

*Innovation and Cooperation During the Emergence of
Local Industrial Clusters - An Empirical Study in
Germany*

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ABSTRACT This paper studies the dynamics that cause the emergence of local industrial clusters on a general level. Predictions about these dynamics are deduced from theoretical modelling. The predictions are tested with the help of empirical data from Germany. 3-digit manufacturing industries are classified according to their dynamics. It is examined whether certain industrial characteristics are able to predict the type of dynamics that is occurring. It is shown that a high number of process innovations and a high share of regional cooperation with suppliers and public research institutes characterise those industries in which local clusters emerge.

KEYWORDS: innovations, cooperation, local industrial clusters, industry study.

JEL classification: C12, L60, R12

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1. Introduction

Local industrial clusters have become a frequently analysed and discussed economic phenomenon. As a consequence, elaborated theoretical concepts exist that explain the emergence, evolution and success of such clusters. These concepts are informed by a huge amount of case studies. The case studies also represent the main source of empirical evidence for the theoretical considerations. However, the predictions that can be deduced from the theoretical concepts are usually not tested in a general empirical study. There are only a few empirical approaches that examine some of the aspects related to local clustering on a general level (see Sforzi 1989, Ellison & Glaeser 1994, and Isaksen 1996). Ellison and Glaeser (1994) show that the spatial distribution of firms in manufacturing industries in the U.S.A. deviates from a random distribution. The other approaches apply certain definitions of local clusters or industrial districts to spatial data of a country. By this they identify all local systems that satisfy the respective conditions.

Beside these studies, most of the general approaches in the literature focus on the characteristics of local clusters and on the reasons for their success. Case studies usually detect the specific factors that are involved in the evolution of the particular cluster that is examined. A general approach that deduces theoretical predictions about the evolution of local industrial clusters, tests them empirically and attempts to identify the causes for the emergence of local industrial clusters on a general level is missing. This paper takes a first step into that direction and shows that industrial characteristics that are related to the emergence of local industrial clusters can be identified in a general approach.

To this end, first some theoretical predictions about the dynamics of the industrial firm population in regions are deduced from a general model of local industrial clusters. The theoretical literature offers many concepts that described the evolution of local clusters comprehensively and on a general level (see, e.g., Krugman 1991, Garnsey 1998, Brenner 2001 and Maggioni 2002). Here the theoretical model developed in Brenner 2001 is used.

In order to test the predictions, data on the number of firms in 3-digit manufacturing industries in all administrative districts in Germany is used. The changes of the firm numbers between 1995 and 2000 are studied. Through this, it is tested whether the theoretical predictions hold and for which industries they hold. The industries are classified into three categories: those that show dynamics typical for the emergence and stabilisation of local clusters, those that show dynamics typical for the disappearance and weakening of clustering and those that show neither of these dynamics.

This classification of industries is used to examine whether the industries in which local clusters emerge share certain characteristics. Two factors exist that are controversially discussed in the literature with respect to their relevance for the emergence of local industrial clusters: innovations and cooperation. The concept of innovative milieu is based on the existence of regions with a high innovativeness and strong synergies (see Camagni 1995). In general, local clusters are assumed to be related to high innovativeness. However, counter-examples exist (see, e.g., Brusco 1982, Russo 1985, Capecchi 1992, Lazerson 1992, and Lorenzen 1998). Furthermore, it is not clear whether a high number of innovations in an industry or region is crucial for the emergence of local clusters or whether is one of the implications of the existence of local clusters. Hence, the role that innovations play in the emergence of local industrial clusters is not comprehensively understood. The study

conducted here sheds some light on this and shows that different kinds of innovations have to be distinguished in this context.

The importance of cooperation in the context of clustering is controversially discussed in the literature. For some scientists cooperation is essential for the success and emergence of local industrial clusters (see, e.g., Sengenberger & Pyke 1992, Dei Ottati 1994, Vou & Wilkinson 1994, and Vipraio 1996). Other scientists, however, claim that the empirical evidence that is collected so far does not confirm the importance of cooperation (see, e.g., Staber 1996, Grotz & Brown 1997, and Paniccia 1998). It is repeatedly claimed that more evidence is necessary to understand the role that cooperation plays in the context of local clusters.

Hence, further studies on the role of innovations and cooperation in the context of local clusters are necessary. If they are necessary for or, at least, support the emergence of local clusters, a high innovativeness and a dominance of local cooperation should be reported for firms in those industries in which local clusters emerge. This relationship is examined here.

The paper proceeds as follows. In the next section the theoretical concept on which the study is based is reported and the predictions about industrial dynamics are deduced. In Section 3 the empirical data that is used is described and discussed. The theoretical predictions are tested in Section 4. In Section 5 it is studied whether several industrial characteristics are able to predict the industrial dynamics observed. Section 6 concludes.

2. Theoretical considerations

In the literature several mathematical models of the emergence and evolution of local industrial clusters are proposed (see, e.g. Krugman 1991, Brenner 2001 and Maggioni 2002). Here the model proposed in Brenner 2001 is used. This model describes the whole evolution of a local industrial clusters from its emergence to its disappearance. It is based on the assumption of local self-augmenting processes. It describes the dynamics of the firm population and the local circumstances in one region. The analysis finds that if there is a sufficiently strong positive feedback between the firm population and the local circumstances, the local system might have two stable states: one with many firms located in the region and one with only a few or no firms located there.

The history of a region determines the stable state to which the local system converges. Switches between the two states might occur. The evolution of local industrial clusters can be described on the basis of such switches and their causes (see Brenner 2001). This allows to distinguish four different stages in the evolution of local industrial clusters. The different stages are characterised by different dynamics within regions. These different dynamics are used in the empirical analysis below. Therefore, the model itself is not presented here (for a description, analysis and discussion see Brenner 2001). Only the stages and the dynamics within regions are presented and discussed.

2.1. STAGES IN THE EVOLUTION OF LOCAL INDUSTRIAL CLUSTERS

Assuming that sufficiently strong local self-augmenting processes do exist does not automatically cause the existence of two stable states. The exogenous conditions, $e(t)$, are decisive in this case. The exogenous conditions are the sum of those local circumstances that do not change during the emergence of an industrial cluster, like culture, geographic

location and part of the local institutions, and the external conditions, mainly the market situation. If these exogenous conditions are very favourable for a region, a local cluster will emerge because this will be the only stable state. If the exogenous conditions are unfavourable, only the stable state that is characterised by a small number of firms or no firms exists. If the exogenous conditions are somewhat between, $e_1 < e(t) < e_2$, both stable states exist and the actual situation in the region determines to which of the stable states it converges (see Figure 1).

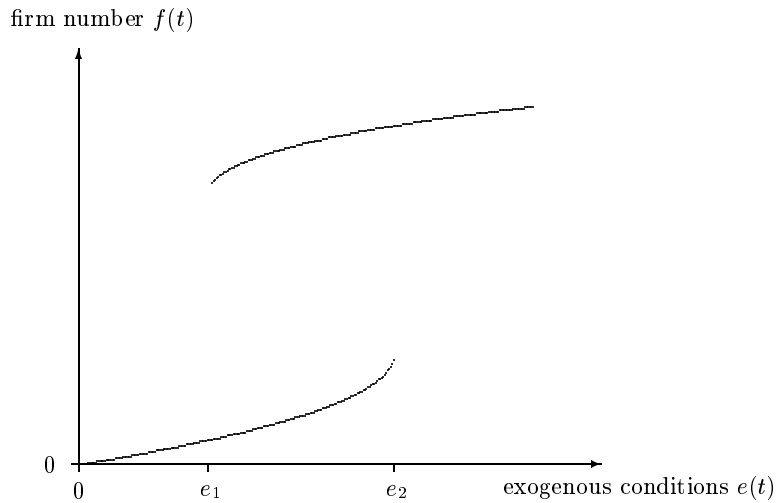


Figure 1: Stable states dependent on the exogenous conditions. As long as the exogenous conditions remain constant, the local system converges to the state (number of firms) given by the solid line. If $e(t) < e_1$ holds, the number of firms in the region becomes small. If $e(t) > e_2$ holds, a local cluster emerges. If $e_1 < e(t) < e_2$ holds, both developments are possible.

This dependence of the existence of stable states on the exogenous conditions can be used to explain the evolution of local industrial clusters and identify several stages and the processes therein. The evolution of many of the local industrial clusters that are studied in the literature follows the developments in the respective industry. This does not hold for all cases. However, it seems to be a typical feature that is well captured by the theoretical model used here. Therefore, a situation in which the evolution of a local cluster is caused by the developments in the respective industry is studied here. The developments in the industry determine the market situation. This, in turn, determines, as argued above, the exogenous conditions $e(t)$. The existence of stable states and the emergence of local industrial clusters depends on the exogenous conditions.

2.1.1. INDUSTRIAL LIFE CYCLE

To study the evolution of a local industrial cluster that is purely determined by the developments in the respective industry, the developments in the industry have to be defined first. A usual industrial life cycle is assumed here. Such a life cycle is characterised by three

phases (an overview about the industrial life cycle is given in Klepper 1997, a discussion in the context of local clusters can be found in Dybe & Kujath 2000).

The initial phase is characterised by high uncertainty, a low market volume and a high number of entries. Competition is based mainly on product innovations in this phase. It is called the embryonic stage.

The growth stage follows. In this phase the products become more stable. Process innovations become more important than product innovations. Demand increases quickly in this phase. Profits of firms are high. The number of entries is lower than in the first stage. Furthermore, shakeouts of firms occur.

The third stage, the so-called mature stage, is characterised by a slow down of output growth. The situation stabilises. The numbers of entries and exits are low. Market shares stabilise and both, product and process, innovations become less important.

2.1.2. FROM INDUSTRIAL DEVELOPMENT TO CLUSTER EVOLUTION

With the help of the model developed in Brenner 2001 the developments of an industry can now be transferred to the evolution of local industrial clusters. It is assumed that the situation is as depicted in Figure 1. $e(t)$ is the higher the more favourable the market situation is, meaning the higher the profits on the market and the less fierce competition is, and the more attractive the region is. For such a system it will now be discussed how the local system reacts to changes in the industry, especially to the development in the different stages of the industrial life cycle.

At the beginning of the embryonic stage there is nearly no demand and the situation is quite unfavourable for firms. This implies a low value of the exogenous conditions $e(t)$. For such a situation only one stable state exists that is characterised by a small firm population (see Figure ??). Hence, no cluster exists in the region and industry under consideration. This is the starting point of the evolution that we are concerned with.

The growth stage of the industrial life cycle comes with a strong increase in the demand for the products of the industry. This implies an increase of the exogenous conditions $e(t)$. As long as they remain below e_2 (see Process 1 in Figure 2), their increase causes only small changes in the firm population, although a second stable state might exist. If the changes of the exogenous conditions are slow compared to the adaptation of the local system the system develops along the lower solid line in Figure 2. Hence, a first critical point in the development of a local industrial cluster is identified. If the demand does not increase sufficiently strongly, the exogenous condition do not exceed the value e_2 and no local industrial cluster emerges. The value e_2 can be called the critical value or critical mass (for other uses of the critical mass in economics see, e.g., Witt 1997).

The exceeding of the critical mass is called the first stage in the evolution of a local industrial cluster here. If the exogenous conditions exceed e_2 , the lower stable state disappears, so that only one stable state exists that is characterised by a large firm population. The local system converges towards this state as long as the external conditions $e(t)$ remain above e_2 (see Process 2 in Figure 2).

The convergence is caused entirely by internal forces, so-called self-augmenting processes (a detailed discussion of these processes is given in Brenner 2000). Since this convergence changes the situation within the region tremendously, it takes some time. It is called the

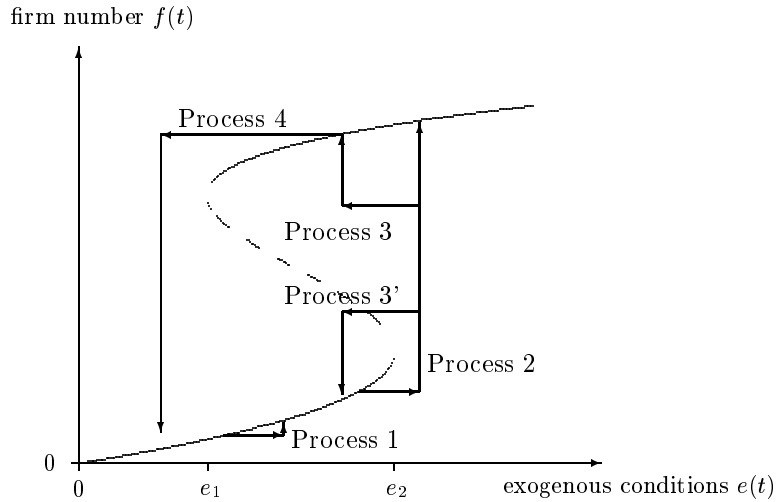


Figure 2: Different changes of the exogenous conditions and the resulting dynamics of the local system (solid lines signify stable states of the system, dashed lines signify unstable states).

second stage in the evolution of a local industrial cluster here. Within this stage the number of firms in the industry increases strongly and finally leads to an increasing occurrence of shakeouts. This means that competitions becomes more fierce. Although the demand might still increase the market situation becomes less favourable. The exogenous conditions $e(t)$ decrease. For the emergence of the local industrial cluster it is decisive how far the convergence process has taken the local system. If the firm population is still quite small it might not be able to survive the increased competition. It might be below the unstable state (dotted line in Figure 2) so that a convergence towards the lower stable state results (see Process 3' in Figure 2). If, instead, the firm population has become large enough, the convergence process towards the higher stable state is continued (see Process 3 in Figure 2). Hence, again a critical mass, this time in the form of a large firm population, has to be exceeded. Only if this critical mass is exceeded, a local industrial cluster emerges.

The third stage, if reached by a region, is characterised by a more or less stable firm population on a high level. This stage is entered once the convergence process towards the higher stable state (given $e(t) > e_2$) has increased the firm population above the critical level. Then, the exogenous conditions $e(t)$ might decrease below e_2 without hindering the further convergence towards the stable state with a large firm population. As long as $e(t) > e_1$, all changes in the exogenous conditions cause only small changes in the firm population. Furthermore, all these changes are reversible. This corresponds to the mature stage in the industrial life cycle.

The end of an industrial life cycle is characterised by a decrease in demand. There are two possible developments with respect to the local cluster: Either the firms are able to enter new markets or they lose, at least, part of their market shares. The latter implies that $e(t)$ decreases tremendously for these firm. If the exogenous conditions decrease below e_1 , the higher stable state disappears. This causes a convergence towards the lower stable

state (see Process 4 in Figure 2). The local industrial cluster disappears (see, for example, the development reported in Isaksen 2002).

2.2. DYNAMICS WITHIN LOCAL INDUSTRIAL CLUSTERS

Below the dynamics of the number of firms within regions are studied empirically. To analyse the results, we have to know how different dynamics can be interpreted. The above theory can be used to deduce such knowledge. Therefore, predictions about the dynamics of the firm population within regions are deduced from the theory outlined above.

In the empirical study many different regions are analysed. Above it has been argued that the variable $e(t)$ depends on those local circumstances of the respective region that do not change during the emergence of industrial clusters. Thus, $e(t)$ differs between regions.

As a consequence, the location of the critical values e_1 and e_2 as well as the size of the firm population that corresponds to the stationary states might differ between regions. Furthermore, the actual state of the firm population differs between regions because their histories differ. In order to deduce predictions for the dynamics within regions, the former difference between regions is mainly neglected. It is assumed that most regions are at least similar to such an extent that the actual exogenous conditions fall within the same range, where the possible ranges are defined as $e(t) < e_1$, $e_1 < e(t) < e_2$ and $e(t) > e_2$. In contrast, the actual size of the firm population is allowed to differ between regions without restriction.

Given this assumptions, the dynamics expected in a region can be studied dependent on the actual situation in the region. To this end, the four stages of the evolution of local industrial clusters are examined separately.

2.2.1. FIRST STAGE

It has been argued above that in the first stage the critical value e_2 is exceeded. According to the assumption that the exogenous conditions fall into the same range for nearly all regions, $e > e_2$ holds almost everywhere. $e > e_2$ implies that the number of firms increases if it has not already reached or exceeded the value at the high stable state. It is unlikely that at the beginning of the first stage any region contains a large number of firms. Thus, the number of firms can be expected to increase in nearly all regions.

2.2.2. SECOND STAGE

In the second stage the exogenous conditions decrease so that $e_1 < e(t) < e_2$ is satisfied. Again this is assumed to hold for nearly all regions. Figure 2 shows that the dynamics in such a case depend crucially on the actual situation in the region (see the Processes 3 and 3'). In regions with a number of firms that is below the unstable stationary state this number converges towards the lower stable state. If the number of firms is, instead, above the unstable state, it converges towards the higher stable state. Hence, there are two ranges of the number of firms for which this number increases. These are the range below the lower stable state and the range between the unstable and the higher stable state. If the number of firms is between the lower stable state and the unstable state or above the higher stable state, it can be expected to decrease.

2.2.3. THIRD STAGE

In the third stage the regions are assumed to have approximately reached the stable states. Small fluctuations might occur. After each disturbance the local systems can be expected to converge towards the stable states again. However, the location of the stable states differs between regions. Hence, it is not possible to predict the direction of development in a region on the basis of its actual state. All that can be said about the third stage is that only minor dynamics should occur.

2.2.4. FOURTH STAGE

According to the discussion above, the exogenous conditions fall below e_1 in the fourth stage. This implies that the size of the firm population converges to the lower, and only, stable state. Since the exogenous conditions have been more favourable before, the firm population can be expected to be above the stable state in most regions. Hence, the number of firms will decrease in most regions, except a few regions in which there are actually nearly no firms belonging to the industry under consideration.

3. Empirical data

Two kinds of data are used in the empirical analysis that is conducted here. On the one hand, data on the spatial distribution of firms in Germany is used. On the other hand, the Mannheimer Innovation Panel is used as a source for data on several characteristics of industries.

3.1. SPATIAL FIRM DISTRIBUTION IN GERMANY

The data on the spatial firm distribution, which is used here, has been collected by the *Bundesanstalt für Arbeit*. It contains the number of firms for each 3-digit industry (according to the WZ73-classification[†]) and each of the 440/441[‡] administrative districts ('Landkreise' and 'kreisfreie Städte') in Germany. The data is recorded for the 30th of June 1995, the 30th of June 1997, and the 12th of April 2000.

According to the WZ73-classification, there are 293 3-digit industries. Only 60 of these industries are used in the empirical analysis that is conducted here. The industries are denoted by i ($\in \{1, 2, \dots, N_i\}$, $N_i = 60$). The regional units are the 440/441 administrative districts, which are denoted by r ($\in \{1, 2, \dots, N_r(t)\}$, $N_r(t) = 440, 441$). They are constructed according to administrative and historical aspects. The administrative districts contain two types of regions. On the one hand, there are cities, called 'kreisfreie Städte'. Most large cities, but also some smaller cities, for example Zweibrücken with 35.800 inhabitants, belong to this type. On the other hand, there are districts that contain many municipalities, called 'Landkreise'. Most of these are rural areas, containing only smaller cities, that are defined such that they contain approximately the same number of inhabitants (between

[†] 'WZ73' stands for the classification of industries (*Wirtschaftszweige*) that was established in Germany in 1973 and used by the *Bundesanstalt für Arbeit* until 1996

[‡] One administrative district was split between 1995 and 2000 so that the number of districts changed during the time of observation.

60.000 and 200.000). However, also some middle-sized cities and some agglomeration of cities are assigned to this type of district, which have up to 500.000 inhabitants. The number of firms in each industry i and each district r is denoted by $f(i, r, t)$ at each time t ($t = 1995, 1997, 2000$)[§].

3.2. MANNHEIMER INNOVATION PANEL

Besides the data about the dynamics of the firm population in regions, data on industrial characteristics is necessary for the approach taken here. Statistical offices do not collect such data. However, different studies exist that record certain characteristics of firm for different industries separately. The Mannheim Innovation Panel is such a source for at least quite a number of industrial characteristics. The Mannheim Innovation Panel (MIP) is conducted by the ZEW (*Zentrum für Europäische Wirtschaftsforschung*) in Mannheim on behalf of the German ministry for education and research (BMBF). Around 2500 firms answer a questionnaire each year. The questionnaire mainly focuses on the innovation activities of firms but addresses also a number of related questions. The data that is used here originates from the questionnaires conducted in the years 1993 and 1999. Data from the year 1993 is used for three characteristics that are related to cooperation because only in this year the firms have been asked about their cooperation activities. With respect to the industrial characteristics related to innovations the most recent available data is used, the one from the year 1999.

The Mannheim Innovation Panel classifies firms according to the WZ93 classification[†]. The data about the firm population is based on the WZ73 classification of industries. However, most of the 3-digit industries in the WZ93 classification can also be found on the 3-digit level in the WZ73 classification. The few cases in which an assignment is not possible have been excluded from the analysis below.

In this way the firms questioned in the Mannheim Innovation Panel are assigned to the WZ73 classification. This results in different numbers of firms assigned to each industry. To measure industrial characteristics the average value of each characteristic of all firms assigned to the industry is calculated.

If there is only one firm in an industry the average values are determined by the characteristics of this firm. Such a value is not very reliable. Therefore, all industries in which less than 5 firms are questioned in the Mannheim Innovation Panel are excluded from the following analysis. This exclusion can also be justified by the following argument. Those industries that are represented by a small number of firms in the Mannheim Innovation Panel are also those industries that contain in total a small number of firms in Germany. This causes the study of the spatial dynamics of the industry to be not very reliable. Hence, an exclusion of these industries seems to be adequate.

Furthermore, the study is restricted to manufacturing industries. 60 industries remain

[§] As a unit of firm the classification *Betrieb* by the *Bundesanstalt für Arbeit* is used here. The *Bundesanstalt für Arbeit* assigns a number to each *Betrieb*. They define *Betrieb* according to economic considerations and location. Each *Betrieb* is assigned to an industry. If a firm has several branches in different municipalities, the branches are defined as several *Betriebe*, while production sites in the same municipality are counted only once.

[†] The WZ93 classification (*Wirtschaftszweige 93*) is the official German classification of industries that has been developed in 1993 and is used nowadays in all official statistics.

after excluding all service, mining and agricultural industries, all industries for which the match between the WZ93 and the WZ73 classification causes problems and all industries that are represented by less than 5 firms in the Mannheimer Innovation Panel. All of the 22 2-digit manufacturing industries (according to the WZ93 classification) are represented by at least one 3-digit industry. The 60 industries seem to be an adequate representation of the manufacturing sector in Germany. They represent around 85% of the firms questioned in the Mannheimer Innovation Panel.

The study that is conducted here aims to identify the impact of innovation and cooperation on clustering dynamics. It is often claimed that the importance of local cooperation and the innovative atmosphere in a region are responsible or at least supportive for the emergence of local industrial clusters. The Mannheimer Innovation Panel does not provide data that reflects the importance of local cooperation or the innovativeness in an industry directly. However, measures can be obtained from the Mannheimer Innovation Panel that should be related to these factors. Since the relationship is far from perfect, several measures are used. To approximate the importance of innovations the following 5 measures are used[†]:

PRODCYC: the average duration of the product cycle of the most important product of the firm

PRODINNO: variable that equals one if the firm has conducted product innovations or activities to develop product innovations within the last 3 years and equals zero otherwise

PROCINNO: variable that equals one if the firm has conducted process innovations or activities to develop process innovations within the last 3 years and equals zero otherwise

INNOEXP: share of turnover that is spent on innovation projects and investments related to innovation projects

REVNEW: share of revenues that are obtained through new or significantly improved products

These measures are obtained from the questionnaire that was conducted in 1999. To approximate the importance of local cooperation three measures, which are obtained from the questionnaire in 1993, are used:

COOPCOM: share of cooperation with competitors that occur locally

COOPSUP: share of cooperation with suppliers that occur locally

COOPUNI: share of cooperation with universities that occur locally

4. Analysing the industrial dynamics

In Section 2 some predictions about the dynamics of the number of firms within regions have been deduced from the theoretical modelling of local industrial clusters. To this end, four stages of the evolution of local industrial clusters have been distinguished. In the

[†] The abbreviations used here differ from those given in the data in order to make it more obvious what each of them describes.

first stage the only possible prediction was the increase of the number of firms in nearly all regions. Such a development appears whenever the market situation in an industry improves. Thus, it seems not to be typical for the emergence of local industrial clusters.

In the second stage, the self-augmenting processes lead to the separation of regions into those in which an industrial cluster evolves and those in which no such clusters appear. During this phase the theory predicts a change in the number of firms that depends on the number of firms existing in a region as depicted in Figure 3. In regions with a small number of firms this number will rather increase. Regions that have a somewhat higher number of firms that is nevertheless below a critical value will experience a decreasing number of firms. Above the critical value the number of firms will increase again, while regions with a very high number of firms should experience decreasing numbers of firms. The latter regions should be rare.

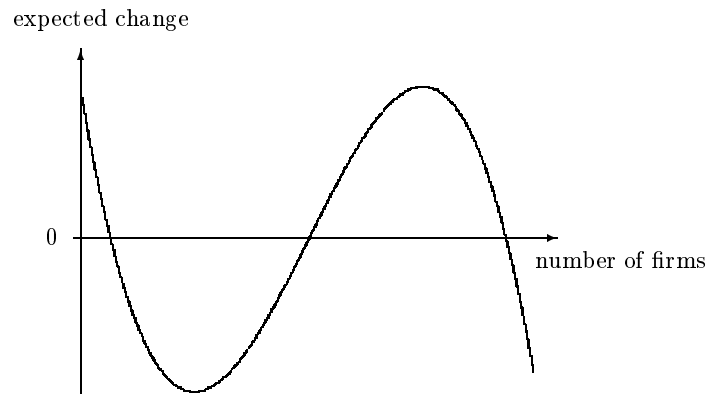


Figure 3: Schematic representation of the theoretically expected change of the number of firms in regions in the second phase of the evolution of local industrial clusters.

The third phase is characterised by a quite stable situation. Only minor fluctuations should occur in this phase. These should be randomly distributed. No structural dependence of changes in the firm population on the number of firms in a region should be observed. The fourth phase has been defined as the disappearance of clusters. This is usually caused by a diminishing of the market for the respective goods. In this case, regions with a large firm population will experience a strong decrease in the number of firms, simply because they contain more firms.

4.1. EMPIRICAL METHOD

To test these predictions, the dependence of the empirical changes in the firm numbers on the actual number of firms is compared with the predictions. The most complex predictions result for the second phase. They are depicted in Figure 3. The simplest mathematical formulation of a function that has the form depicted in Figure 3 is a polynomial of third order. Therefore, a regression analysis is conducted for such a function. The independent

variable is the number of firms $f(r, i, t_0)$ at time t_0 ($t_0 = 1995, 1997$). The dependent variable is the change of the number of firms from time t_0 to time t_1 ($t_1 = 1997, 2000$), given by $f(r, i, t_1) - f(r, i, t_0)$. The regression function is given by

$$f(r, i, t_1) - f(r, i, t_0) = \alpha_0 + \alpha_1 \cdot f(r, i, t_0) + \alpha_2 \cdot f(r, i, t_0)^2 + \alpha_3 \cdot f(r, i, t_0)^3. \quad (4.1)$$

α_0 , α_1 , α_2 and α_3 are the regression parameters. The regression is conducted for each industry i and each pair of times $(t_0, t_1) \in \{(1995, 1997), (1995, 2000), (1997, 2000)\}$ separately. The regression is furthermore done for the relative and the absolute numbers of firms[†]. Hence, altogether there are 6 regressions conducted for each of the 60 industries that are studied.

It is impossible to discuss each regression and its results. Therefore, the results have to be structured in some way. To this end, the theoretical predictions are transformed into predictions about the regression parameters. We are mainly interested in the dynamics that appear during the emergence of local industrial clusters and in the dynamics that appear while local clusters disappear.

Parameter α_0 reflects the average development in the whole industry. If the number of firms in an industry increases (decreases), the value of α_0 will be positive (negative). Hence, α_0 is unimportant for the test of the theoretical predictions about clustering.

In the second phase of the evolution of local clusters, dynamics similar to those depicted in Figure 3 are expected. These, are described by negative values of α_1 and α_3 and a positive value of α_2 . It has been argued above that there might be no region containing a number of firms high enough to be described by the last term in Equation (4.1). In such a case the last term is not necessary to describe the data and α_3 will not significantly differ from zero. Hence, the prediction for the second phase reads as follows: α_1 should be significantly negative, α_2 should be significantly positive, and α_3 should at least not be significantly positive. The same holds if clustering is for some reasons strengthened. Dynamics that are characterised by such regression parameters are called ‘clustering’ dynamics here.

In the fourth phase of the evolution of local industrial clusters the number of firms will decrease in all regions, except of some regions that contain very low numbers of firms. This means that there are forces that tend to equalise the numbers of firms in regions. The phenomenon of clustering disappears. Therefore, we expect that at least one of the parameters α_1 , α_2 and α_3 is significantly negative while none of them is significantly positive. Such dynamics are called ‘equalising’ dynamics here.

As a consequence, three empirical situations can be distinguished:

clustering: If clustering emerges or is strengthened, α_1 should be significantly negative, α_2 should be significantly positive, and α_3 should not be significantly positive.

equalising: If the spatial firm distribution is driven towards a uniform distribution, none of the parameters α_1 , α_2 , and α_3 should be significantly positive, while at least one of them should be significantly negative.

other: If none of the above developments occurs, that means if either the existing local

[†] The relative numbers of firms in a region are obtained by dividing the number of firms by the share of employees that work in this region and by the total number of regions. The relative numbers of firms are used because most of the approaches on local clusters in the literature argue on the basis of such relative economic activity.

clusters are stable or no clusters exist, the regression parameters are expected to satisfy none of the above conditions.

4.2. CLASSIFICATION OF REGRESSION RESULTS

Above it has been stated that this empirical approach is applied to the relative and the absolute numbers of firms separately. It could be expected that they lead to similar results. This is not the case. Sometimes clustering dynamics are obtained for one of the numbers while equalising dynamics are obtained for the other. However, such a situation is rare. A situation in which only for one of the numbers a clear assignment to either ‘clustering’ or ‘equalising’ is obtained frequently.

The same holds for the different periods of times. Often clustering or equalising dynamics can only be found for one or two of the time periods. Often the parameters of the regression have the same signs for the other time periods but are not significantly different from zero. The empirical test that is used here seems to underestimate the existence of clustering and equalising dynamics. Therefore, the results of the six regressions that are conducted for each industry are combined.

The first step is a combination of the two results, for the relative and absolute firm numbers, for the time period 1995-2000. Only if for this period of time no significant results are obtained, the results for the other periods are considered. The dynamics of an industry are classified as ‘clustering’ if at least one result is ‘clustering’ and ‘equalising’ is not obtained as a result, as ‘equalising’ if at least one result is ‘equalising’ and ‘clustering’ is not obtained as a result, and as ‘other’ if both ‘equalising’ and ‘clustering’ are obtained.

If the results for the time period 1995 to 2000 are both classified as ‘other’, the other time periods are considered. The dynamics of an industry are classified as ‘clustering’ if at least one result is ‘clustering’ and ‘equalising’ is not obtained as a result, as ‘equalising’ if at least one result is ‘equalising’ and ‘clustering’ is not obtained as a result, and as ‘other’ in all other cases. By this clustering dynamics are obtained for 16 industries, equalising dynamics for 25 industries and the remaining 19 industries are classified as ‘other’ (the results of this classification for all 3-digit manufacturing industries are listed in Brenner 2002).

5. Analysis

The aim of this analysis is to study whether innovations and local cooperation are related to the emergence of local industrial clusters. If a high number of innovations and strong local cooperation would cause the emergence of local clusters, such clusters should especially emerge in those industries that are characterised by a high innovativeness and a huge amount of local cooperation. This is to be tested here. Above, 5 variables have been defined that reflect the innovativeness of an industry. 3 variables have been chosen to represent the local share of cooperation. In the following analysis it is studied whether high values of these variables coincident with clustering dynamics and whether low values coincident with equalising dynamics.

5.1. METHOD AND DESCRIPTIVE STATISTICS

Two dependent variables are examined. One variable highlights all those industries that show clustering dynamics in the studied period of time. This variable is denoted by CLUST and takes the value 1 for all industries that show clustering dynamics and the value 0 for all other industries. The other dependent variable is denoted by EQUAL and takes the value 1 for all industries that show equalising dynamics. For all other industries the value of the variable, EQUAL, is 0. This means that both dependent variables can only take the values 0 or 1. Therefore, a logistic regression is conducted.

A logistic regression means that it is assumed that it is possible to predict the likelihood of the dependent variables to be one on the basis of the independent variables. Let us denote the independent variables by X_i ($i \in \{1, 2, \dots, 8\}$) and the dependent variables by Y_j ($j \in \{1, 2\}$). Then, the assumed dependence is given by

$$P(Y_j = 1) = \frac{1}{1 + \exp \left[\sum_{i=1}^8 \beta_i \cdot X_i \right]} \quad (5.1)$$

where β_i are the regression coefficients.

Eight independent variables are used: PRODCYC, PRODINNO, PROCINNO, INNOEXP, REVNEW, COOPCOM, COOPSUP, and COOPUNI. Their correlations are given in Table 4 in the appendix. Some of the correlations between the variables that represent the importance of innovations are quite high. This implies that multicollinearity might be a problem. Therefore, the regressions are also run excluding each time one of the variables PRODCYC, PRODINNO, PROCINNO, INNOEXP, and REVNEW. The significant results do not change. Hence, multicollinearity is no problem, so that only the results obtained from the regression that includes all independent variables are presented and discussed here.

The average values and the variances for all independent variables are listed in Table 1. The dependent variables are binary variables. The frequency with which they take the two values '0' and '1' are given in Table 2.

5.2. RESULTS AND DISCUSSION

The results of the logistic regressions are given in Table 3. A comparison of the regression results for the dependent variables CLUST and EQUAL shows that the independent variables that are chosen here are better able to explain the variable CLUST than the variable EQUAL. There are also more significant factors obtained for the regression with CLUST as the dependent variable. Hence, innovation and local cooperation seem to be more important in those industries that show clustering dynamics. The opposite, a lower importance of innovation and local cooperation in industries that show equalising dynamics, is less supported by the results. This implies that innovation and cooperation are involved in the emergence of local industrial clusters, while they are less involved in their disappearance. Furthermore, local clusters do not simply disappear if the conditions that characterise their emergence turn into the opposite.

Therefore, the discussion of the results will focus on the results for the dependent variable CLUST. Three independent variables, namely PROCINNO, COOPSUP and COOPUNI, are found to have a significantly positive impact on the variable, CLUST. This means

variable	average	std. deviation
PRODCYC	10.51	5.57
PRODINNO	0.702	0.179
PROCINNO	0.634	0.175
INNOEXP	0.0532	0.0395
REVNEW	15.42	9.45
COOPCOM	0.040	0.069
COOPSUP	0.150	0.181
COOPUNI	0.020	0.054

Table 1: Descriptive statistics for the independent variables.

variable	frequency of the value	
	'0'	'1'
CLUST	44	16
EQUAL	35	25

Table 2: Descriptive statistics for the dependent variables.

that high values of these variables characterise industries in which clustering dynamics are observed. 'Clustering dynamics' should not be confused with the existence of clusters. The variable CLUST highlights those industries in which clusters are emerging or in which clustering is strengthened in the time between 1995 and 2000.

Hence, we do not study the factors that characterise local clusters here. Instead, factors that appear significantly strongly during the emergence of clusters are studied. This still does not allow us to conclude that the identified factors are responsible for the emergence of local clusters. However, it can be concluded that they are not a consequence of the existence of local clusters. Either they are responsible for the emergence of local clusters or they are caused by or related to the same factors that also cause the emergence of such clusters.

The regression results will be discussed for the innovativeness of industries and the importance of local cooperation separately. Let us start with the innovativeness of industries.

The importance of innovations in an industry is measured by five different variables. Significant results are only obtained for the number of process innovations. A high frequency of process innovations seems to be related to a high probability for clustering dynamics.

independent variable	CLUST		EQUAL	
	parameter	p-value	parameter	p-value
const.	-8.26	0.011	3.30	0.098
PRODCYC	0.036	0.707	0.018	0.788
PRODINNO	-3.78	0.446	2.23	0.498
PROCINNO	12.58	0.010	-8.76	0.006
INNOEXP	0.877	0.954	-13.45	0.209
REVNEW	-0.052	0.476	0.110	0.091
COOPCOM	5.76	0.369	-11.61	0.053
COOPSUP	6.40	0.029	-2.45	0.242
COOPUNI	17.19	0.050	-7.23	0.331
R ²	0.352		0.337	

Table 3: Results for the logistic regressions for the variables CLUST and EQUAL (significant results are given in bold letters).

Hence, a high frequency of process innovations seems to be one possible cause for the emergence of local industrial clusters.

The same seems not to hold for product innovations. No significant results are obtained for the frequency of product innovations, even if the variable related to process innovations is excluded from the analysis. Product and process innovations seem to have different impacts on the emergence of local clusters. This is well in line with the observation that process innovations are especially important during the stage of the industrial life cycle in which local clusters emerge.

Hence, it is not innovations per se that matter for the emergence of local clusters. Only process innovations seem to have a significant impact. This is confirmed by the other regression results. For the total amount of innovation expenditures (INNOEXP), the length of the product life cycle (PRODCYC) and the share of new products among the sales of a firm (REVNEW) also no significant results are found.

Let us now consider the results on local cooperation. Cooperation within a region is very often considered as an important factor in the context of local industrial clusters in the literature. However, the empirical evidence provided is mixed and no proof of this influence is given (a discussion of this can be found, e.g., in Grotz & Braun 1997). It has been found that cooperation with local partners accounts for a large share of all cooperation of a firm (see, e.g., Fritsch 1999). However, this does not prove that local cooperation causes the emergence of local industrial clusters. It rather suggests that the existence of local industrial clusters might increase the amount of cooperation.

Here, evidence for the impact of local cooperation on the emergence of local industrial

clusters is obtained. The variables COOPSUP and COOPUNI measure the share of cooperation with suppliers and universities, respectively, that takes place locally. They both show a significant positive impact on CLUST. Hence, if cooperation takes place mainly locally in an industry, clustering dynamics are more likely to occur.

This holds not for all kinds of cooperation. A positive impact is only found for cooperation with suppliers (COOPSUP) and universities (COOPUNI). No impact is found for cooperation with competitors (COOPCOM). Hence, there is no evidence for the claim that local cooperation among competitors is important for the emergence of local clusters. Such a claim has been repeatedly put forward in the context of the Italian industrial districts (see, e.g., Dei Ottati 1994).

Nevertheless, the study conducted here provides empirical evidence for the fact that those industries in which local cooperation with suppliers and universities plays an important role are more likely to show clustering dynamics. Local cooperation with suppliers and universities seems to be in some way related to the emergence of local clusters.

6. Conclusions

In this paper predictions about the dynamics during the evolution of local industrial clusters are deduced from theoretical consideration. This is done on a general level. Then, it is shown that the predictions are confirmed by the dynamics observed in 3-digit industries in Germany. This shows that a general theory of local industrial clusters can be developed and used, despite the strong difference between industrial clusters that is repeatedly stated in the literature. Furthermore, it shows that industries can be classified according to the dynamics observed.

For around 25% of the manufacturing industries clustering dynamics are observed. This means that in quite a number of industries a tendency towards the existence of local clusters or a strengthening of already present clustering is observed. It is furthermore shown in this paper that these clustering dynamics occur in relation to certain industrial characteristics. Two kinds of industrial characteristics are tested: the innovativeness and the importance of local cooperation. It is shown that those industries with a high number of process innovations are more likely to show clustering dynamics. The same does not hold for product innovations and all other measures of the innovativeness of industries. Hence, clustering seems to be not restricted to high-tech industries but seems to be more likely if process innovations are frequent. Furthermore, it is shown that industries with clustering dynamics show a high share of local cooperation with suppliers and universities. This confirms the claim that local cooperation plays an important role for the emergence of local industrial clusters. The importance of local cooperation among competitors, instead, is not confirmed.

The results show that the phenomenon of local industrial clusters can be approached on a general level. Systematic empirical studies can be conducted on a national level, including many regions, and for all manufacturing industries. Such an approach leads to a more unifying understanding of the phenomenon. This paper provides one step into this direction. Hopefully more steps follow.

7. Appendix

	PROD- CYC	PROD- INNO	PROC- INNO	INNO- EXP	REV- NEW	COOP- COM	COOP- SUP	COOP- UNI
PRODCYC	1	-0.307*	-0.80	-0.145	-0.450**	-0.061	-0.107	-0.042
PRODINNO	-0.307*	1	0.663**	0.338**	0.727**	0.197	-0.099	0.103
PROCINNO	-0.80	0.663**	1	0.285*	0.464**	0.306*	-0.035	0.071
INNOEXP	-0.145	0.338**	0.285*	1	0.335**	-0.082	-0.215	0.012
REVNEW	-0.450**	0.727**	0.464**	0.335	1	0.104	-0.148	0.122
COOPCOM	-0.061	0.197	0.306*	-0.082	0.104	1	0.190	0.070
COOPSUP	-0.107	-0.099	-0.035	-0.215	-0.148	0.190	1	-0.132
COOPUNI	-0.042	0.103	0.071	0.012	0.122	0.070	-0.132	1

Table 4: Pearson correlations between the independent variables (*= correlation is significant on a level of 0.05, **= correlation is significant on a level of 0.01).

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