:** **Hochsauerlandkreis, Ortenaukreis**
- wooden goods:** Lippe, Bernkastel-Wittlich, Bittburg-Prüm, Daun, Trier-Saarburg, Garmisch-Partenkirchen, Freyung-Grafenau, Regen, Straubing-Bogen, Coburg, Kronach, Lichtenfels, Haßberge, Annaberg, Freiberg, **Mittlerer Erzgebirgskreis**, Aue-Schwarzenberg, Weißeritzkreis, Wartburgkreis, Schmalkalden-Meiningen, Hildburghausen, Sonneberg, Saale-Holzland-Kreis
- glass:** Holzminden, **Main-Tauber-Kreis**, Regen, Neustadt a. d. Waldnaab, Bayreuth, Kaufbeuren (city), **Ilm-Kreis, Sonneberg**, Saalfeld-Rudolstadt
- ferrous-metal production & steel:** Mettmann, **Oberbergischer Kreis**, Märkischer Kreis, **Olpe, Siegen-Wittgenstein**, Esslingen, **Ludwigsburg**, Emmendingen, **Zollernalbkreis**, Alb-Donau-Kreis, Sigmaringen
- foundry:** Solingen (city), **Mettmann, Märkischer Kreis**, Olpe, Pforzheim (city), Enzkreis, Aue-Schwarzenberg
- metal tools:** **Remscheid (city)**, **Solingen (city)**, **Wuppertal (city)**, **Mettmann, Märkischer Kreis**, Pirmasens (city), Esslingen, Rems-Murr-Kreis, Ostalbkreis, Berlin (West), Berlin (East), **Schmalkalden-Meiningen**
- lights:** **Hochsauerlandkreis**
- watches & clocks:** **Pforzheim (city)**, Calw, **Enzkreis**, Breisgau-Hochschwarzwald, Rottweil, **Schwarzwald-Baar-Kreis**, Tuttlingen, Lörrach, Zollernalbkreis, Weilheim-Schongau, Weißeritzkreis, Wartburgkreis
- ships & boats:** **Ostholstein**, Plön, **Schleswig-Flensburg**, Hamburg (city), Emden (city), Wilhelmshaven (city), Wesermarsch, Bremen (city), Bremerhaven (city), Berlin (West), Müritz
- jewellery, coins & cutlery:** **Birkenfeld**, Ostalbkreis, **Pforzheim (city)**, **Enzkreis**, Kaufbeuren (city)

musical instruments: Tuttlingen, Bad Tölz-Wolfratshausen, Garmisch-Partenkirchen, Mühldorf am Inn, Straubing-Bogen, Forchheim, Erlangen-Höchstadt, Fürth, Neustadt a. d. Aisch-Bad Windsheim, **Vogtlandkreis**

film: **Hamburg (city)**, Hannover, Düsseldorf, **Köln**, Erftkreis, Frankfurt am Main (city), **Wiesbaden (city)**, Stuttgart (city), Baden-Baden (city), **Munich (city)**, **Munich**, Starnberg, Nürnberg, **Berlin (West)**, **Berlin (East)**, **Potsdam (city)**, Dresden (city), Leipzig (city)

For the following industries local clusters are found for the relative numbers of firms:

dairy products: Cuxhaven, Osterholz, Rotenburg (Wümme), Uelzen, Ravensburg, Ebersberg, Bamberg, Lindau, Ostallgäu, Unterallgäu, Oberallgäu, Uckermark, Demmin, Mecklenburg-Strelitz, Annaberg, Mittlerer Erzgebirgskreis, Anhalt-Zerbst, Wittenberg, Sangershausen, Stendal

feeding grain: Verden, Cloppenburg, Vechta, Bördekreis

textile processing: Zollernalbkreis, Hof, Kulmbach

bed & decor textiles: Vogtlandkreis

other textiles: Wuppertal (city), Zollernalbkreis, Bayreuth, Hof, Neustadt a. d. Aisch-Bad Windsheim, Plauen (city), Annaberg, Chemnitzer Land, Vogtlandkreis, Mittweida

hosiery & knitwear: Mittlerer Erzgebirgskreis

leather clothes: Westerwaldkreis, Tuttlingen, Berchtesgadener Land, Passau, Reggen, Regensburg, Bayreuth, Kronach, Lichtenfels, Aschaffenburg, Haßberge, Miltenberg, Zwickauer Land, Schmalkalden-Meiningen

chipboard: Osterode am Harz, Gütersloh, Herford, Höxter, Lippe, Rastatt, Weilheim-Schongau, Prignitz

basic chemicals: Ennepe-Ruhr-Kreis, Bitterfeld, Merseburg-Querfurt

ceramics: Westerwaldkreis, Tirschenreuth, Kronach, Wunsiedel i. Fichtelgebirge, Saalfeld-Rudolstadt, Saale-Holzland-Kreis

cement: Goslar, Osterode am Harz, Warendorf, Soest, Hersfeld-Rotenburg, Bad Kreuznach, Rhein-Lahn-Kreis, Daun, Donnersbergkreis, Rottweil, Alb-Donau-Kreis, Bad Tölz-Wolfratshausen, Rosenheim, Schwandorf, Forchheim, Nürnberger Land, Main-Spessart, Schweinfurt, Donau-Ries, Märkisch Oderland, Bernburg, Saalkreis, Saale-Holzland-Kreis

- metal tubes:** Schleswig-Flensburg, Delmenhorst (city), Oldenburg, Olpe, Siegen-Wittgenstein, Altenkirchen, Rhön-Grabfeld, Haßberge, Schweinfurt, Oderspreewald-Lausitz, Jerichower Land, Stendal, Altmarkkreis Salzwedel, Eichsfeld, Nordhausen, Kyffhäuserkreis, Saale-Holzland-Kreis
- weapons & munition:** Rottweil, Suhl (city)
- toys:** Coburg, Mittlerer Erzgebirgskreis, Sonneberg
- other consumer goods:** Solingen (city), Odenwaldkreis, Birkenfeld, Südliche Weinstraße, Lörrach, Tirschenreuth, Coburg, Kronach, Lichtenfels, Ansbach, Fürth, Kaufbeuren (city), Ostallgäu, Aue-Schwarzenberg, Köthen, Sonneberg
- metal recycling:** Daun, Elbe-Elster, Oderspreewald-Lausitz, Güstrow, Burgenlandkreis, Saalkreis, Sangershausen, Altmarkkreis Salzwedel, Kyffhäuserkreis, Schmalkalden-Meiningen, Hildburghausen, Saale-Holzland-Kreis, Altenburger Land
- non-metal recycling:** Märkisch Oderland, Anhalt-Zerbst, Köthen, Saalkreis, Hildburghausen, Weimarer Land

For the following industries local clusters are found for the absolute numbers of firms:

- leather goods:** Heinsberg, Göppingen, Ludwigsburg, Rems-Murr-Kreis, Reutlingen, Hof, Günzburg
- packages from wood:** Hochsauerlandkreis, Märkischer Kreis, Main-Kinzig-Kreis, Rems-Murr-Kreis, Ortenaukreis, Berlin (West)
- publishers:** Hamburg (city), Düsseldorf, Köln, Frankfurt am Main (city), Stuttgart (city), Munich (city), Berlin (West), Berlin (East)
- printers:** Hamburg (city), Munich (city), Berlin (West)
- petroleum processing:** Hamburg (city)
- tyres:** Hamburg (city), Main-Kinzig-Kreis, Berlin (West), Berlin (East), Dresden (city)
- sculptor & stonecutter:** Hamburg (city), Mayen-Koblenz, Berlin (West)
- ferror metal production:** Hagen (city), Märkischer Kreis, Siegen-Wittgenstein
- non-ferror metal processing:** Märkischer Kreis
- smiths:** Märkischer Kreis
- metal surface refinement:** Hamburg (city), Solingen (city), Mettmann, Recklinghausen, Gütersloh, Ennepe-Ruhr-Kreis, Hochsauerlandkreis, Märkischer Kreis, Esslingen, Göppingen, Ludwigsburg, Rems-Murr-Kreis, Heilbronn, Ostalbkreis, Karlsruhe, Rhein-Neckar-Kreis, Enzkreis, Ortenaukreis, Rottweil, Schwarzwald-Baar-Kreis, Tuttlingen, Berlin (West), Berlin (East)

other metal goods: Märkischer Kreis

machine tools: Märkischer Kreis, Enzkreis

electrical equipment: Essen (city), Mettmann, Köln, Dortmund (city), Märkischer Kreis, Esslingen, Karlsruhe, Berlin (West), Berlin (East)

electronics: Märkischer Kreis, Schwarzwald-Baar-Kreis, Dresden (city)

telecommunication: Düsseldorf, Frankfurt am Main (city), Munich (city), Berlin (West), Berlin (East)

medical instruments: Hamburg (city), Tuttlingen, Munich (city), Berlin (West)

measurement instruments: Hamburg (city), Lahn-Dill-Kreis, Munich (city), Berlin (West)

aeospace: Bodenseekreis, Munich

motor cycles: Bielefeld (city)

software: Hamburg (city), Köln, Frankfurt am Main (city), Stuttgart (city), Munich (city), Munich, Berlin (West), Berlin (East)

data processing: Hamburg (city), Hannover, Düsseldorf, Bonn (city), Köln, Dortmund (city), Frankfurt am Main (city), Stuttgart (city), Munich (city), Berlin (West), Berlin (East), Dresden (city), Leipzig (city)

radio & TV: Kiel (city), Hamburg (city), Hannover, Düsseldorf, Bonn (city), Köln, Frankfurt am Main (city), Mainz (city), Baden-Baden (city), Munich (city), Munich, Augsburg, Berlin (West), Berlin (East), Potsdam (city), Dresden (city), Leipzig (city)

4.3. COMPARISON WITH CASE STUDIES

In the literature quite a number of case studies of local industrial clusters in Germany can be found. Most case studies that are cited and discussed in the context of industrial districts, local clusters and the likes describe the historical development of a specific industry in a certain region. In contrast, many studies of German regions are conducted in order to evaluate advantages and disadvantages and to identify possible ways of improving the prosperity of a region. Factors that influence specialisation and clusters are sometimes discussed in this context. Therefore, it is not claimed here that the following list of case studies conducted in Germany is complete. However, it has to be stated that the list is restricted to those local systems that fit into the concept used here. The fitting case studies are:

iron and steel: Ruhr area (Grabher 1993)

biotechnology: Munich, upper Rhine, Heidelberg and Mannheim, Frankfurt, middle Rhine, and Berlin (Zeller 2001 and for Munich see, in addition, Lechner & Dowling 1999)

machinery: Baden-Württemberg (Cooke 1994)

printing machinery: several places around Offenbach, Frankenthal, Heidelberg, Leipzig, Würzburg and Augsburg (Porter 1990)

automobiles: Bergisches Land, Bochum, Zwickau, Regensburg, Cologne, Frankfurt, Hannover, Wolfsburg, Munich and Mittlerer Neckar (Rehfeld 1992)

train building: mainly Berlin, but also Ruhr area, Braunschweig, Nürnberg and Saxony (Dybe & Kujath 2000)

textiles: Zollernalbkreis (Grotz & Braun 1997b), Reutlingen (Staber 1997)

media: Berlin/Babelsberg and Cologne/Düsseldorf (Staber, Lutz & Sydow 2002)

In addition, Munich is regarded as an innovative milieu in the literature because it is strong in the vehicles, aerospace, electronic engineering, precision instruments/optics, and office machinery/data processing industries (see Sternberg & Tamásy 1999).

The comparison leads to very different results. In some cases quite a good correspondence is found, although industries or regions are not always defined in exactly the same way. For example, the industrial districts in textiles show up in the analysis conducted here as a local cluster in textile processing, other textiles, clothes and curtains. Similarly, metal processing is subdivided into many different industries here. Many of them show clustering. Most of these local clusters are found in the Ruhr area. The same holds for the media industry. In some of these cases more local clusters are found in the analysis above than are described in the literature.

There are also many industries for which local clusters are discussed in the literature but no significant clustering is observed in the above analysis. These are the machinery, automobiles and train building industries. This discrepancy might have different causes. First, the statistical approach used here is only able to reject the assumption that no local clusters exist in an industry. It might fail to identify all industries that show clustering. Second, the approach taken here is based on the distribution of firms, while case studies usually refer to the number of employees in an industry and region. For example, in the case of automobiles the clusters described in the literature are characterised by a very large factory site or company. The above approach does not identify the locations of large firms, but only agglomerations of many firms. Therefore, it might lead to very different results. Finally, in the literature, regions are often discussed that are much larger than administrative districts. Examples are the machinery and printing machinery

industry regions. If clustering occurs in such large spatial units, it is not identified by the approach taken here. However, it might be doubted whether, in such large regions, the local self-augmenting processes that are discussed in the theoretical literature have a significant impact on the developments.

The case of biotechnology differs from the other cases discussed. Biotechnology firms are usually assigned to the industries of pharmaceuticals or measurement instruments in the WZ93 classification. Some even belong to other industries. Hence, the analysis is not able to capture the developments in this industry adequately. Nevertheless, it seems to be able to catch some of the clustering in the form of local clusters in the industry of measurement instruments.

4.4. REGIONAL PERSPECTIVE

The local industrial clusters that have been identified are listed above according to the industry to which they belong. Alternatively, their spatial distribution might be given. This is done in Figure 4. The spatial distribution has several characteristics that are worth discussing here.

First, 158 of the 441 administrative districts contain at least one industrial cluster. Above it has been stated that the approach taken here might underestimate the number of industries that show clustering and therefore might underestimate the total number of clusters. Hence, a sizeable share of all districts contain industrial clusters. In other words, the existing local industrial clusters are well scattered across space.

Nevertheless, local industrial clusters are not everywhere. They are not uniformly distributed across Germany. There are some areas in which they are concentrated. In Figure 4 three such areas can be easily identified: the Ruhr area, an area in the north of Bavaria and the south of Thuringia and Saxony, and an area in the south of Baden-Württemberg. In addition there are many smaller spots, many of them around large cities such as Berlin, Hamburg, Hannover, Leipzig, Frankfurt a. Main, Stuttgart and Munich. Some areas are completely empty. This is especially the case in the north-east, where, for example, no cluster is found in the state of Mecklenburg-West Pomerania.

The large empty spots match quite well with those regions in which there is little industrial employment and development. These regions seem to be unable to exceed the critical mass for the emergence of local industrial clusters. Although random processes are involved in the determination of the location of clusters and although these clusters are quite scattered within Germany, certain regions do not

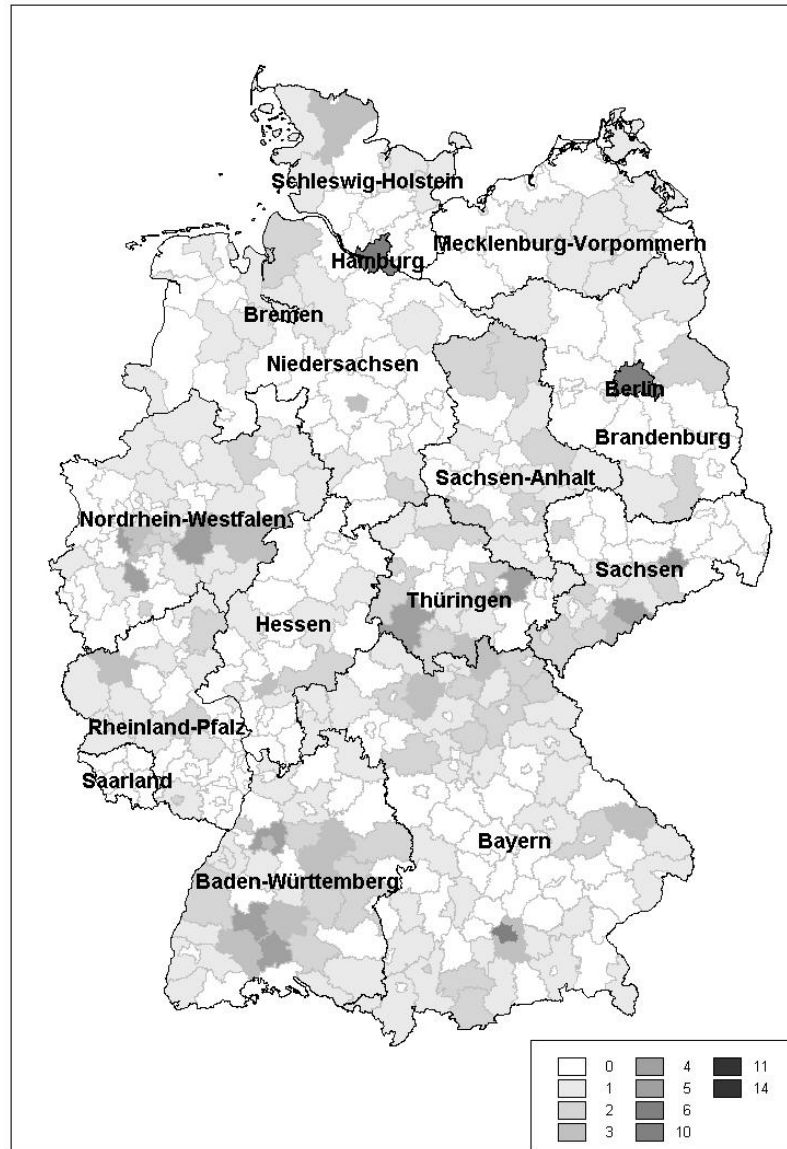


Figure 4: Clustering in Germany (shaded according to the number of industrial clusters that each district contains).

seem not to offer sufficient circumstances. This can be seen as evidence for the existence of at least one necessary condition with respect to local circumstances. It does, however, not help us to identify this necessary condition. In this context, we can only speculate. There is little discussion about what is lacking in those

regions that are lagging behind (an exception is found in Seri 2003). Research in this direction would be helpful to understand the local conditions necessary for the emergence of industrial clusters.

While the empty spots in Figure 4 match the distribution of economic activity in Germany quite well, the same does not hold for the place in which many local clusters exist. In Baden-Württemberg (south-west of Germany) there should be many more districts containing one or several clusters, for example in the east of Stuttgart and along the Rhine from Karlsruhe to Mannheim. At the same time, the strong concentration of clusters in the north of Bavaria and the south of Thuringia does not match the lack of economic prosperity of this area. This shows that the existence of local industrial clusters should not be mixed up with economic prosperity. They might differ tremendously. Two factors are responsible for this.

On the one hand, the spatial distribution of local clusters reflects the history of places rather than their actual situations. Many clusters remain stable over decades or even centuries. For example the area in the north of Bavaria and the south of Thuringia and Saxony was strong in handcrafts many decades ago. Textiles, porcelain, toys, musical instruments and other similar things have been produced there. This is still the case today. Although employment has decreased strongly in many of these industries, the respective districts are still strong in these industries compared to other regions in Germany. The same holds for metal processing and metal goods production in the Ruhr area. Most of the clusters identified above can be assigned to a particular time in which they emerged. Many case studies in the literature confirm this. At this time they cause economic prosperity for the region. Later on they remain stable in many cases but without a further impulse for economic development and sometimes even causing problems for the region if the respective industry declines (see Grabher 1993 and Pouder & St. John 1996).

On the other hand, the identification of local industrial clusters neither identifies regions that prosper because of a heterogeneous mix of industries nor those that are characterised by a large, successful firm. Baden-Württemberg is usually claimed to be one of the major locations of the automobile, machinery and chemical industries (see Cooke 1994 for a detailed discussion of the economic situation in Baden-Württemberg). However, most of these industries are characterised by a few very large firms, so that most of them are not identified as clustering industries above and are not included in the search for local clusters in this section. Furthermore, these industries are quite scattered within Baden-Württemberg, so that they seldom fall into the same administrative district. Baden-Württemberg

is a very decentralised state with respect to its economic activity (this becomes very obvious in, for example, the patent distribution shown in Greif 1998). It is furthermore characterised by a heterogeneous mix of industries. This, among other aspects, causes Schmitz (1992) to argue that the concept of industrial districts does not fit the situation there.

These discussions show that we should not confuse local industrial clusters and economic development. Their existence in a region does not necessarily imply economic development there, although their emergence might well do. It seems that their economic impact appears in a particular period of time around their emergence. Later, the success of the region depends on other factors, but not purely on the existence of clusters.

5. Conclusions

The approach above shows that the phenomenon of clustering can be studied empirically using a general approach. The main result is that clustering is more than a random result of an uneven distribution of local circumstances. There is evidence for the existence of local self-augmenting processes that cause the industrial firm-distribution among regions to be bimodal. On the basis of this finding those industries are identified here in which local clusters exist in Germany. Furthermore, it has been shown that the condition with respect to the number of firms for the identification of local clusters can be obtained empirically. This means that the respective condition does not have to be set arbitrarily but can be deduced from the empirical data for each industry separately. This makes the study of local industrial clusters much more objective and helps to choose regions and industries for further case studies.

References

- Bottazzi, G., Fagiolo, G. & Dosi, G. (2002). *Mapping Sectoral Patterns of Technological Accumulation into the Geography of Corporate Locations. A Simple Model and Some Promising Evidence*. LEM Working Paper Series 2002/21, Pisa.
- Braunerhjelm, P. & Carlsson, B. (1999). Industry Clusters in Ohio and Sweden, 1975-1995. *Small Business Economics* **12**, 297-293.
- Brenner, T. (2000). *The Evolution of Localised Industrial Clusters: Identifying the Processes of Self-organisation*. Papers on Economics & Evolution #0011, Max-Planck-Institute Jena.
- Brenner, T. (2001). *Self-organisation, Local Symbiosis of Firms and the Life Cycle of*

- Localised Industrial Clusters*. Papers on Economics & Evolution #0103, Max-Planck-Institute Jena.
- Brenner, T. (2003a). *The Existence, Emergence and Evolution of Local Industrial Clusters*. Habilitation thesis, University Jena.
- Brenner, T. (2003b). *A Methodology to Identify Local Industrial Clusters and Its Application to Germany*. mimeo, Max Planck Institute Jena.
- Cooke, P. (1994). Die baden-württembergische Maschinenbauindustrie. *International Journal of Technology Management* **9**, 52–68.
- Dumais, G., Ellison, G. & Glaeser, E.L. (2002). Geographic Concentration as a Dynamic Process. *The Review of Economics and Statistics* **84**, 193–204.
- Dybe, G. & Kujath, H.J. (2000). *Hoffnungsträger Wirtschaftscluster*. Berlin: edition sigma.
- Ellison, G. & Glaeser, E.L. (1997). Geographic Concentration in U.S. Manufacturing Industries: A Dartboard Approach. *Journal of Political Economy* **105**, 889–927.
- Ellison, G. & Glaeser, E.L. (1999). The Geographic Concentration of Industry: Does Natural Advantage Explain Agglomeration?. *American Economic Review* **89**, 311–316.
- Grabher, G. (1993). The Weakness of Strong Ties: The Lock-in of Regional Development in the Ruhr Area. In: (G. Grabher (ed.)) *The Embedded Firm: On the Socioeconomics of Industrial Networks*, pp. 255–277. London: Routledge.
- Greif, S. (1998). *Patentatlas Deutschland - Die räumliche Struktur der Erfindungstätigkeit*. München: Deutsches Patentamt.
- Grotz, R. & Braun, B. (1997). Territorial or Trans-territorial Networking: Spatial Aspects of Technology-oriented Cooperation within the German Mechanical Engineering Industry. *Regional Studies* **31**, 545–557.
- Isaksen, A. (1996). Towards increased Regional Specialization? The Quantitative Importance of New Industrial Spaces in Norway, 1970–1990. *Norsk Geografisk Tidsskrift* **50**, 113–123.
- Lechner, C. & Dowling, M. (1999). The Evolution of Industrial Districts and Regional Networks: The Case of the Biotechnology Region Munich/Martinsried. *Journal of Management and Governance* **3**, 309–338.
- Mittelhammer, R.C. (1995). *Mathematical Statistics for Economics and Business*. New York: Springer.
- Paniccia, I. (1998). One, a Hundred, Thousands of Industrial Districts. Organizational Variety in Local Networks of Small and Medium-sized Enterprises. *Organizational Studies* **19**, 667–699.
- Porter, M.E. (1990). *The Competitive Advantage of Nations*. New York: The Free Press.
- Pouder, R. & St. John, C. (1996). Hot Spots and Blind Spots: Geographical Clusters of Firms and Innovation. *Academy of Management Review* **21**, 1192–1225.
- Rehfeld, D. (1999). *Produktionscluster*. München: Rainer Hampp Verlag.
- Schmitz, H. (1992). Industrial Districts: Model and Reality in Baden-Württemberg, Germany. In: (F. Pyke & W. Sengenberger) *Industrial Districts and Local Economic Regeneration*, pp. 87–121. Geneva: International Institute for Labour Studies.

- Seri, P. (2003). Learning Pathologies in Losing Areas: Towards a Definition of the Cognitive Obstacles to Local Development. In: (D. Fornahl & T. Brenner) *Cooperation, Networks, and Institutions in Regional Innovation Systems*, pp. 128–148. Cheltenham: Edward Elgar.
- Sforzi, F. (1990). The quantitative importance of Marshallian industrial districts in the Italian economy. In: (F. Pyke, G. Becattini & W. Sengenberger (eds.)) *Industrial Districts and Inter-firm Co-operation in Italy*, pp. 75–107. Geneva: International Institute for Labour Studies.
- Sforzi, F., Openshaw, S. & Wymer, C. (1997). *La procedura di identificazione dei sistemi locali del lavoro*. I sistemi locali del lavoro 1991, ISTAT.
- Staber, U. (1996). Accounting for Variations in the Performance of Industrial Districts: The Case of Baden-Württemberg. *International Journal of Urban & Regional Research* **20**, 299–316.
- Staber, U., Lutz, A. & Sydow, J. (2003). TV-Content Production in Media Regions: The Necessities and Difficulties of Public Policy Support for a Project-Based Industry. In: (D. Fornahl & T. Brenner (eds.)) *Cooperation, Networks, and Institutions in Regional Innovation Systems*, pp. 194–219. Cheltenham: Edward Elgar.
- Sternberg, R. & Tamásy, C. (1999). Munich as Germany's No. 1 High Technology Region: Empirical Evidence, Theoretical Explanations and the Role of Small Firm/Large Firm Relationships. *Regional Studies* **33**, 367–377.
- Zeller, C. (2001). Clustering Biotech: A Recipe for Success? Spatial Patterns of Growth of Biotechnology in Munich, Rhineland and Hamburg. *Small Business Economics* **17**, 123–141.