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Evidence from the German MST-industry

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Evolving localization patterns of company foundations – Evidence from the German MST-industry

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Abstract:

We investigate company foundations in the German micro technology industry by means of a spatial-temporal micro-geographic analysis. In order to deal with our unusual detailed data, we develop a new distance-based framework for a logistic regression that is able to present results in a continuous space. Locations of company foundations are investigated with respect to their spatial proximity to similar firms, patent owner, related industries and research institutions and are benchmarked with the overall distribution of company foundations in Germany. We demonstrate that spatial proximity has a clear influence on where new companies are founded. Furthermore, the influence of proximity to different agents is not constant over times but evolves with the industry's life cycle.

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Keywords: Spatial concentration, localization, clusters, MAUP, distance-based measures

JEL Classifications: C40, M13, R12

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1 Introduction

New technologies and industries are one of the main driving forces of the economy. In the early phase (expansion phase) of their life-cycle, industries often show high growth rates (e.g. Klepper 1996, Audretsch and Feldman 1996) and an increasing tendency towards spatial concentration (Dumais et al. 2002). Furthermore, clusters usually develop on the basis of new technologies or industries (e.g. Brenner 2004). On average, clusters generate employment, economic growth and higher wages in the long run (Porter 1998). Hence, regions benefit greatly from new industries establishing therein.

Therefore, it is of strong interest to understand where new technologies and industries emerge and locate. What are the circumstances that make the appearance of a new industry in a region more or less likely? Unfortunately, we know little about this. Studies of a whole industry including its early development and explaining the spatial distribution in these early times are very rare. An exception is the work by Steve Klepper and co-authors (Klepper 2006 and Klepper and Buenstorf 2009) who analyze the development of a number of industries such as the automobile industry and the tire industry. Most of the literature that discusses the geographic location of industries focuses on one location, e.g. in the context of cluster studies. These studies explain why a specific location was a good place for the industry to establish. Many relevant factors can be identified from this huge amount of literature (see e.g. Brenner und Mühlig 2012).

We apply a different approach here, which adds comprehensive evidence to this literature. The basic idea is in line with the arguments by Klepper (2006): start-ups, including spin-offs and their location are of great importance for the spatial distribution of industries. Therefore, we examine the location of all company foundations of one German industry. In contrast to most of the approaches in the literature, we apply spatial econometrics for studying the factors that make company foundations more likely in one location than in another. This means that we do not examine the motives and origin of each founder but analyze whether company foundations appear especially near to other specific factors that might constitute a source of founders. In addition, we repeat the analysis for a number of time periods in order to study whether the relationships change during the industrial life-cycle.

The analysis is restricted to one industry: the micro technology industry. Micro technology, or microsystems technologies (abbr. MST), is a high-tech industry that combines different microelectronics components in an embedded system in a very small measure. Its fields of application range from automobile up to medical technology. The MST is a young industry that evolved from microelectronics at the end of the eighties. Therefore, it is an adequate subject for studying the factors that influence the location of company foundations. It allows for studying an industry nearly through all its so far existence. Furthermore, it was possible to identify nearly all relevant actors in this industry in Germany and their addresses, enabling the usage of micro geographic data in our analysis.

The collection, evaluation and processing of micro geographic data has attracted an increasing interest from many sides such as the private sector, government agencies and the scientific community. In a recent article, Harvey Miller (2010) even sees an avalanche of spatial-temporal data and calls for new methods to handle this large amount of information. Such data, obtained by "new" sources, such as the internet, GPS systems or RFID-chips, do not only allow insights into new fields of research but also the avoidance of false results and misleading data. As Miller points out, until recent years, science had to match their methods with limited and inaccurate information (Miller 2010: 181). While the availability of micro geographic data is no longer a secret, many researchers do not exploit these possibilities as the "new" data does not fit to the "old" methods.

To use the available micro geographic data in our case, we develop a novel framework for a logistic regression that deals with the exact location of company foundations in relation to the presence of other factors in space without being dependent on any spatial subdivisions such as counties or zip-code regions. Beside the empirical results for the German MST industry, the development of such a framework is the second aim of the paper.

The rest of the paper is structured as follows: Section 2 provides the paper's underlying theoretical framework. Following the structure of our paper, this includes both thematic and methodological aspects. Section 3 discusses related existing statistical methods. In Section 4 we present the data that we use in the empirical part. Section 5 starts with the description of our new distance-based framework for a logistic regression. Its application to company foundations in the German MST-industry, the results and interpretation are presented afterwards. The last section concludes.

2 Theoretical framework

2.1 Spatial patterns of company foundations

Company foundations in high-tech industries do not happen anywhere but are generally highly concentrated. The wide amount of literature on company foundations is doubtlessly due to the fact that this topic is wildly examined from different scientific communities such as economists, geographers or sociologists. Despite the different academic leitmotifs, there is a common sense about the general spatial aspects of company foundations in high-tech industries. In the following, a selection of central theories is briefly discussed, whose topic are related to the question of the paper at hand.

Entrepreneurs' location choices

One central aspect for the location of a company foundation is the spatial proximity to firms of the same industry. Different factors make it more likely that a firm is founded in proximity to existing firms: One aspect are intra-industry knowledge spillovers. It has been shown that the productivity of firms does not only dependent on their own R&D spending, but also on geographically proximate firms of the same industry (e.g. Jaffe et al. 1993). If entrepreneurs want to benefit from those externalities, they might decide to locate close to existing firms. While this approach somehow implies that an entrepreneur chooses his location by comparing different opportunities, many researchers argue that the location of a firm is not the result of choices but is mainly driven by the entrepreneur's existing social network. Often, new entrepreneurs have worked in other firms of the same industry where they got insight into technology and market opportunities and then found their own company close to their previous employer where they can benefit from their existing relationships (Stuart and Sorenson 2003: 231). Schmude has shown that 71.9 % of German start-ups are located in the founders' municipality (Schmude 2003: 295). The data that we use in this paper does not allow for a distinction between the multiple influences of firms in the same industry, but generally it is plausible to assume that spatial proximity to existing MST-firms positively influences the founding of a new MST-firm.

Not only firms of the same industry, but also the presence of related industries may be important for a high regional funding activity. This is particularly true for young industries when the level of standardization is low and innovation depends on combining knowledge across industries (Neffke et al. 2008: 4). Furthermore, firms in related industries often serve as suppliers (Stuart and Sorenson 2003: 231). As a proxy for the presence of related industries, we include the number of skilled workers in different industries into our investigation.

As it has been argued above, the local innovation capacity is an important aspect for high-tech firms. Beside the spillover between firms, universities are seen as the central driver of innovation. Especially young high-tech industries tend to cluster around research institutions and universities due to local spillover of tacit knowledge (e.g. Audretsch et al. 2005). Following Caniëls (2000), universities tend to distribute their knowledge more openly than companies. Besides supporting companies with knowledge spillover, research institutions are often themselves the source of new firms. Analogous to company spinoffs, academic spinoffs are often located closely to the entrepreneur's prior place of work. According to a survey of the German Ministry of Education and Research, one third of all academic spinoffs are located at a 10 km distance from their incubator's place (BMBF 2002: 42). In a 2006 survey conducted by IVAM, an international association of companies and institutes in the field of micro technology, the access to research institutions was ranked the most important fact for the location choice of a start-up firm (IVAM-Research 2006: 1). Thus we argue that spatial proximity to relevant research institutions should have a positive influence on company foundations in the German MST industry.

Beside the presence of research institutions, the proximity to innovative persons (normally measured by patent applications) is also often used as a proxy for the local innovation capacity. Acs et.al (2002) show, that patent data give a reliable measure of innovative activity for the US metropolitan statistical areas. Again, the proximity to patent owners might influence the founding activity in two ways: Firstly, a patent owner might start up his own company, whose location, as argued above, should be close to the owner's current residence. Secondly, firms might locate closely to patent owners to profit from local knowledge spillover.

Temporal dynamics of location choices

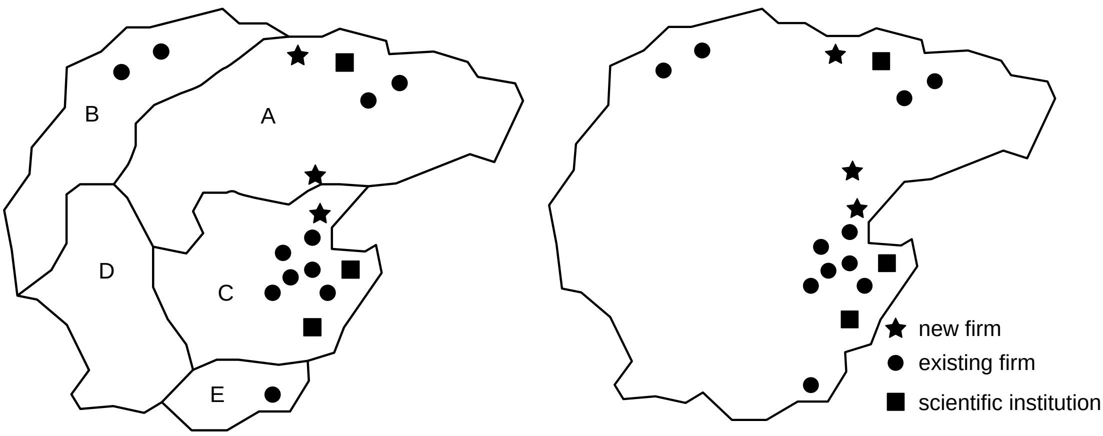
So far, we have argued that spatial proximity to other firms of the same industry, research institutions, patent owners and skilled works has a general positive influence on company foundations. While this holds true for nearly all high-tech industries it is reasonable to assume that the importance of these factors is not constant over time but depends on the stage of the industry's life cycle. The industry life cycle theory (Gort and Klepper 1982, Klepper 1996, Audretsch and Feldman 1996) examines an industry with respect to temporal change of industry specific factors such as innovation patterns, firm growth, entry and shakeout.

In the early phase, a new industry emerges through radical innovation. The entry rate is high and new firms are often diversifying entrants of existing industries (Klepper 2006: 152).Tacit knowledge plays an important role and firms concentrate on rapid product innovations (Audretsch and Feldman 1996: 259). As the industry is characterized by missing standardization, innovation input comes from different sources; especially the influence of producers outside of the industry is important during the early stage (Gort and Klepper 1982: 632). Neffke et al. (2008) have shown that industries in the early stage depend more on spillover from other industries than in later stages. Both, the high ratio of diversifying entrants and the importance of inter-industry spillover suggest that the proximity to firms in related industries should have a higher influence on company foundations in the MST industry during the early stage. Missing technical standardization and a high demand for research and innovation make it also more likely that universities and research institutions have a higher influence during the early phase (Audretsch and Feldman 1996: 269).

In the following stages (mature and declining stage), the industry becomes more self-contained both with respect to their technological design and their spatial concentration. A higher rate of standardization leads to similar products, sharp drop in prices and a focus towards process driven innovation (Neffke et al. 2008: 7). Innovation requires very specialized, industry specific knowledge, skills and machinery so that intra-industry spillover processes become more important. Following the higher rate of standardization, implicit knowledge replaces tacit knowledge as the decisive force of knowledge spillover (Audretsch and Feldman 1996: 270). Through spinoff process, early cluster of leading firms can lead to an extraordinary agglomeration in an industry (Klepper 2006: 153). Brenner (2004) sees the existence of a tipping point where clusters create self-augmenting processes that attract more and more firms. Hence, the presence of the industry itself in a region should become more and more decisive for the location of foundations in the industry with time.

To sum it up, we want to investigate whether the proximity to observed agents (MST-firms, research institutions, patent owners and skilled works) changes over time. The existing literature suggests that the proximity to research institutions and other industries plays a key role in the early phase while the proximity to other MST-firms becomes more important during the later stages.

2.2 Spatial statistics and the MAUP



(a) standard aggregated approach (b) none-aggregated approach

Figure 1: Two concepts of measuring spatial economic activity

As mentioned in the introduction, the second aim of our paper is the presentation of a logistic regression model that is able to deal with micro geographic data. Hereby, we cannot only exploit our unusual detailed data but also circumvent the Modifiable Areal Unit Problem, a well-known problem in spatial econometrics. The MAUP states that results of statistics that use spatial aggregated data always depend on the chosen level of aggregation[1]. Nearly all popular spatial economic indices such as the Elison-Glaeser-, or the Gini-index are affected by this problem.

To give an example for the MAUP, we will discuss a wildly investigated question in spatial econometrics, whether company foundations can be explained by the spatial proximity to similar firms and relevant scientific institutions.

Consider a country that exists of five regions *A*-*E* (see Figure 1). A common approach would be to look at which spatial subunits new firms are founded and how these subunits

[1] For a detailed analysis of the MAUP see Openshaw, S. (1984)

are characterized by the observed agents. For example, region A shows two new firms and is characterized by three existing firms and one scientific institution. By comparing the different regions one can quantify the importance of existing firms and scientific institutions for a company foundation through a spatial regression model:

$$New\ firms = \beta_0 + \rho W\ New\ firms + \beta_1 exisiting\ firms + \beta_2 scientific\ institution + \varepsilon \qquad (1)$$

where $\beta_{1,2}$ represent the strength of the parameters on the outcome of a company foundation and ε is error term. The spatial autoregressive coefficient ρ indicates the impact of company foundations in neighboring regions whose individual influence is determined by the spatial weights matrix W.

Using a spatial regression model, spatial dependencies can be included as it is reasonable to assume that company foundations cannot only be explained by the properties of a firm's region but also by the founding activity of surrounding regions. Nonetheless, results still depend on regions instead of real locations. Normally these regions do not concern the economic structure of the area under investigation but depend on administrative classifications that provide the data for the analysis. The arbitrariness of boundary lines is referred to as the zoning-problem of the MAUP. The scale problem is the result of a possible variation in the spatial aggregation level, once a boundary line has been chosen. For example, if regions *A-E* stand for a county, one might change the aggregation level to zip-codes, that lie inside the counties.

There are only few papers and even less models that deal with the investigation of economic activity without the MAUP. To our knowledge merely two different groups of MAUP-free methods exist: The first group is represented by the Geographical Weighted Regression (GWR) that is able to check for local differences in parameter estimations without an a priori specified spatial subdivision. The other methods belong to the group of distance-based test statistics[2] that check whether firms are located more concentrated or disperse to each other in space. Representatives are, for instance, the DO-index by Duranton and Overman (2005), the M-function by Marcon and Puech (2010) or the cluster-index by Scholl and Brenner (2012).

In order to avoid the shortcomings of the MAUP, the operational unit has to be shifted from regions to real geographical distances, which is the core concept of all distance-based methods. However, despite methodological progress and the increasing availability of spatial data, there is a natural limit of circumventing the MAUP for some research topics. Consider that one would also be interested in how the number of qualified labor influences the founding of firms. An absolute MAUP-free answer to this question would be to look at each spe-

[2] By the term "test-statistics" we refer to statistical methods that are in first line index based tests (by instance Student`s t-test).

cific spatial position of a worker, e.g. his home-address. There are two points that limit this approach: On the one hand, such detailed information about private persons is often not available and its collection is controlled by strict laws in most countries. On the other hand, the methodological approach for such spatial data is different. In comparison to firms or research institutions, workers are not fixed in space as they normally do not work at home but commute. Hence, there is no exact spatial position of workers but they are characterized by spatial fuzziness. In the empirical section we show how we deal with that problem.

Considering the number of publications, MAUP free methods have not attracted much interest in spatial econometrics. In his recent review “Thirty years of spatial econometrics” Luc Anselin even excludes work that “does not take an explicit regression approach”, such as test statistics (Anselin 2010:4). The author also mentions that the GWR has rarely been used in economic research (Anselin 2010:14). If MAUP free methods provide a more accurate investigation and if more and more micro spatial data is available then why are they used so rarely? Here, we see a lack of matching the methods to the needs of spatial econometric analysis. As test-statistical methods normally only allow the observance of one outcome, they cannot be used for multivariate analyses that are standard in econometrics. While the GWR is able to handle multiple variables, its core concept is to check for local deviations in parameter estimations and is therefore a local model while the majority of econometric research focuses on global outcomes. The framework for a logistic regression that we present here is able to fill this methodological gap as it is distance-based, allows the observation of multiple variables and gives results for global models.

3 Existing distance based methods

In this section, we will present different distance-based approaches in spatial econometrics that are related to our new approach but show some properties that impair their usage for the question of our paper. Though the Geographic Weighted Regression also allows a MAUP free investigation, we will not consider it here, due to the yet mentioned fact that the GWR is a local model. If n agents are observed, the GWR presents n different parameter estimations. In comparison to the GWR, our new approach is a global model that performs a single parameter estimation for the whole area under investigation. Thus, we will only compare our method to other global models.

3.1 Distance based test-statistics

In contrast to regression models, distance based test-statistics focus on significance levels instead of parameter estimations. As mentioned in section 1, there exist several MAUP-free test-statistics. Though the metrics differ in their mathematical models they all base on the same structure. Here, we will discuss the index by Duranton and Overman (2005) that is one of the most established metrics for MAUP-free investigations of economic activity. The idea

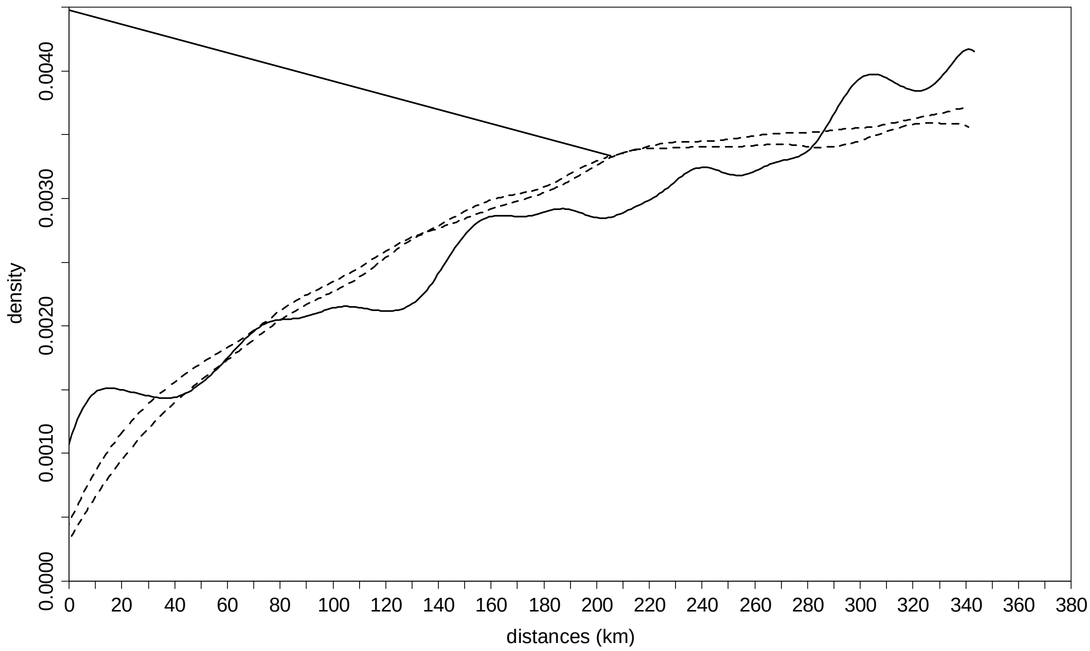


Figure 2: *K*-density for the German MST industry.

of the D&O-index is to check whether the number of neighborhoods at a specific distance

between firms is significantly higher or lower than expected by random. To this end, a smoothed density over all neighborhoods, expressed by the term *K(d)*, is used. The first step to compute *K(d)*-values is to build the geographical distances between all possible pairs of firms so that one gains $N(N\text{-}1)/2$ unique bilateral distances. In the next step, one counts the number of firm pairs that have a certain distance. The last step is smoothing the observed numbers using a Gaussian kernel function. The solid line in Figure 2 plots the *K(d)*-values for the German MST-industry. The dashed lines refer to the confidence intervals that are built by a bootstrapping approach (Duranton & Overman 2005:1086). Figure 2 shows that the German MST-industry has significantly more neighborhoods for the distances of 0-30 km and 290-360 km. This suggests that there are several clusters that are located at larger distance to each other.

Although distance-based test-statistics show a lot of interesting features, their fields of application are quite narrow. Until now, the methods only allow the testing for differences in the (co-) localization pattern of firms and industries, but combining several aspects in one research design is difficult (Duranton & Overman 2005:1079). Furthermore, the indices can only deal with distances between firms but, for instance, characteristics explained by dummy-variables cannot be included.

3.2 Klier & McMillen's approach

Before we will present our new approach we will discuss the paper of Klier & McMillen (2008) since their method is the closest to ours as far as we know from the existing literature. In their study about the U.S. auto-supplier industry Klier & McMillen investigate whether the location choice of new firms in the timeframe of 1991-2003 can be explained by a logistic regression. As explanatory variables they use the distance to the closest assembler, the number of other existing suppliers[3] within a radius of 100 miles, the distance to Detroit and the presence of an Interstate highway in the zip-code of the firm. Furthermore, they consider social statistic variables drawn from the 1990 U.S. Census such as the population density, the proportion of white population or the proportion of employees who work in manufacturing jobs at a zip-code level (Klier & McMillen 2008: 253).

The dependent variable of a logistic regression can only take the value one (condition fulfilled) or zero (condition not fulfilled) and both cases are mandatory for the parameter estimation (see section 5.1). The zero value can also been seen as the null hypothesis or as a benchmark. In their investigation, Klier & McMillen define the null hypothesis as five randomly drawn zip-codes that represent a hypothetical company site. On the other hand, the value one stands for the spatial position of a zip code where a new auto-supplier was founded.

The yet mentioned points show that the paper of Klier & McMillen deals with similar aspects as the paper at hand: The authors investigate the founding of firms from a micro-geographic perspective by means of a logistic regression. Furthermore their approach has a time component as they divide the population of supplier firms into two groups, depending on whether the firm was founded before or after 1991. Similar to our approach, Klier & McMillen investigate, whether company foundations occur close to different agents using geographical coordinates and distances instead of regions. Hence, their paper builds the starting point for our approach. However, we will go beyond their approach in three aspects:

MAUP

Although Klier & McMillen use geographic coordinates to locate their firms, their approach is still affected by MAUP effects. On the one hand, even in conurbations, US zip-code areas show a diameter of approximately 20 km. On the other hand, information on the independent variables is aggregated at an arbitrarily defined level. For instance, the authors model the distance to other suppliers by counting the number of firms within a radius of 100 miles. In contrast, our approach considers each single distance between the observed agents separately allowing for a clear reduction of MAUP.

Random benchmarks

[3] firms founded before 1991

The construction of benchmarks is an important step for a logistic analysis because its results are very sensitive to a chosen benchmark. Klier & McMillen create their benchmark by drawing five random zip-codes for each company foundation. However, Duranton & Overman (2005) argue that a purely stochastic pattern should not be used for a benchmark, as industries cannot settle anywhere in a country. It is obvious that natural barriers (lakes, rivers, mountains) or political restriction (nature reserves, residential areas) limit the location choice of entrepreneurs (Duranton & Overman 2005:1085). Therefore, we will build random samples of real company locations and use them as a benchmark.

Temporal aggregation

The last point refers to the temporal aspect in Klier & McMillen's paper. As noted above, the authors divide their period of investigation into two timeframes: One timeframe for the period before 1990 and one for the period of 1991-2003. Thereby the authors gain two explanatory variables: Firstly, firms that were founded before 1991. Secondly, social statistic data, drawn from the 1990 U.S. census that can be seen as exogenous variables as the starting point of their investigation is 1 year after the census (Klier & McMillen 2008: 251). Hence, in their approach all that happens after 1990 is explained by all that was there in 1990. As the title of the paper suggests, we go beyond this and explain the location of each company foundation by all factors that have been present at the date (at least month or year) of this foundation.

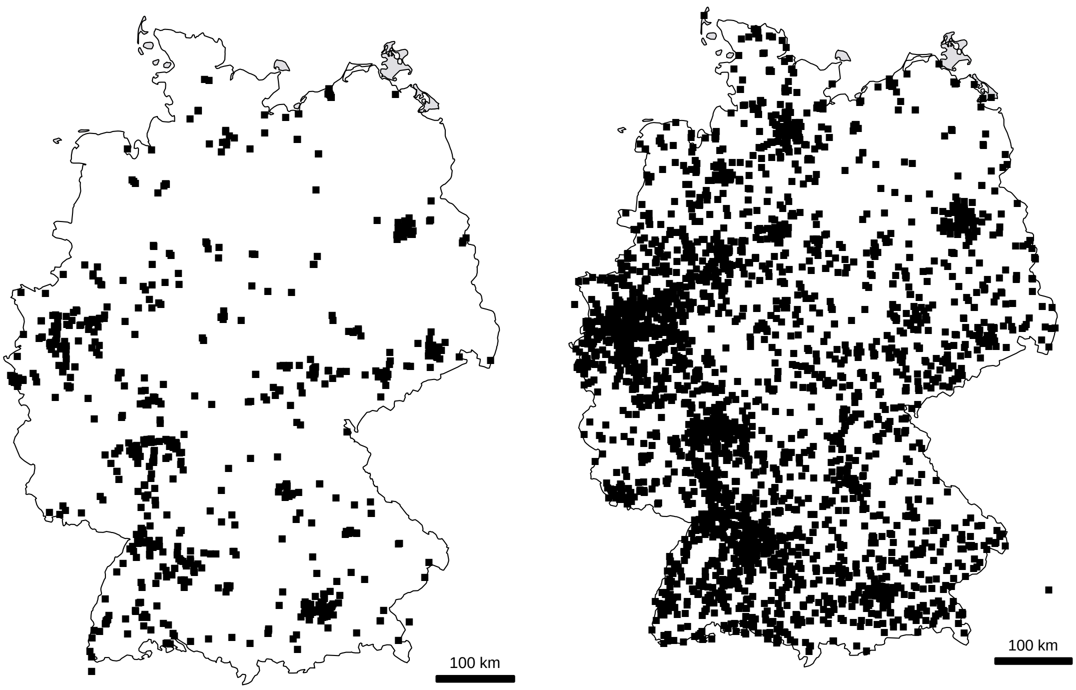
4 Data

The central part of our dataset is built by the exact location (street, house number and postcode) of all German MST-firms and research institutions. It was provided by the German-based IVAM, an international association of companies and institutes in the field of micro technology. The dataset included around 873 firms and 212 institutions that fulfill at least one or more of the following prerequisites:

- (former) members of the IVAM or another associations in the field of micro technology
- firms that are listed in specific databases (e.g. www.mst-online.de)
- participants of fairs or conferences that deal with micro technology
- participants of public/federal projects covering micro technology
- firms that are mentioned in trade journals
- firms that are listed in the German Commercial Registry under the headword "micro"

For all firms and institutions the IVAM checked via the company's homepage whether they are really active in the MST-sector. Additionally, we double-checked the data with the

Germen Commercial Registry, in order to obtain the date of inception and to check whether firms still exist or have relocated. If they relocated during the period of 1999 and 2007 we included this change in our model. Finally, 861 MST-firms and 199 institutions were in-



(a) MST-firms (N=861) (b) benchmark-firms (N=4000)

Figure 3: Distribution of the MST-firms and the benchmark-firms in the area under investigation

cluded in the statistical analysis. We computed the easting and northing of the firms' and institutions' exact location (street, house number and postcode) whereby we gain data that is absolutely free of any spatial aggregation.

The patent data included all 3886 MST applications for the period of 1991 and 2008, provided by the Federal Ministry of Education and Science (BMBF). For every patent, the date of submission and the zip-code of the owner were given. We computed the easting and northing of all German zip-codes and assigned the coordinates to the patents.

As described in section 2.1, we consider the number of skilled workers to represent the proximity to related industries. Together with the IVAM, we selected the most convincing branches out of the WZ2003 classification, provided by the German federal office of statistics:

- Production of electronic devices
- Production of medical devices and orthopedic appliances

- Production of measuring, check and navigation instruments

The data was available on a municipality level for the time period of 1998-2009. The 15,648 municipalities are the lowest aggregation level for Germany (average size 25.5 km^2). Analog to the zip codes we computed their centroid's easting and northing. The availability of employment data was the temporal limiting factor of our analysis. Thus we present results for company foundations in the MST only for the time period of 1998-2009 (383 firms).

The construction of our benchmark was conducted as follows: For each investigated year, we draw 1000 German manufacturing firms from the list of all manufacturing firms in the Creditreforms' MARKUS database (most comprehensive database on German firms) that were founded in the respective year. Analogous to the MST-firms, we computed the easting and northing of the firms' exact location.

5 A spatial-temporal investigation of company foundations

After having presented our data, we can now take a closer look how to handle this large amount of information. As the main part of our data is free of any spatial aggregation, we cannot use standard spatial regression models that always require the comparison of regions. Instead, we compare locations of company foundations in the MST industry with places of foundations in other industries. The following section discusses in all details how this approach can be implemented. After this step, section 5.2 presents the empirical results for the MST industry using our new distance based framework.

5.1 Methodological approach

Spatial approach

The mathematical concept of our new framework bases on building sums of inverted distances, as it has been proposed in Sorenson & Audia (2000), Stuart and Sorenson (2003) and Scholl and Brenner (2012). For each firm, we compute cluster values, which are built by the average inverted distances of a firm *i* to other agents in the area under investigation:

$$D_i = \frac{1}{J-1} \sum_{j=1, j \neq i}^{J} \left(d_{i,j}\right)^{-1}, \qquad (2)$$

where $\left(d_{i,j}\right)$ stands for the orthodromic distance in km from firm *i* to agent *j*. Obviously, the sum on the right-hand side increases with the number of observations *J*. Therefore, an average is established to make values comparable. Because the term $\frac{1}{J-1}$ makes the index independent of the number of observations, we can include several cluster indices in one model (e.g. the centrality to other firms or research institutions).

As an example, consider the new MST firm *A*, three existing MST-firms *B*-*D* and two research institutions *R1* and *R2* (see *Figure* 4). According to formula (2), the cluster value of firm *A* to other firms is:

$$\frac{1}{3} \cdot \left(\frac{1}{5km} + \frac{1}{21km} + \frac{1}{55km}\right) = 0.088 \left[\frac{1}{km}\right], \tag{3}$$

while the cluster value to research institutions is 0.096 $\left[\frac{1}{km}\right]$.

Using inverted distances ensures that only close objects have a significant influence on a firm's cluster value as the inverted distance to remote agents converges to zero. However, inverting distances lead to problems when very short distances occur. Consider a firm *E* located in the same building as firm *A*. Then the foundation of *A* would mainly be explained by the distance to *E* as their inverted distance $(d_{i,j})^{-1}$ to each other is infinite. In order to deal adequately with small distances, we need a threshold that groups such values. In our empirical work, we tested three thresholds[4] from which the 5km threshold performed best. We suggest that the choice of the threshold should always depend on the object of research. In our example, a 5 km threshold is a reasonable choice because the costs and ability for communication and interaction between the observed actors should not differ that much between 0 and 5 km. Furthermore, the same threshold was used by Kosfeld et al. (2011) in a similar distanced-based investigation (Kosfeld et al. 2011: 320).

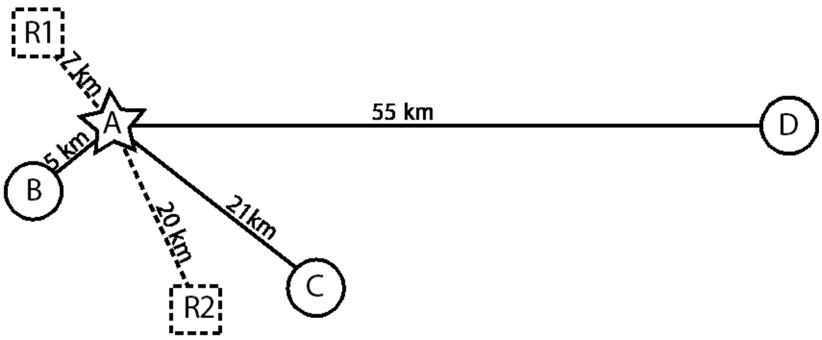


Figure 4: Exemplary distribution of firms and research institutions

Temporal approach

A temporal component is included in the model in such way that the founding of a firm *i* in period *t*+1 is only described by the distance to other firms that at least exist since period *t*. In mathematical terms we use a Markov chain because we only regard a system's actual

[4] We tested a 0 km, 5 km and 10 km threshold

state but neglect its path to this state. Including both, the temporal aspect and the threshold, formula (2) turns to:

$$FIRM_i = \frac{1}{J_t - 1} \sum_{j_t=1, j_t \neq i}^{J_t} \frac{1}{\max\{5km, d_{i,j}\}}, \tag{4}$$

where $FIRM_i$ is an interval scaled variable of the geographic proximity of a new founded firm *i* to yet existing MST firms J_t. The same computation is used for the proximity to research institutions K_t (denoted by the regressor RESEARCH) and to owners of patents L_t (denoted by the regressor PATENT).

Logistic regression model

Now, we may discuss how to include theses regressors into a regression model. Note, that there are two striking differences between our distance-based approach and the spatial regression model in section 2.1: Firstly, spatial dependence is not modeled by concerning additional weighted parameters, but the variables FIRM, RESEARCH and PATENT are themselves genuine representatives of spatial proximity. Secondly, the form of the dependent variable is different. In equation (1), the dependent variable stands for the observed number of company foundations per region; however, in our model the dependent variable is the geographical coordinate of a new MST firm *i* that is free of any spatial aggregation. A solution to this problem is the usage of a logistic regression: Here, the dependent variable can only be 1 (condition fulfilled) or 0 (condition not fulfilled). In our model, the first case represents the spatial position of a company foundation in the MST industry, while the latter case represents a company foundation in other manufacturing industries. Including FIRM, RESEARCH and PATENT into a logistic regression, our regression model has the form:

$$\begin{aligned} log\left(\frac{\pi_i}{1-\pi_i}\right) &= \beta_0 + x_1 \frac{1}{J_t - 1} \sum_{j_t=1}^{J_t} \left(d_{i,jt}\right)^{-1} + x_2 \frac{1}{K_t - 1} \sum_{k_t=1}^{K_t} \left(d_{i,k_t}\right)^{-1} \\ &+ x_3 \frac{1}{L_t - 1} \sum_{l_t=1}^{L_t} \left(d_{i,l_t}\right)^{-1}; \quad d_{i,(j,k,l)_t} = \max\{5km, d_{i,(j,k,l)_t}\}, \end{aligned} \tag{5}$$

where the dependent variable represents the chance that a company foundation in the MST industry occurs at time *t+1* at any place in Germany.

Proximity to related industries

In order to investigate the relevance of the proximity to related industries, the availability of skilled workers in three related industries at the place of the founding is included. As discussed in section 2.2, this computation is slightly different from the approach above for two reasons: Firstly, data on workers is only available on the level of municipalities. Secondly, workers have, at least, two locations: their work and their living place. Hence, they are not fixed to one location in space. We account for this fact by distributing them in space according to commuting distances. Form the German micro census 2004 we obtained the commuting probabilities of German employees in km and computed the best fitting commuting function:

$$f(x) = 0.629 * \left(\frac{2}{e^{0.066x+0.377} - 0.2}\right). \quad (6)$$

By means of formula (6), a proxy for the hypothetical number of available skilled workers at the municipality of firm *i* at time *t* is computed. As an example, consider municipality *M* that has 100 skilled workers. Municipality *N* has 45 workers and is located at a10 km distance from *M*. Hence, the number of available workers for firm *i* located in municipality *M* is:

$$WORK_i = f(0) \cdot 100 + f(10) \cdot 45 = 100 + 21.6 = 121.6 \quad (7)$$

In comparison to Klier & McMillen's approach we do not only consider the municipality of a firm's location but all 15648 German municipalities are included to compute $WORK_i$. This allows a clear reduction of the MAUP but in contrast to the other variables, $WORK_i$ is still a spatially aggregated variable and depends to the size of the municipality and its' location. For example values for municipalities close to borders are systematically underestimated. To deal with this problem, we normalize the value through dividing it by the summed proximity values to all municipalities given by function *f*. This value depends highly on the number of close municipalities. Thus, the final formulation for the hypothetical number of available skilled workers at the municipality *i* is:

$$WORK_{i,t}^{CL} = \sum_{j=1}^{J} \frac{WORK_{j,t}^{CL} * f(d_{i,j})}{\sum_j^J f(d_{i,j})}, \quad (8)$$

where *CL* stands for the three considered industries. Hence, we compute three variables for the related industries ELEC (Production of electronic devices), MED (Production of medical devices and orthopedic appliances) and NAVI (Production of measuring, check and navigation instruments).

East-west dummy and complete model

The last aspect of the regression model is the dummy variable *EAST* that tests for the location of a firm in Eastern Germany. This variable controls for the still existing notable differences in the economic structures between the former Federal Republic of Germany and the former German Democratic Republic. Including all presented variables, formula (9) describes the probability of a company foundation in the MST industry at the time period *t+1* by the spatial proximity to firms, research institutions and patent owners, the presence of three other industries and its location in Eastern or Western Germany.

$$log\left(\frac{\pi_i}{1-\pi_i}\right) = \beta_0 + x_1\frac{1}{J_t-1}\sum_{j_t=1}^{J_t}\left(d_{i,jt}\right)^{-1} + x_2\frac{1}{K_t-1}\sum_{k_t=1}^{K_t}\left(d_{i,k_t}\right)^{-1} + x_3\frac{1}{L_t-1}\sum_{l_t=1}^{L_t}\left(d_{i,l_t}\right)^{-1}$$
$$+x_4 WORK_{i,t}^{ELEC} + x_5 WORK_{i,t}^{MED} + x_6 WORK_{i,t}^{NAVI} + x_7\ EAST \quad (9)$$
$$d_{i,(j,k,l)_t} = \max\{5km, d_{i,(j,k,l)_t}\}.$$

Benchmarking with the overall founding activity

In order to estimate the regressors of a logistic regression, the observance of both possible cases (condition fulfilled, condition not fulfilled) is mandatory. Thus, we need to compute formula (9) also for the benchmark firms. For each observed year,1000 manufacturing firms that were founded in the same year are selected from the MARKUS-database. For the whole time period these are 12,000 firms. This procedure concerns possible global temporal shifts in the spatial pattern of company foundations in the German manufacturing sector.

Note, that in a logistic regression, the parameters represent the factor of how the chances multiply if the independent variable grows by one (expressed by the *odds-ratio*). Here we have to consider that with exception of EAST all variables are interval-scaled and base on different value ranges. In order to obtain a better comparability, their coefficients were normalized.

Variable	Description
FIRM	Cluster index to other MST firms.
RESEARCH	Cluster index to relevant research institutions.
PATENT	Cluster index to patent owners.
EAST	Localization of a firm in Eastern Germany (dummy variable).
ELEC	Number of hypothetical available skilled workers from the production of electronic devices.
MED	Number of hypothetical available skilled workers from the production of medical devices and orthopedic appliances.
NAVI	Number of hypothetical available skilled workers from the production of measuring, check and navigation instruments.

Table 1: Listing of included variables

5.2 Empirical results for the German MST-industry

The main aim of this paper is to study the local factors that influence the founding of new MST firms. We conduct the study for the MST-industry here, while other industries might be studied in a similar way in the future. The examination of the MST-industry is divided into two parts: first the MST-industry is studied for the time period of 1998 to 2009; then three successive time periods (1998-2001, 2002-2005 and 2006-2009) are studied separately in order to analyze changes in the relevance of the various factors.

The analysis of the whole time period, 1998-2009, shows that three local factors influence the start-up activity in the MST-industry positively (see Table 2): the proximity to existing firms (FIRM), the proximity to public research (RESEARCH) and the number of employees in the surrounding who work in the industry of measuring, control and navigation instruments (NAVI).

Variable	Estimate	Odds ratio	Sig.	R^2
FIRM	**.502*** **	1.651	.000	.142
RESEARCH	**.464*** **	1.590	.000	
PATENT	-.021	.979	.690	
EAST	.182	1.200	.436	
ELEC	.166	1.180	.409	
MED	**-.699*** **	.497	.000	
NAVI	**.321* **	1.378	.037	
Constant	**-6.167*** **	.002	.000	

Table 2: Regression results for the total time period 1998-2009 (normalized values).

The proximity to existing MST firms and relevant scientific institutions has the highest positive influence on the chance that a MST firm is founded. This confirms our central theoretical expectation that most founders of MST firms originate from existing MST firms or from scientific institutions and found their own company in proximity to their previous working place. A comparison of the odds ratios suggests that both factors, existing MST firms and scientific institutions play a similar role.

Surprisingly, the distance to workers in the field of MED (Production of medical devices and orthopedic appliances) shows a highly significant negative relationship with the start-up activity. We conclude from this that firms producing medical devices and orthopedic appliances are no relevant source for founders of MST firms. Beyond this, places with many such firms even seem to have characteristics that cause a lower start-up activity in the MST industry. A potential explanation is the fact that the production of medical devices and orthopedic appliances is quite concentrated in Germany in a few less central places, such as Tuttlingen and Jena.

Considering all other industries that we included in the analysis (ELEC, MED and NAVI), we obtain a clear picture: Only the presence of industry NAVI (measuring, control and navigation instruments) has a positive relationship with the start-up activity in the MST industry. Furthermore, this relationship is less significant and has a lower odds ratio than the relationships of the variables FIRM and RESEARCH. From a geographic perspective the MST industry seems not to develop out of an already existing industry. However, the industry NAVI seems to have, at least, some influence on the location of the MST industry.

Interestingly, we do not find a significant relationship between the local patent activity in

MST and the respective start-up activity. Locations that are characterized by a high patent activity do not show higher numbers of company foundations. From a geographic perspective, the generation of innovations that are patented seems not to be a prerequisite for founding companies in the MST industry.

The dummy variable EAST (a firm is located in the newly-formed German states) has no significant relationship to company foundation. Hence, there seems to be no clear difference in the MST start-up activity between the old and new German states.

5.3 Temporal changes in the relevance of local factors

Until now, we have conduced one regression for the whole period of investigation. In order to study the impact of the industrial life-cycle on the relevance of the various local factors, we separate the period into three subintervals and perform separate regressions for each interval (Table 3).

Time period	Variable	Regressor	Odds ratio	Sig.	R^2
1998-2001	FIRM	**.465*** **	1.591	.000	.173
	RESEARCH	**.525*** **	1.691	.000	
	PATENT	.100	1.106	.261	
	EAST	.400	1.491	.062	
	ELEC	**.216** **	1.242	.001	
	MED	**-.425* **	.653	.022	
	NAVI	.111	1.117	.529	
	Constant	**-6.142*** **	.002	.000	
2002-2005	FIRM	**.488*** **	1.629	.000	.142
	RESEARCH	**.459*** **	1.582	.000	
	PATENT	.038	1.038	.690	
	EAST	.171	1.187	.436	
	ELEC	.067	1.069	.409	
	MED	**-.692*** **	.501	.000	
	NAVI	**.337* **	1.400	.037	
	Constant	**-5.909*** **	.003	.000	
2006-2009	FIRM	**.752*** **	2.122	.000	.153
	RESEARCH	**.482*** **	1.619	.000	
	PATENT	-.144	.866	.348	
	EAST	-.944	.389	.059	
	ELEC	.090	1.094	.536	
	MED	**-1.035** **	.355	.002	
	NAVI	.288	1.334	.213	
	Constant	**-7.305*** **	.001	.000	

Table 3: Regression results for the three time periods (normalized values).

FIRM and RESEARCH have the highest positive influence on company foundation in all three periods. Hence, their influence is dominant and permanent. However, while the impact of RESEARCH slightly decreases, the importance of proximity to other MST firms (expressed by the odds ratio for variable FIRM) grows constantly. This confirms the expectations that are formulated at the end of section 2.1. The more the MST industry is established, the more the locations of new firms in this industry are determined by the locations of the firms that already exist. This implies self-augmenting processes in company foundation that are in line with the arguments on cluster formation by Klepper (2006) and Brenner (2004). It also supports the idea that at the beginning of an industry the location of public research is the dominant geographic factor, while at later stages the industry becomes more self-contained from a geographic perspective. This might be due to a shift from tacit to explicit knowledge in the industry's life-cycle.

While we do not observe any significant changes for the variables PATENT and EAST, there are changes in the relevance of the other considered industries. We find the negative relationship between workers in the industry MED (medical devices and orthopedic appliances) in all three periods, so that the above discussed regional characteristics seem to be constant in all phases. More interesting are the varying results for the other two industries, ELEC and NAVI. Both show a significantly positive relationship with MST start-ups in one of the three time periods: ELEC in the first time period and NAVI in the second time period. In the third time period none of the considered industries shows a significant positive relationship. This supports the above finding that the MST industry has become more self-contained in the third time period.

Instead, in the first two time periods it is influenced by the location of other industries, at least to some extent. In the first time period the electronic devices industry matters, while in the second time period the industry producing measurement, control and navigation instruments matters. We might conclude that part of the founders originate from these industries in the early stage of the industrial life-cycle of the MST industry or that spillover from other industries are crucial for product innovation. This supports the argument that new industries often develop out of existing industries, so that their spatial distribution is influenced by the location of these already existing industries. Only later in their development - at later stages of their industrial life-cycle - the spatial distribution becomes less dependent on factors outside of the industry, nevertheless still depending on the initial spatial development, which was influenced by other factors.

6 Conclusion

The aim of our paper was twofold: Firstly, we have investigated spatial dependencies of company foundations in the German MST industry and their change over time. The results have revealed some interesting findings that stand in line with well-established theories: Spatial proximity to other MST firms and to relevant research institutions has a clear positive influence on where a new firm is founded. This might be due to positive local spillover or to spinoffs from firms or research institutions. While this confirms that MST-firms depend on a high local innovation capacity, the proximity to owners of patents and to qualified workers in related industries has little or even a negative influence.

Furthermore, the influence of the different actors is not constant over time but evolves with the industry's life cycle. The increasing importance of spatial proximity to firms stands in line with the self-augmenting process theory of Brenner (2004) while the parallel decreasing importance of proximity to research institutions suggests a shift from tacit to explicit knowledge. The analysis shows that the MST industry becomes more self-contained and that proximity to related industries is of decreasing importance.

The second aim of the paper was the introduction of a new distance based framework for a logistic regression. This framework enables the usage of micro geographic data that is free of any spatial aggregation but also dummy variables and aggregated data can be included. A temporal component was integrated by means of a Markov chain so that our model allows both, a micro spatial and a micro temporal analysis. The model detects spatial dependencies on a firm level instead on an aggregated regional level. Furthermore, results are benchmarked with the overall distribution of German manufacturing firms.

Despite the interesting results, the global fit of the model is quite low. Primarily, this is due to the benchmarking with real company sites of German manufacturing firms. On the other hand it is reasonable to assume that the complexity of spatial patterns of company foundations cannot be fully described by means of seven variables. Thus, a starting point for further research might be the integration of additional distance based variables.

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