Papers in Evolutionary Economic Geography

09.17

Regional Factors and Innovativeness – An Empirical Analysis of Four German Industries

Tom Broekel & Thomas Brenner

Utrecht University
Urban & Regional research centre Utrecht

Regional Factors and Innovativeness - An Empirical Analysis of Four German Industries

Tom Broekel [$], [§]   Thomas Brenner [#]

[$] Department of Economic Geography,

Faculty of Geosciences, Utrecht University, The Netherlands

[#] Economic Geography and Location Research,

Philipps University Marburg, Germany

27th October 2009

Abstract

A growing body of work emphasizes the importance of regional factors for regional innovativeness. In this paper, about seventy variables approximating the social-economic characteristics of regions are aggregated to twelve regional factors. In four industry-specific set-ups their influence on firms' innovativeness is tested. The study confirms that inter-industrial differences exist in the importance of these factors. In the empirical analyses a log-linear model is compared with a linear approach. While both are theoretically problematic it is shown that the log-linear model performs better in the empirical assessment.

[§] *Corresponding author:* Tom Broekel, Department of Economic Geography, Urban & Regional Research Centre Utrecht (URU), Faculty of Geosciences, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, The Netherlands. *Phone*: +31 30 253 3206. *Fax*: +31 30 253 2037. *E-mail*: t.broekel@geo.uu.nl

1   Introduction

The spatial component of innovation has attracted much attention in the literature. The question why some regions are more innovative than others is particularly addressed. Among others the answer is found in regional characteristics, e.g. a region's endowment with specific factors (Jaffe, 1989; Anselin et al., 1997). The spatial proximity to certain actors and the embeddedness into certain regional structures "...promotes information transfer and spill-overs that lower the costs and reduce the risks associated with innovation" (Feldman and Florida, 1994, p. 214).

Given the influence of these regional factors on the innovation performance of local firms, it is important to identify precisely which factors matter. Here the literature offers a wide range of studies that promote a variety of variables to be crucial. For example, regional factors such as human capital and the number of firms have been analyzed to play a role in this respect (see, e.g., Weibert, 1999; Brenner, 2004). However, usually studies in this field do not include all of the factors that are put forward, but analyze only selections of these. Such bears the risk of spurious correlation and misleading conclusions. There are few studies that include a larger bandwidth of variables, of which the work by Feldman and Florida (1994) is probably best known. In a similar manner, we consider more than seventy variables, which are aggregated to twelve regional factors. These are tested for their influence on regional innovativeness.

A number of recent studies shows that the importance of regional factors varies between industries (Brenner, 2004; Brenner and Greif, 2006). The analyses are therefore conducted separately for four different industries: chemicals, manufacturers of transport equipment, electrics & electronics, and a mixed branch of optics, medical devices, computer engineering and measurement engineering. The study confirms the existence of such inter-industry differences. Besides the R&D conducted in a region, the financial situation and the quality of the human capital turn out to be the most relevant factors.

The *knowledge production function* and its typical log-linear implementation has almost become standard in this type of research (Audretsch, 1998). Its assumptions and applicability are seldom questioned or reviewed, though. By discussing the implications of the log-linear and a simple linear regression model the paper challenges the appropriateness of the log-linear model. Moreover, in the empirical assessment both approaches are employed and compared with respect to the satisfaction of the models' assumptions and the meaningfulness of their results. It is shown that both models are not optimal, the log-linear model however fits better to the employed cross-sectional data.

The paper proceeds as follows. In the next section we discuss the relationship between firms' innovativeness and the presence of regional factors. Section 3 compares the linear and the log-linear model theoretically and describes relevant technicalities. The employed data and its sources are presented in Section 4. The results of the multivariate regressions are discussed in Section 5. Section 6 concludes.

2 Theoretical considerations

2.1 Regional characteristics

Based on the observation that the innovative activity differs among regions that are part of the same national innovation system, the question of the source of this disparity is raised. The concept of *regional innovation systems* claims that a region's specific social-economic environment has a crucial impact on the firms' innovativeness located in it. For example, the region's specific endowment with economic factors, such as human capital, the existence of certain institutions, the activity of local authorities, as well as the interaction between actors in networks are argued to play a role in this context (Cooke, 1992).

There are good arguments for the importance of the regional level in innovation processes (see, e.g., Fischer, 2001; Broekel and Binder, 2007). There is however no commonly accepted definition or precise understanding of the regional innovation system's elements. Many studies claim different regional actors and factors to be crucial for regional innovative performance. Most empirical studies base their choice of factors on theoretical arguments. The innovation process is however complex and for nearly any factor plausible arguments can be found that support its relevance. Not surprisingly, empirical studies do not find a common set of factors to be relevant. For example, factors, such as the presence of firms of a specific size (Stenke, 2000; Brenner and Greif, 2006), science institutions (ISI, 2000; Soete et al., 2002), various kinds of human capital (Fröderer et al., 1998; Soete and Stephan, 2003), financial resources (OECD, 2000; Peter, 2002), and spillover, cooperation and networks (Pittaway et al., 2003), have been identified in the literature as being significantly related to regional innovativeness.

As a consequence, we conduct an empirical study that contains many variables and discuss for each of these variables the arguments and the empirical evidence that is available for its relevance. Our approach is primarily empirically driven and therefore spans different theories and schools of thoughts. We test the spatial co-location of regions' socio-economic characteristics and highly innovative firms.

Following the ideas of the national innovation system literature (see, e.g., Freeman, 1987), Feldman and Florida (1994) define a 'regional technological infrastructure' including the agglomeration of firms in related industries, university R&D, industrial R&D, and business-service firms (Feldman and Florida, 1994, S. 211). Furthermore, they include a range of control variables, e.g. the population of the federal state and an index of geographic concentrations.

In this study we follow their idea of testing simultaneously a large number of factors and consider more than seventy regional characteristics that can be, or have been, attributed to influence firms' innovation processes. Mainly because of methodological reasons these factors are condensed to twelve structural regional factors that describe a region's situation with respect to a) firms' R&D efforts; b) characteristics of an industry in a region; c) urbanization; d) structure of employment; e) economic structure; f) presence of universities; g) quality of human capital; h) potential human cap-

ital; i) presence of public research institutes; j) financial situation; k) firm founding; and l) regional attractiveness. However, there is also a theoretical reason behind merging the factors into a number of structural categories: Often the factors measure similar things in different ways. For example the overall tax gains, the income tax gains, the trade tax gains and the sales tax gains are strongly related to each other and measure all the financial resources in the region. It is not adequate to include them all into the analyse but it is also unclear which factor matters. Therefore, we merge them into a joint variable.

Nevertheless, our analysis includes more different kinds of factors than the usual approaches in the literature. This makes our concept of regional factors broader than the 'technological infrastructure' by Feldman and Florida (1994) because we also include regional characteristics that do not correspond to an infrastructure concept. However, the intention is to include as many different factors as possible, given that there is some research for assuming that the factors matter.

Some factors are not included in our study. These are factors that cannot be measured quantitatively or for which no approximations are given in the available data. They regard mainly actors' interactions and sector-specific cultural foundations. For example the 'innovative milieu' approach is built around the idea of a shared cultural base in terms of social-economic problems and solutions. Here, only the coherence of the production systems, the culture and the most important actors allow such a milieu and its positive impact on the innovation activity of local firms to develop (Camagni, 1991). Also local as well as non-local networks and linkages are often claimed to play a crucial role for innovation processes (Boschma and ter Wal, 2007). As we do not have data from which we can model inter-organizational linkages its role is not investigated in this study.[1]

In the following the variables are presented that can be brought into a relationship with the level of regional innovativeness. Some of these variables share as similar theoretical context and only describe the same underlying factor in different ways. We therefore group these variables sharing the same context. In total twelve such *regional factors* are formed. These superordinate regional factors are seen as the relevant influences impacting firms' innovativeness.

2.1.1 R&D employees

The most important element in innovation processes are creative minds. Organized in groups, teams or just by oneself, professional R&D employees are the innovative entity in industrial innovation processes. They search for and recombine existing knowledge in order to generate innovative products that are in some cases patented. In regional innovation economics it is argued that a stimulating and supportive regional environment facilitates their innovation activities causing their productivity to differ systematically inter-regionally (Desrochers, 2001). Hence, the R&D employees can be considered the necessary resource for innovation processes, while the factors presented below represent supportive elements.

---

[1] See however the study by Broekel and Meder (2008) that empirically investigates the impact of cooperation behavior on regional innovation performance.

2.1.2 Industry characteristics

Some of the most prominent regional factors argued to influence firms' innovativeness relate to the industrial structure of regions (Feldman and Florida, 1994). Following the arguments of Marshall (1890), agglomeration (localization) economies are frequently analyzed and found to stimulate innovation activities (Greunz, 2004). In the later analysis we approximate this externality by the production specialization index of the industries' employment in a region. The effects of this externality might however also be related to the absolute number of employees working in an industry in a region (Brenner, 2004). Therefore, this number is considered as well. In particular, in the cluster literature it is highlighted that a large population of firms in a region that are active in the same industry is beneficial for these firms' innovation processes (see for an extensive treatment Brenner and Greif, 2006). In the light of this the absolute number of firms belonging to the industry under investigation is taken into account. It is still controversial whether larger firms or smaller firms are more innovative. In a regional context however the function of large firms as gatekeepers (Graf, 2007) and the particular role of their headquarters for regional development (Feldman and Florida, 1994) suggest to expect a positive relationship between the presence of large firms in a region and regional firms' innovativeness. The average firm size of an industries' firms in a region is used to approximate this characteristic.

2.1.3 Urbanization

It is widely accepted that firms located in larger cities have advantages in generating innovations (see, e.g., Frenkel and Schefer, 1998). Urbanized regions are advantaged because of the higher average utilization of their public infrastructure. In addition, the availability of trained workers, the spatial proximity to potential cooperation partners, and a better access to relevant markets work in favour of firms located in highly urbanized regions (Koschatzky, 2001). Spillovers between corporations, institutions and other participants in innovation processes have a spatial component. The exchange of not codified knowledge is bound to face-to-face contact (Audretsch, 1998) for which the likelihood of benefiting from such spillovers is higher in agglomerations. On the other hand, high urbanization also has disadvantages. A lower disposability of industrial estates and higher costs of labour and taxes tend to go along with a high population density (Nerlinger, 1998).

To account for urbanization one can use dummy variables (see, e.g., Brenner and Greif, 2006). As a very rough approximation for urbanization, dummies for regions with urbanized centers, with cities, and for rural areas are taken into consideration. Besides these dummies, we include a number of variables that either measure the concentration of economic activity directly, such as the population density, nature related area per inhabitant, density of employees in employment, density of work places, type of region, or measure something that is clearly related to the density of economic activity and the collection rate of communities for trade tax.

2.1.4 Economy structure

The variables assigned to this factor reflect the sectoral structure of a region. Patents are mainly generated in the secondary sector (manufacturing), i.e. if a region has a higher stake in the tertiary sector it has a disadvantage in generating relatively high numbers of patents. We include therefore the share of these two sectors and the gross added value per employee in these two sectors in the analysis. The share of employees in the business service sector measures additionally the local availability of business services, such as consultants, financial services, etc. They are expected to positively influence the patent activity of local firms (Preisl and Wurzel, 2001).

The turnover per employee is a variable accounting for various factors. Among others it reflects the market success of regional products and measuring the ability of local firms to turn their inventions into innovations and selling them. This variable is also affected by firm size and agglomeration (Rohl, 2000), which are expected to have positive impacts on patent activity.

2.1.5 Available human capital

In the literature it is frequently claimed that human capital is crucial for innovation processes (see, e.g., Faggian and McCann, 2006). The lack of highly qualified workers is especially a substantial constraint for innovations (Kugler, 2001).

The potential impact of the share of employees with low qualification and with high qualification are frequently used measures of the quality of local human capital (Weibert, 1999). In addition, apprentices are important for the diffusion and generation of knowledge (Soete et al., 2002). The number of courses at adult education centres represent the opportunities for off-the-job training, i.e. the approximation of the change of in-the-job human capital quality.

The number of school leavers with a qualification for university entrance is included as well, because it determines the quality of the apprentices in a region. In this sense the variable is used as proxy for the quality of the young workforce that enters firms through apprenticeships.

2.1.6 Structure of human captial

A somewhat different issue is the structure of the regional workforce with respect to certain social-economic groups. It can be argued that young employees are especially relevant for innovation activity. They are representing creativity and ideas coming directly from the educational system into corporations, the so-called 'knowledge transfer via heads' [2] (ISI, 2000).

The share of female employees and the share of potential employees in work, as well as the rate of unemployment approximate the extent to which the endowment of a region's human capital is used. Commuting moreover impacts a region's human capital. The capability of a region to absorb human capital from other regions increases the quality of the over-all human capital through selection and

---

[2] Translated by the author.

accumulation processes (Stenke, 2000). To take this into account, the numbers of commuters moving into and leaving a region are included.

2.1.7 Potential human captial

While the previously presented variables deal mainly with the human capital active in the job, the following capture the potential human capital, i.e. the structure and quality of the future employment in a region.

It is unknown whether undergraduates and graduates are going to stay in the region after their education. In general, the geographic mobility of German graduates is limited (Mohr, 2002). It can be argued that people will first look for employment in the region they live in. If they have to choose between equal jobs in different regions, they will prefer the job offered closest to their current location. Hence, the potential human capital approximates the regional human capital pool, from which firms can chose in the future.

The potential human capital impacts the quality of the active employees due to selection mechanisms and competition. For this reason for example the German government founded new universities in order to advance rural areas and regions lacking in infrastructure (Blume and Fromm, 2000).

According to the German educational system, graduates are broken down into graduates of universities and the graduates of technical colleges. Because technical colleges are more often specialized in the same technological fields as local corporations (Beise and Stahl, 1999) they should contribute stronger to firms' innovation activities.

Empirically assessing the importance of the various education fields has not been done in this literature strand. Hence, we can only speculate about the relationships. Math & natural science and engineering graduates are included in the study, because they are the researchers and engineers of the future. Their influence will likely depend on the industry analyzed. We also include graduates of economics. They are crucial during the founding process of a business, where services and consultants play an important role (Nerlinger, 1998). Six variables approximate the number of graduates in a region differentiating between the graduates from technical colleagues and universities as well as between the three different educational fields. The total numbers of graduates of each educational field are considered as well.

2.1.8 Presence of universities and technical colleges

Universities and technical colleges not only provide qualified human capital, they can also act as research institutions and cooperation partners. In this respect they are major players in innovation processes. In Germany, they represent approximately one third of the over-all R&D capacities (ISI, 2000) and are the core of formal and informal regional networks (Soete et al., 2002). In addition, they offer support for business foundations, consultants, use of laboratory equipment, and are important sources for spin-offs (ISI, 2000).

Spillovers from universities and technical colleges to local firms are generated through various mech-

anisms, such as cooperation, master theses, internships, movement of employees, and informal contacts between employees. The benefits of these spillovers seem to decrease with increasing geographic distance (Beise and Stahl, 1999; Adams, 2002).

It is difficult to separate the two functions of these institutions from each other and measure independently the impact of the provision of human capital and of their function as research institutes on the patent activity of local firms. We argue though that the first may be stronger related to the number of graduates while the latter is rather based on the number of faculties in a region. Hence, the numbers of faculties from different scientific fields are totaled for every region. The data is disaggregated to universities and technical colleges because they differ in their local impact and their spatial reach. Usually universities spend a larger share of their budget on research, varying between thirty percent for clinics and sixty percent for engineering faculties. For certain faculties of technical colleges this share is as low as five percent (Beise and Stahl, 1999).

At the same time, technical colleges have a stronger local focus and are more application oriented (Blind and Grupp, 1999). They "have gained a reputation for down-to-earth research and applicable engineering know-how, compensating the shortcomings of universities which are oriented towards basic research" (Beise and Stahl, 1999, p. 5). This is one important reason for the fact that co-location with these institutions is of varying importance for different industries (Pavitt, 1984).

2.1.9 Public research institutions

Public research institutions are naturally generating many patents themselves. However, in the context here their role as partners in cooperation, as emitters of a wide range of spillovers, as suppliers, and as customers are in the focus. Nicolay and Wimmers (2000) find that 82 percent of innovation firms have contacts to such institutes. Independent of firm size, two thirds of these were referring to institutions located in the same region.

Another aspect is their role in the launch of small innovative firms. The latter can share the laboratories of research institutes and find partners, customers or suppliers in these institutions. Adding to that, public research institutions are themselves emitters of spin-offs, that are likely to be located close by (Nerlinger, 1998).

Different industries prefer to cooperate with different institutions. Firms with a high R&D intensity are more likely to cooperate with public research institutes, while firms having a middle R&D intensity cooperate rather with universities and technical colleges (Spielkamp and Vopel, 1998). For the industries included here, this implies a stronger relationship between public research institutes and ELEC as well as INSTR, because they show a higher R&D intensity (Pavitt, 1984).

The regional factor *public research institutions* consists of the numbers of research-related employees in research organizations in a region. We consider the 'big four' institutions in Germany: the *Helmholtz Association*, the *Max Planck Society*, the *Fraunhofer Society* and the *Leibnitz Association*. The Max Planck Society and the Fraunhofer Society are concentrated in the southwest of Germany and often located next to universities (ISI, 2000). While the latter focuses on applied

research, the first is more into basic research (Beise and Stahl, 1999). In addition, the Helmholz Association consists of fourteen large scale institutes all over Germany. The institutes of the Leibnitz Association have been part of programs to help regions lacking in infrastructure, especially regions in the former GDR (ISI, 2000).

2.1.10 Financial facilities

Firms' financial resources are constraint and so are their R&D resources. External founding is therefore necessary for R&D projects. Variables belonging to the regional factor *financial facilities* are the gross domestic product per inhabitant and the wages & salaries in manufacturing per employee. They account for the demand for new products but also for the availability of capital for investments into innovation activities.

Tax revenues indicate moreover the financial situation of the inhabitants and the local municipalities. The higher they are the more likely they can give grants to R&D projects, start-ups, etc. In addition, the financial situation is relevant for the local demand for new products and services. The overall, income, trade, and sales tax gains per inhabitant are considered to approximate the regional wealth in terms of tax revenues.

The relation between financial facilities, tax gains, and regional innovativeness is subject to a causality problem. This holds especially for public finances. Because innovative firms are more likely to generate profits, the income of communities through tax payments will rise. This is to be considered in the interpretation of the results.

2.1.11 Founding situation

The number of business foundations per inhabitant symbolizes an active and subserve economic climate in the region which reduces the risks and increases the probability of realizing innovations. Besides this, founding a firm is one way of turning an invention into an innovation. Thus, good conditions for the foundation of businesses are an incentive for doing research in the first place. For this reason it is not surprising that Acs and Audretsch (1992) find a positive relationship between innovation activity and business registrations in regions.

Founding activities usually require investments. Small- and medium-sized enterprises (SME) need especially external financial resources. The survey on the financial situation of SMEs by von Reden and Struck (2002) reveals that SMEs rank reserved granting of credits highest among external constrains to innovation. However, external funding is sparse in Germany implying that entrepreneurs will first use their private or family's resources (Nerlinger, 1998) and the resources provided by public programs. The programs by the KfW Bankengruppe (KfW banking group) are especially relevant. The multitude of regional and national programs makes it difficult to find acceptable data. The variable public subsidiaries per inhabitant tries to add up a variety of such programs.

Recently, also venture capital (VC) is becoming increasingly important in Germany. In addition to financial resources, VC-firms provide guidance, consulting, and expertise. These firms gain through

contracting a partial control over the management (Baltzer, 2000). In the USA evidence was found that firms partly financed by VC are growing faster and have lower rates of bankruptcy (Soete and Stephan, 2003). They apply more often for patents, but do not have a higher share of R&D resources (OECD, 2000). In Germany the market for venture capital is yet small in comparison with the Anglo-Saxon countries. Its importance should not be overestimated. The remarkable growth during recent years justifies including the number of offices of venture capital companies who are members of the *German Venture Capital Association e.V.* in the study.

As in the case of the financial situation, there is again a causality problem to the relation between venture capital facilities and the innovativeness of a region. If firms are very innovative, a lot of spin-offs or start-ups are likely to occur and the market becomes attractive for VC-corporations. Again, this has to be kept in mind for this factor's results.

2.1.12 Regions' attractiveness

To attract highly qualified workers and keep them in the region, attractive occupations and pleasant surroundings in the sense of soft location factors, are beneficial (Stenke, 2000). Often they are difficult to measure and are overlaid by 'hard' factors (Grabow et al., 1995). Their impact can be nevertheless considerable (Weibert, 1999). The choice of variables for inclusion in the analysis is difficult because it is often not the quantity, but the subjectively perceived quality that is relevant. In his study Weibert (1999) uses the number of overnight stays per $1,000$ inhabitants in a region as a proxy. But this number can vary strongly on a short term basis for which the more stable endowment with beds in hotels, motels, and resorts is used instead. The recreation area per inhabitant is self-explanatory as well as the places in kindergartens per inhabitant. It has to be noted though that the latter is much larger in the territories of the 'Neue Lander', indicating a significant difference in the social infrastructure between the two parts of Germany (Brenke et al., 2002). Other variables that are considered here are the rate of persons moving into the region and leaving it in terms of changing residence. These indicate the attractiveness of a region with respect to job opportunities and the living situation.

2.2 The technological dimension

Although concepts like the *regional innovation system* might be seen as sector spanning, it is well-known that innovation processes have a technological dimension. Innovativeness is also of varying importance for different industries (Pavitt, 1984; Malerba and Orsenigo, 1996). In empirical assessments this needs to be considered, in particular if innovations are approximated by patents because the relevance of patenting is highly industry dependent (Arundel and Kabla, 1998). Commonly control variables for the regional industry structure are added to the econometric model to account for this. Such allows however only a conclusion whether a certain relationship between a regional factor and the innovativeness measure holds in general even when controlling for the industrial structure.

What seems to be more interesting though is whether the relationship is the same in all industries or if there exist differences between industries. In order to get a hold on this issue, industry-specific analyses are required. Analyses that separately investigate industries and compare the results are though rather an exception (but see, e.g., Brenner and Greif, 2006; Broekel, 2008).

We follow them and investigate separately: chemistry (CHEM), transport equipment manufacturers (TRANS), manufacturers of electric & electronic devices (ELEC), and manufacturers of instruments, medical & optical equipment (INSTR).[3] For these industries patenting represents an important property rights protection mechanism (Arundel and Kabla, 1998). This ensures that the innovation measure captures most, or at least a significant share of, innovations in these industries. These industries are also known to be relatively R&D intensive (Audretsch, 1998; ISI, 2000). This guarantees a sufficient number of patents in every region.

Pavitt (1984) classifies industries by the organization of their innovation activity and the characteristics of the base-technologies. Applying his categorization to the industries studied here, ELEC and CHEM are *science based*, implying a high relevance of strong connections to public science institutions. In contrast TRANS is considered to be a *scale intensive* industry. Here the most important source of technological know-how are suppliers and consulting engineers which suggests that the innovation activity of TRANS should be positively affected by the agglomeration of firms and industries. In case of INSTR, which Pavitt (1984) characterizes as *specialized suppliers*, customers and users are more crucial for firms' innovation processes.

Note that we aim to exame whether importance of the considered factors for regional innovativeness differs between industries. Hence, we analyse four industries separately but include some variables in all analyses in the same way. Different industry-specific variables are used for the dependent variable, the R&D employment and industrial characteristics variables. The other regional factors in contrast are identical for each industry.

3 Method

3.1 Functional form of regression approach

In contrast to the frequently discussed topic which regional factors are relevant for innovation processes, less attention has been paid to the way their influence can be analyzed empirically. This regards in particular the following issue: what is the adequate empirical method to analyze factors' influences on regional innovativeness? This will be dealt with in this section. In the literature most commonly the relationship between regional innovativeness and regional factors is empirically studied using regression approaches. Based on the works of Griliches (1979) and Jaffe (1989) the relationship between these is argued to be described by a log-linear dependency (see, e.g., Feldman and Florida, 1994; Acs et al., 2002). Borrowing from the neoclassic Cobb-Doublas type production

---

[3] Please note that the terms 'sector' and 'industry' can be arbitrarily used in this context. For the sake of readability the term 'industry' is used in the remainder of the paper.

function the idea is that the regional innovation 'output' is created from a number of factors that are multiplicatively connected:

$$Y = d * X_1^{c_1} * X_2^{c_2} \ldots * X_n^{c_n} * u \ , \tag{1}$$

where Y denotes the innovation output and X_1 to X_n are the n regional factors that are considered in the analysis. c_1 to c_n are the coefficients denoting the strength of each factor's impact and d represents a constant. The main attractiveness of this approach is that by taking the logarithm it can be estimated with a simple ordinary least square regression technique:

$$log(Y) = log(d) + log(X_1) * c_1 + log(X_2) * c_2 \ldots + log(X_n) * c_n + log(u) \ . \tag{2}$$

The assumption of a log-normally distributed error term is theoretically quite doubtful but commonly assumed for practical reasons (Chatterjee and Price, 1995). Another advantage of this type of function is that the coefficients can be interpreted as elasticities. However, besides these advantages, there is no particular reason for why the relationship between innovative outcome and regional factors should be log-linear. In deed, in very frequent cases this type of function delivers theoretically implausible results. For example, commonly the innovation output is measured either by patents, which to a great extent come from firms, or by the numbers of innovations conducted by firms according to their own responses. Let us now assume that the number of firms, university graduates numbers, and employees of public research institutes are included in the analysis as regional factors. They are to be tested for their influence on the regional innovativeness. If applying a log-linear knowledge production function one implicitly assumes that in a region with many firms and some public research but no university graduates no innovations have to be expected. This is because in the non-transformed version the regional factors are connected multiplicatively and a zero value in one implies that no innovative output is to be expected. This is clearly unrealistic.[4]

This problem can be overcome by assuming a simple linear relationship with additively connected regional factors which is also found in the literature (see, e.g., Weibert, 1999)

$$Y = d + b_1 X_1 + b_2 X_2 \ldots + b_n X_n + u \ , \tag{3}$$

where Y denotes again the innovation output and X_1 to X_n are the n regional factors that are considered in the analysis. b_1 to b_n are the regression coefficients that denote the strength of each factors' impact. d is a constant. u is the statistical error term with the usual characteristics. From an application oriented view this approach is comfortable and the factors can also be meaningfully interpreted. In contrast to the log-linear model the linear approach would predict a positive number of innovations in the previously mentioned case of a region with many firms and some public research but no university graduates. In case of a region with no firms but some graduates and public research this model still predicts a positive innovation number. This seems also not adequate because with no firm

---

[4] In practice a small constant is added to zero values, for which however no theoretical justification is provided.

R&D efforts we would rather suspect (and will likely see in reality) no innovations at all. The reason for this is that if one measures the innovation output of firms the existence of firms is a necessary condition. Note that we do not take innovations by other actors in a region into account, e.g. public research institutes. Studies in this field mainly aim at determining the impact of public research on firms' innovation performance and not the other way around. Hence, it is to be analyzed whether regional factors help firms to generate more or less innovations and not whether the innovative output of all regional actors is increased. This basic and simple insight is however seldom discussed in the literature.

From the above it becomes clear that both types of approaches are not perfect. One may say that the linear approach is more appropriate in 'extreme' situations, i.e. situations in which regional factors (that are not related to the presence of firms) show extreme low (zero) values. This is frequently the case because in many regions there are e.g. no universities implying to expect zero innovation in the log-linear model. However, in 'moderate' situations, i.e. all regional factors have positive values, the log-linear model might be more appropriate. It is thus the aim of this paper to empirically compare these two models, which are both not optimal from a theoretical point of view, to get an insight on which fits the observed empirical patterns better.

The relationship between the regional factors and regional innovativeness is estimated twice for each industry. First, the standard linear regression model is applied and second the log-linear model. In order to test which model is more suitable it is checked whether the assumptions for their application are fulfilled. In addition, two exact tests are conducted verifying which model is more appropriate. To be more precise, the diagnostics of the two models include the standard issues as multicolinearity, heteroskedasticity, spatial autocorrelation, mis-specification, and the check for normally distributed error terms. Diagnostics for multicollinearity are done by the variance inflation factors (VIF) for each of the independent variables, (see Greene, 2000). According to informal rules of thumb applied to the VIF, there is evidence of multicollinearity if the largest VIF is greater than 10, (see Chatterjee and Price, 1995). We follow this rule here but also check the models with respect to a VIF larger than 5. Heteroskedasticity is tested with the Breusch-Pegan test (Breusch and Pagan, 1979). In case that the heteroskedasticity hypothesis cannot be rejected, robust (hc03) standard errors are estimated (Long and Ervin, 2000). Spatial autocorrelation are tested with the LM test for error dependence (LMerr), the LM test for a missing spatially lagged dependent variable (LMlag). It is also tested if the variants of LMerr and LMlag are robust to the presence of the respective other (RLMerr, RLMlag) (see Anselin et al., 1996). For the estimation we consider a maximum range of potential spillovers of 300 km (Bottazzi and Peri, 2003).

Normality of the error term is analyzed with the robust Jarque-Bera test (Jarque and Bera, 1980; Gel and Gastwirth, 2008). General model mis-specification, e.g. omitted variables, are tested with Ramsey's Regression Equation Specification Error Test (RESET) (Ramsey, 1969).

The two exact tests for evaluating which model is more appropriate are the Bera-McAleer test (BM-test) introduced by Bera and McAleer (1989) as well as the PE-test which was developed by MacK-

innon et al. (1983). Comparing both models with these tests requires in principle that all previously mentioned assumptions are met. Such is unlikely as e.g in the case that the log-linear model is appropriate this implies that the relationship between regional factors and the innovativeness measure is non-linear. In the linear model this will likely cause heteroscedasticity problems and non-normally distributed error terms. Hence, the fulfillment of the assumption will already give a strong hint at the results of two exact tests.

Last but not least a plausibility check is done. Based on the arguments presented in Section 3 the variables approximating industrial R&D need to be significant.

Some more remarks on the data have to be made. As will be shown in Section 4, the depended variable is per definition a continuous and non-negative value, including some 'zero-values'. Such makes a tobit-regression or truncated model an adequate choice (Wooldridge, 2003). However there are only two 'zero-values' in the dependent variable in CHEM and one in ELEC. The two other industries' dependent variables are strictly positive. In addition, using a tobit-regression we cannot control for heteroscedasticity, which will turn out to be frequently present in the *linear model*. Also, the BM and PE-test are only defined for standard ordinary least square techniques. We therefore stick to the OLS approach. Nevertheless, tobit models have been estimated and found to confirm the results of the OLS estimation.

3.2 Reducing dimensionality

More than seventy independent variables have been presented and grouped according to shared theoretical contexts. These contexts are what we call *regional factors*, i.e. these are underlying factors that impact regional innovativeness. Official statistics seldom measure such factors in a single variable, e.g. the quality of human capital in a region. Most of the provided variables rather capture some but not all of parts of this factor. In other words, the provided information by the statistical offices do not match completely the theoretical factors that are put forward in the literature to impact regional innovativeness.

We solve this problem by employing a principal component analysis. This analysis extracts the statistical variance common to the variables assigned to one regional factor. We assume the largest part of the variance that can be extracted in one variable (first component) to be an appropriate measure of that regional factor. Note that we use this method to construct an index value representing most of the considered variables' information, which is slightly different from standard principal component analysis.[5] This approach yields two methodological advantages. Firstly, it allows us to deal with the great number of variables that would otherwise prevent a statistically sound analysis given few observation. The principal component analysis reduces the number of independent variables to a manageable number while at the same time a maximum of each variable's variance is kept. Sec-

---

[5] We use the standardized but not centered principal component analysis (PCA) because all our variables exhibit positive values and we are not interested in the differences to the mean but in an index representing the variables. This implies that the first component is driven by the mean function resulting in rather similar loadings. In addition we obtain only strictly positive loadings.

ondly, it lowers the number of variables similarly correlated with the dependent variable. Or put differently, multicollinearity becomes less likely.

We employ the principal component analysis on eleven of the twelve theoretically motivated factors. In case of R&D employment this is not necessary because it is defined by the sum of an industry's R&D employees. The first component then is used as an approximation of the regional factor. There are two important things to be pointed out. Because each variable loads differently on this component (see Table 4), the component represents the variables to a different degree. Hence, not all variables are treated equally. Moreover, this procedure implies that depending on their loading we ignore some explanatory power of each variable. This is the price that we have to pay for reducing dimension.

One could have used the principal component analysis also to directly generate the regional factors. In this case the analyses is applied to all variables and a certain number of components are generated based on their shared statistical variance alone. In our eyes this approach is inferior to the chosen one because it bears the danger of obtaining compontents that are theoretically not meaningful. The reason is that variables might be spatially correlated although they do not refer to the same theoretical context.

In our case, the regional factors are created on a theoretical basis ensuring that each of the resulting first components has a consistent theoretical meaning. Table 2 in the Appendix summarizes the eleven regional factors (first components) and the assigned variables. In Table 3 the variance covered by the first component for each regional factor is presented. The descriptives can be found in Table 5 in the Appendix.

Except for the regional factors urbanization, research institutes, and founding situation the covered proportion of variance is very high. Even in the mentioned cases it stays well above sixty percent though. The created factors cover by and large most of the included variables' information.

Table 6 shows the correlation structure of the created regional factors. Some of these regional factors contain zero values, which prevent taking the logarithm, which is necessary for the log-linear model. As suggested by Feldman and Florida (1994) all regional factors are therefore beforehand transformed by:

$$\tilde{X} = 10 * (X + 1) \ . \tag{4}$$

4 Data sources

As an approximation of a region's innovation output we use the patent applications of the year 2000, published by the *Deutsches Patent- und Markenamt* (German Patent Office) in the year 2002 (Greif and Schmiedl, 2002). The spatial arrangement of patent applications relates to the residence of inventors. As regional units, the German *Raumordnungsregionen* are chosen dividing the country into 97 separate regional units. These regions are formed on a basis that takes into account the geographic nature of such economic functions as commuter flows, which have been identified to crucially in-

fluence patent statistics (Deyle and Grupp, 2005). With respect to patent data the place of residence and the work place of an inventor belongs most likely to the same *Raumordnungsregion.* Thus, the chosen spatial unit offers an adequate way to analyze the link between the social-economic endowment of such a region and patent data.

Aware of the strengths and weaknesses of the information provided by patents (see, e.g., Feldman and Florida, 1994; Rohl, 2000; Malerba and Orsenigo, 1996; Deyle and Grupp, 2005), we will use them as dependent variables in this study. Based on the categorization of the patent data, we use the sum of patent applications from corporations and private persons. This excludes the patent applications of public science institutions, that would potentially bias the results. This bias results from the trivial fact that the more science institutions are located in a region the more patents of this category will be applied for.

In a cross-section analysis, time lags between the effects of a change in regional factors on the innovative outcome are observed to be a problem. This leads also to a causality problem because the ambient conditions of a region may have been influenced by the economic success of innovations in the past. Because the time lag between innovations and their effect on the economic surroundings is unknown, it cannot be excluded that innovations may influence the economic situation of a region. This effect is not explicitly included in the analysis here. In fact, we don't expect this to be a problem because patent applications are of short-term and medium-term stability in volume as well as in spatial and industrial structure. Because of this they can be used in empirical analyses with economic data even in greater temporal differences (Greif and Schmiedl, 2002). Nevertheless, we use social-economic data from the year 2000 if possible. If data from 2000 is not available we collected the data for 1999.

The data used for constructing the regional factors are obtained form the German federal states' statistical offices. This data is jointly published as Easystat (2002). Moreover, the German Federal Office for Building and Regional Planning ('Das Bundesamt für Bauwesen und Raumordnung') provides regional data as 'Aktuelle Daten zur Entwicklung der Städte, Kreise und Gemeinden' (INKAR, 2002). The data of the R&D employees are taken from the employment panel of the German Institute for Labor Market and Occupation Research (*Institut für Arbeitsmarkt- und Berufsforschung*). We follow Bade (1987) and define R&D employees as the occupational groups of engineers, chemists and natural scientists.[6] The employment data is matched with the patent application using the concordance developed by Broekel (2007). This concordance is based on the concordance of Schmoch et al. (2003), but is adapted to our data sources. Table 1 provides the industries' definitions in terms of patent classes and NACE codes.

---

[6] Bade (1987) defines R&D workers as employees belonging to the occupational groups 032, 60, 61 or 883 of the German occupation classification (IAB, 2008).

5 On the specification of the regression models

5.1 Linear vs. log-linear approach

The results for all industries and the two different models are presented in Tables 7, 8, 9, 10 in the Appendix. For all linear and log-linear models multicollinearity is of some relevance. In the original models the VIF is always well below 10. If we apply a benchmark of 5, in some models financial situation and economic structure as well as the human capital cause multicollinearity effects. It appears though that the financial situation carries most of the (negative) effect related to the economic structure. Multicollinearity between the two variables causes the sign of the coefficient of economic structure to change from negative to positive when the financial situation is excluded. Similar applies to some human capital variables (potential human capital and universities). We focus on the results obtained with the variables that are most strongly related to regional innovativeness, which are in these cases the financial situation and the potential human capital.

There are serious signs of spatial autocorrelation in the TRANS models. To deal with this requires the use of spatial regression techniques (see, e.g., Anselin, 2005). One aim of the paper is however to compare the linear and the log-linear model on the basis of OLS techniques (the BM and PE test are only defined for OLS). We therefore refrain from applying spatial regression. The results for TRANS though have to be interpreted with care.

Heteroskedasticity turns out to be a major problem for all linear models. The Breusch-Pegan tests are highly significant in all four cases. The residuals are also significantly non-normally distributed (Jarque-Bera test).[7] In addition, with exception of the log-linear model in INSTR, the RESET test suggests in all cases specification problems that relate to the observed heteroskedasticity. The latter is also true for some of the log-linear models. However, the significance levels of the RESET tests are much lower for the log-linear models than those for the linear models. We conclude that in the log-linear models heteroskedasticity is not a serious problem. From an econometric point of view the latter seems to be the preferable approach for this data because the assumptions of the estimation procedure (OLS) are violated more in the linear model.

The log-linear model does not seem to be the optimal choice, though. In all but one case the RESET tests point at specification problems that might be caused by missing but relevant variables (Ramsey, 1969). This is unlikely because the most important variables determining the number of patent applications in a region - R&D employment - as well as a large number of other important variables are included in the analyses. Additionally, the models predict regional innovativeness fairly well (high R^2). We suspect therefore that the assumption of a log-linear functional relationships is not correct. This is also backed by the observation of the somewhat non-normally distributed error terms (at a low significance levels).

Further evidence for the better fit of the log-linear model deliver the BM and PE tests. Except for

---

[7] Note that the Jarque-Bera test also suggest non-normally (spatially) distributed residuals for the log-linear model of TRANS. This is likely a result of the spatial autocorrelation.

CHEM the BM test yields supportive results for the log-linear model. The results of the PE test add to this in case of INSTR. In the other cases it is inconclusive. The results favoring the log-linear model moreover achieve higher significance levels than those backing the linear model.

For all models the R^2 are sufficiently high. As pointed out before a necessary model check is whether the estimated models are plausible and meet the theoretical predictions. In our case this implies that the R&D variables are significant, which we find to be true in all relevant log-linear models. The rather low significance of R&D in case of TRANS is caused by its comparatively high correlation with the financial situation (r=0.41***) and the economic structure (r=0.29***). Once either variable is excluded R&D becomes highly significant.

Despite the problems regarding the specification of the log-linear functional relationship, the log-linear models fulfill the most important requirements. On their basis the role of regional factors for firms' innovativeness can be analyzed.

5.2   Regional factors and innovativeness

For CHEM only R&D and the industrial characteristics are found to be crucial for regional innovation performance. This suggests that for this industry most regional factors are not relevant. The still high R^2 results from the very high explanatory power of R&D. Its standardized coefficient (Beta-value) clearly dominates all the others, indicating that this variable's contribution to the explanatory power of the model is largest. This is more or less the same for the other industries. In contrast, the contribution of industrial characteristics is less strong, although significant . It suggests that this industry benefits from being agglomerated in regions, which corresponds to results of other studies (Brenner and Greif, 2006; Broekel, 2008).

One of the most interesting results is that a good financial situation turns out to be a highly significant factor in the regression models for ELEC, INSTR, and TRANS. This reflects the important role of the south-western regions, which are financially well situated and show a strong concentration of these industries. As we have pointed out before, cross-sectional analyses are troubled by a causality problem because it cannot be clarified whether innovativeness impacts the regional financial situation or the other way around.[8] From a theoretical point of view, the literature points to the crucial role of the financial support for innovation projects particularly in case of small firms (Christensen, 2007). While TRANS is clearly dominated by large firms (see Brenner and Greif, 2006), in ELEC and INSTR small and medium sized firms are often innovation leaders. In their cases our results are in line with the literature.

Some more inter-industrial similarities show up in the importance of human capital. The quality of the available human capital seems to be important for all industries but particularly important for ELEC, and INSTR. INSTR is characterised by a higher relevance of interactions with customers and suppliers (Pavitt, 1984). If the customer industries' production facilities are located in the same region, knowledge exchange and interaction are easier established and maintained. The customer

---

[8]   Instrumental variables approaches might be a solution in future work.

industries of INSTR can be considered as high-tech industries themselves. This implies that these industries demand and attract highly qualified human capital, which explains the significance of the available human capital variable. ELEC is a science based industry itself (Pavitt, 1984), which might explain the strong results for the available human capital.

Furthermore, the science based characteristic of CHEM and ELEC should imply that spatial proximity to universities and technical colleagues enhance innovation performance. We therefore expected to find variables significant that are related to the presence of universities and technical colleagues. This is only the case of INSTR for which the potential human capital seems to have a positive effect. The non-significant coefficients in the other models are in line with the non-industry specific study by Fritsch and Slavtchev (2007). Our variables that approximate the presence of universities in a region are based on the number of graduates and the number of faculties. These variables reflect mainly the size of the universities. Fritsch and Slavtchev (2007) show that the mere size of universities in terms of the number of employees or the regular budget has no effect on regional innovativeness. In this respect our study confirms their general results for the four studied industries. While Fritsch and Slavtchev (2007) moreover show that the quality of universities' research activities impact regional innovativeness, we lack the data to test this here.

Similar to CHEM, we find industrial characteristics to be important for INSTR. The positive coefficient of this variable suggests that the firms' innovation activities benefit from being agglomerated regionally. This somewhat contrasts the results of Broekel (2008), especially the finding that localization externalities are not of high importance for this industry. However, this industry is known to form clusters with positive effects that go beyond mere localization externalities (see Brenner, 2006). According to Brenner and Greif (2006) these benefits are likely being related to the local labour markets and cooperation activities.

The analyses generally highlight the importance for conducting industry-specific studies. As it turns out the relationships between regional factors and innovativeness are very different between industries. This questions some results of previous studies that account for the technological dimension to a limited extent. Their results most likely reflect differences in the regional industry mix. At the same time this finding demands more research to be conducted verifying or rejecting the results of the non-industry specific studies. For policy this implies that there are still large scientific gaps in the knowledge of how regional factors influence regional innovativeness. With respect to our study it clearly shows that the quality of the human capital is of uttermost importance. For two industries, chemicals and instruments, moreover co-location to other firms of the same industry are beneficial. In this respect the concentration of this industry in few regions seems recommendable.

6 Conclusion

The study analyzed key characteristics of the 97 German planning regions that are endowed with highly innovative firms. In contrast to many previous studies this was done taking a very broad set

of regional characteristics into account. More than seventy variables have been considered that are argued to be potentially related to differences in regional innovativeness. They have been aggregated to twelve regional factors. Their influence on regional innovativeness was tested with a multivariate regression framework. In addition, the paper compared two different types of regression approaches: the linear and the log-linear model. It was argued that both are not optimal from a theoretical basis. One of the most important outcomes of the present study is that the choice of the functional relationship defining the regression approach is far from being easy and deserves more attention. It was shown that it matters not only from an theoretical perspective but also in the empirical application. While the linear regression did not proof to be superior to the most commonly employed log-linear model, the comparison highlighted some weaknesses of the log-linear model. For example, in the log-linear models of two industries the specification test (RESET) suggested that the model can be improved by adding further variables or allowing for non- log-linear relationships.

Despite the many studies conducted in this field, we argue that too little attention has been paid to the way regional innovativeness and its determinants should be empirically analyzed. This regards for example R&D employment as a necessary component in innovation processes. In contrast to the other regional factors they are not substitutable, which is something not accounted for in standard regression approaches. Promising in this respect is the 'regional innovation efficiency approach' by Fritsch and Slavtchev (2006) and Broekel (2008), in which the impact of regional factors is tested on the relationship between the regional numbers of R&D employment and the observed innovative output.

While in the literature many studies in the field are done in a non-industry-specific way (e.g., Feldman, 1994; Fritsch and Slavtchev, 2005), recently it was argued that this can be regarded as a major shortcoming (Brenner and Greif, 2006; Broekel and Brenner, 2007; Broekel, 2008). The present study adds to this by highlighting inter-industrial differences in the importance of specific regional factors. For example, for the chemical industry regional factors seem to be of low relevance. In contrast, the financial situation in a region can be positively associated to the innovativeness of the transport equipment, electrics & electronics, and precision & optical instruments industries. In case of the latter two, the regional endowment with human capital also plays a stimulating role. This role seems not to be related to the mere size of the universities present in the regions, which backs the not industry-specific findings by Fritsch and Slavtchev (2007), but rather to the presence of other high-tech industries.

The characteristics of an industry in a region, e.g. degree of specialization, firm number, was found to play a role for the chemical industry as well as the manufacturers of precision & optical instruments, underlining again inter-industrial differences. Hence, while the regional innovation system approach might be considered as being sector-spanning in empirical investigations the sectoral dimension can not be neglected.

This work marks a starting point for further research. It provides some suggestions for enhancement of future studies dealing with this subject. It also delivers industry-specific insights into the coher-

ence between the endowment of a region with a crucial set of factors and the innovativeness of local firms. The analysis lacks a dynamic component, which would answer to what extent the variation of the identified factors have an impact on the firm's ability to generate patents over time. Also the causality relationship can be explored in a more appropriate fashion if data is available for larger time spans.

References

Acs, Z. and Audretsch, D. (1992). *Innovationen durch kleine Unternehmen*. Wissenschaftszentrum Berlin für Sozialforschung, Berlin.

Acs, Z. J., Anselin, L., and Varga, A. (2002). Patents and Innovation Counts as Measures of Regional Production of New Knoweldge. *Research Policy*, 31:1069–1085.

Adams, J. D. (2002). Comparative Localization of Academic and Industrial Spillovers. *Journal of Economic Geography*, 2(3):253–278.

Anselin, L. (2005). Exploring Spatial Data with GeoDa: A Workbook. *Center for Spatially Integrated Social Science*.

Anselin, L., Bera, A. K., Florax, R., and Yoon, M. J. (1996). Simple Diagnostic Tests for Spatial Dependence. *Regional Science and Urban Economics*, 26:77–104.

Anselin, L., Varga, A., and Acs, Z. (1997). Local Geographic Spillovers between University Research and High Technology Innovations. *Journal of Urban Economics*, 42(3):422–448.

Arundel, A. and Kabla, I. (1998). What Percentage of Innovations are Patented? Empirical Estimates for European Firms. *Research Policy*, 27(2):127–141.

Audretsch, D. (1998). Agglomeration and the Location of Innovative Activity. *Oxford Review of Economic Policy*, 14(2).

Bade, F.-J. (1987). *Regionale Beschäftigungsentwicklung und produktionsorientierte Dienstleistungen*. Sonderheft 143. Deutsches Institut für Wirtschaftsforschung, Berlin.

Baltzer, K. (2000). *Die Bedeutung des Venture Capital für innovative Unternehmen*. Shaker Verlag, Aachen.

Beise, M. and Stahl, H. (1999). Public Research and Industrial Innovations in Germany. *Research Policy*, 28(4):397–422.

Bera, A. K. and McAleer, M. (1989). Nested and Non-Nested Procedures for Testing Linear and Nested and Non-Nested Procedures for Testing Linear and Log-Lienar Regression Models. *The Indian Journal of Statistics*, 51:212–224.

Blind, K. and Grupp, H. (1999). Interdependencies between the Science and Technology Infrastructure and Innovation Activities in German Regions: Empirical Findings and Policy Consequences. *Research Policy*, 28(5):451–468.

BLK (2003). *Studien- und Berufswahl*. Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung (BLK), BW Bildung und Wissen Verlag und Software GmbH, Berlin.

Blume, L. and Fromm, O. (2000). Regionalökonomische Bedeutung von Hochschulen. *Kasseler Wirtschafts- und Verwaltungswissenschaften, Deutscher Universitäts Verlag, Wiesbaden*, 11.

Boschma, R. A. and ter Wal, A. L. J. (2007). Knowledge Networks and Innovative Performance in an Industrial District: The Case of a Footwear District in the South of Italy. *Industry and Innovation*, 14(2):177–199.

Bottazzi, L. and Peri, G. (2003). Innovation and Spillovers in Regions: Evidence from European Patent Data. *European Economic Review*, 47(4):687–710.

Brenke, K., Geppert, K., Hopf, R., Pfeiffer, I., Spies, C. K., Vesper, D., and Wagner, G. G. (2002). Bausteine für die Zukunft Berlins. *DIW-Wochenbericht*, 10/02.

Brenner, T. (2004). *Local Industrial Clusters: Existence, Emergence and Evolution*. Routledge, London.

Brenner, T. (2006). Identification of Local Industrial Clusters in Germany. *Regional Studies*, 40(9):991–1004.

Brenner, T. and Greif, S. (2006). The Dependence of Innovativeness on the Local Firm Population an Empirical Study of German Patents. *Industry and Innovation*, 13(1).

Breusch, T. S. and Pagan, A. R. (1979). A Simple Test for Heteroscedasticity and Random Coefficient Variation. *Econometrica*, 47:1287–1294.

Broekel, T. (2007). A Concordance between Industries and Technologies - Matching the Technological Fields of the Patentatlas to the German Industry Classification. *Jenaer Economic Research Papers*, 2007-013.

Broekel, T. (2008). From Average to the Frontier: A Nonparametric Frontier Approach to the Analysis of Externalities and Regional Innovation Performance. *Papers in Evolutionary Economic Geography*, 08.04.

Broekel, T. and Binder, M. (2007). The Regional Dimension of Knowledge Transfers - A Behavioral Approach. *Industry and Innovation*, 14(2):151–175.

Broekel, T. and Brenner, T. (2007). Measuring Regional Innovativeness - A Methodological Discussion and an Application to One German Industry. *DIME Working Paper*, 2007-13.

Broekel, T. and Meder, A. (2008). The Bright and Dark Side of Cooperation for Regional Innovation Efficiency. *Papers in Evolutionary Economic Geography*, 08.11.

BVK (2003). *Sitz der Mitglieder*. Bundesverband Deutscher Kapitalbeteiligungsgesellschaften e.V, http://www.bvk-ev.de.

Camagni, R. (1991). Local "Milieu", Uncertainty and Innovation Networks: Towards a New Dynamic Theory of Economic Space. In Camagni, R., editor, *Innovation Networks: Spatial Perspectives*. Belhaven Stress. London, UK and New York, USA.

Chatterjee, S. and Price, B. (1995). *Praxis der Regressionsanalyse*. R. Oldenbourg Verlag, München, 2. edition.

Christensen, J. L. (2007). Constraints on Innovation Finance in North Jutland, Denmark. *European Planning Studies*, 15(9):1163–1180.

Cooke, P. (1992). Regional Innovation Sytems: Competitive Regulation in the New Europe. *Geo-Forum*, 23:356–382.

Desrochers, P. (2001). Local Diversity, Human Creativity, and Technological Innovation. *Growth and Change*, 32:369–394.

DESTATIS (2002). *Klassifikation der Wirtschaftszweige, Ausgabe 2003 (WZ2003)*. Statistisches Bundesamt, Wiesbaden.

Deyle, H. and Grupp, H. (2005). Commuters and the Regional Assignemtn of Innovative Activities: A Methodological Patent Study of German Districts. *Research Policy*, 34(2):221–234.

Easystat (2002). *Easystat - Statistik Regional, CD-Rom*. Statistische Ämter der Länder des Bundes, Wiesbaden.

Faggian, A. and McCann, P. (2006). Human Capital Flows and Regional Knowledge Assets: A Simultaneous Equation Approach. *Oxford Economic Papers*, 52:475–500.

Feldman, M. (1994). *The Geography of Innovation*. Economics of Science, Technology and Innovation, Vol. 2, Kluwer Academic Publishers, Dordrecht.

Feldman, M. P. and Florida, R. (1994). The Geographic Sources of Innovation: Technological Infrastructure and Product Innovation in the United States. *Annals of the Association of American Geographers*, 84(2):210–229.

Fischer, M. M. (2001). Innovation, Knowledge Creation and Systems of Innovation. *The Annals of Regional Science*, 35(2):199–216.

Fraunhofer-Society (2000). *Befristete und unbefristete Wissenschaftler*. Fraunhofer Gesellschaft, München.

Freeman, C. (1987). *Technology and Economic Performance: Lessons from Japan*. Printer Publishers. London. UK.

Frenkel, A. and Schefer, D. (1998). Local Milieu and Innovations: Some Empirical Results. *The Annals of Regional Science*, 32:185–200.

Fritsch, M. and Slavtchev, V. (2005). The Role of Regional Knowledge Sources for Innovation. *Freiberg Working Papers*, 2005-15.

Fritsch, M. and Slavtchev, V. (2006). Measuring the Efficiency of Regional Innovation Systems: An Empirical Assessment. *Freiberg Working Papers*, 2006-6.

Fritsch, M. and Slavtchev, V. (2007). Universities and Innovation in Space. *Industry and Innovation*, 14(2):201–218.

Fröderer, K., Krey, K., and Palme, K. (1998). Innovation und Mittelstand, eine Umfrage bei 1871 Unternehmen. *Beiträge zur Gesellschafts- und Bildungspolitik, Institut der Deutschen Wirtschaft, Köln*.

Gel, Y. R. and Gastwirth, J. L. (2008). A Robust Modification of the Jarque-Bera Test of Normality. *Economic Letters*, 99:30–32.

Grabow, B., Henckel, D., and Hollbach-Grömig, B. (1995). Weiche Standortfaktoren. *Schriften des Deutschen Instituts für Urbanistik*, 89.

Graf, H. (2007). Gatekeepers in Regional Networks of Innovation. *Jenaer Economic Research Papers*, 54.

Greene, W. H. (2000). *Econometric Analysis*. Prentice Hall International (UK), London.

Greif, S. and Schmiedl, D. (2002). *Patentatlas 2002 Dynamik und Strukturen der Erfindungstätigkeit*. Deutsches Patent- und Markenamt, München.

Greunz, L. (2004). Industrial Structure and Innovation - Evidence from European Regions. *Journal of Evolutionary Economics*, 14(5):563–592.

Griliches, Z. (1979). Issues in Assessing the Contribution of R&D to Productivity Growth. *Bell Journal of Economics*, 10:92–116.

Helmholtz-Association (2000). *Programme - Zahlen - Fakten*. Helmholtz Association of National Research Centres.

IAB (2008). *Sozialversicherungspflichtige Beschäftigte (ohne Personen in Ausbildung) und Arbeitslose*. IAB Institut für Arbeitsmarkt- und Berufsforschung.

INKAR (2002). *Aktuelle Daten zur Entwicklung der Städte, Kreise und Gemeinden, CD-Rom, Berichte 8*, volume 14. Bundesministerium fur Bauwesen und Raumplanung, Berlin.

ISI (2000). *Endbericht an das BMBF Regionale Verteilung der Innovations- und Technologiepotentialen in Deutschland und Europa*. Fraunhofer Institut für Systemtechnik und Innovationsforschung, München.

Jaffe, A. (1989). Real Effects of Academic Research. *American Economic Review*, 79(5):957–970.

Jarque, C. and Bera, A. (1980). Efficient Tests for Normality, Homoscedasticity and Serial Independence of Regression Residuals. *Economic Letters*, 6(255-259).

Koschatzky, K. (2001). *Räumliche Aspekte im Innovationsprozess*. Wirtschaftsgeographie, Vol. 19, LIT, Munster.

Kugler, F. (2001). Gründungsforschung in der Region Südthüringen. *Kurzbericht zum AIF-Projekt, Fachhochschule Schmalkalden, Schmalkalden*.

Leibniz-Gemeinschaft (2000). *Gesamtpersonal 2000*. Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz e.V., Bonn.

Long, J. S. and Ervin, L. H. (2000). Using Heteroscedasticity Consistent Standard Errors in the Linear Regression Model. *The American Statistician*, 54:217–224.

MacKinnon, J. G., White, H., and Davidson, R. (1983). Tests for Model Specification in the Presence of Alternative Hypotheses: Some Further Results. *Journal of Econometrics*, 21:53–70.

Malerba, F. and Orsenigo, L. (1996). Schumpeterian Patterns of Innovation are Technology-Specific. *Research Policy*, 25(3):451 – 478.

Marshall, A. (1890). *Principles of Economics*. MacMillian, London (8th edition 1920).

Max Planck Society (2000). *Jahrbuch 2001*. Max Planck Society, Munich.

Mohr, H. (2002). Räumliche Mobilität von Hochschulabsolventen. In *Arbeitsmärkte fur Hochqualifizierte*, pages 249–281. L. Bellmann & J. Velling, Nürnberg.

Nerlinger, E. (1998). *Standorte und Entwicklungen junger innovativer Unternehmen*. Nomos Verlagsgesellschaft, Baden-Baden.

Nicolay, R. and Wimmers, S. (2000). *Kundenzufriedenheit der Unternehmen mit Forschungseinrichtungen*. Deutscher Industrie- und Handelstag (DIHT), Berlin.

OECD (2000). A New Economy? The Changing Role of Innovation and Information Technology in Growth. *Information Society, OECD*.

Pavitt, K. (1984). Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory. *Research Policy*, 13(6):343 – 373.

Peter, V. (2002). Institutionen im Innovationsprozess. In *Technik, Wirtschaft, Politik*. Schriftenreihe des Fraunhofer - Instituts für Systemtechnik und Innovationsforschung, Physica -Verlag, München.

Pittaway, L., Robertson, M., Munir, K., Denyer, D., and Neely, A. (2003). Networking and Innovation: A Systematic Review of the Evidence. *International Journal of Management Reviews*, 5/6(3&4):137–168.

Preisl, B. and Wurzel, U. (2001). Zur Rolle der privaten und öffentlichen Forschungseinrichtungen in europaischen Innovationssystemen. *DIW-Wochenbericht*, 30/01.

Ramsey, J. B. (1969). Tests for specification error in classical linear least squares regression analysis. *Journal of the Royal Statistical Society*, Series B 31:350–371.

Rohl, K.-H. (2000). Die Eignung der sächsichen Agglomerationsräume als Innovations- und Wachstumspole fur die wirtschaftliche Entwicklung des Landes. *Diskussionsbeiträge aus dem Institut für Wirtschaft und Verkehr, No. 1/2000, Technische Universität Dresden, Fakultät für Verkehrswissenschaft, Dresden*.

Schmoch, U., Laville, F., Patel, P., and Frietsch, R. (2003). Linking Technology Areas to Industrial Sectors. *Final Report to the European Commission, DG Research, Karlsruhe, Paris, Brighton*.

Soete, B. and Stephan, A. (2003). Nachhaltiges wirtschaftliches Wachstum durch Innovationen: Die Rolle von kleinen und mittleren Unternehmen. *DIW-Wochenbericht*, 38/03.

Soete, B., Wurzel, U., and Drewllo, H. (2002). Innovationsnetzwerke in Ostdeutschland: Ein noch zu wenig genutztes Potential zur regionalen Humankapitalbildung. *DIW-Wochenbericht*, 16/02.

Spielkamp, A. and Vopel, K. (1998). Mapping Innovative Clusters in National Innovation Systems. *ZEW Discussion Papers*, 98-45.

StBA (2000). *Absolventen der Universitäten und Fachhochschulen nach Fächergruppen geordnet.* Statistisches Bundesamt, Wiesbaden.

Stenke, G. (2000). Großunternehmen in innovativen Milieus, Das Beispiel Siemes / München. *Kölner Forschungen zur Wirtschaft- und Sozialgeographie*, 54.

von Reden, E. and Struck, J. (2002). Nutzen und Wirkung öffentlicher Förderprogramme für Wachstumsunternehmen. In *Wertorientierts Start - Up Management*, pages 413 – 428. Verlag Franz Vahlen, München.

Weibert, W. (1999). *Regionale Determinanten der Innovation*. Nomos Verlagsgesellschaft, Baden-Baden.

Wooldridge, J. (2003). *Introductory Econometrics a Modern Approach*. South Western Publ., Mason, 2 edition.

A Appendix

Industry	Technological fields*	Industries**	Control ***
Chemistry	TF5, TF12, TF13, TF14, TF15	DG24, DI26	TF6 ,TF20, DF23
Machine building	TF1, TF2, TF3, TF7, TF8, TF9, TF11, TF17, TF18, TF19, TF20,TF21, TF23, TF24, TF25	DA15, DA16, DB17, DB18, DC19, DC20, DE21, DE22, DH25, DJ27, DJ28, DK29, DN36	TF6, TF22, DM34
Transport equipment	TF10, TF22	DM34, DM35	TF23, TF20
Electrics & electronics	TF27, TF28, TF29, TF30, TF31	DL30, DL31, DL32	DL33
Medical & optical equipment	TF4, TF16, TF26	DL33, DF23	TF6, TF15, DL30
* As defined in Greif and Schmiedl (2002) ** According to the GIC DESTATIS (2002) *** Technological fields of industries which have to be controlled for			

Table 1: Definitions of industries

Variables, principal components, and their sources	
Industry characteristics	**sources**
Industry's total employment	(IAB, 2008)
Number of firms in an industry	(IAB, 2008)
Degree of specialization	[#]
Average firm size	[#]
Urbanization	**sources**
Population density	(INKAR, 2002)
Collection rate of communities for trade tax aggregated for planing regions	(Easystat, 2002)
Density of employees in employment	(INKAR, 2002)
Density of work places	(INKAR, 2002)
Type of region (classification by German	
Federal Office for Building and Regional Planning)	(INKAR, 2002)
Region with agglomerations (Agglomerationsräume)	(INKAR, 2002)
Region with cities (Verstädterte Raeume)	(INKAR, 2002)
Rural areas (ländliche Räume)	(INKAR, 2002)
Universities	**sources**
Engineering faculties at universities & technical colleges per inhabitant	(BLK, 2003)
Math & natural science faculties at universities & technical colleges per inhabitant	(BLK, 2003)
Economic faculties at universities & technical colleges per inhabitant	(BLK, 2003)
Medicine faculties at universities & technical colleges per inhabitant	(BLK, 2003)
Engineering faculties at universities per inhabitant	(BLK, 2003)
Math & natural science faculties at universities per inhabitant	(BLK, 2003)
Economics & business administration faculties at universities per inhabitant	(BLK, 2003)
Medicine faculties at universities per inhabitant	(BLK, 2003)
Engineering faculties at technical colleges per inhabitant	(BLK, 2003)

Math & natural science faculties at technical colleges per inhabitant	(BLK, 2003)
Economics & business administration faculties at technical colleges per inhabitant	(BLK, 2003)
Medicine faculties at technical colleges per inhabitant	(BLK, 2003)
HC structure	**sources**
Share of employees at age 20 - 30	[#]
Share of female employees	(INKAR, 2002)
Share of employees fit to work	(INKAR, 2002)
Rate of unemployment	(INKAR, 2002)
Rate of commuters into the region	(INKAR, 2002)
Rate of commuters out of the region	(INKAR, 2002)
HC quality	**sources**
Share of employees with low qualification	(Easystat, 2002)
Share of employees with high qualification	(Easystat, 2002)
Number of curses at adult education centres per inhabitants	(INKAR, 2002)
Share of employees that are apprentices	(INKAR, 2002)
School leaver with qualification for university entrance	(INKAR, 2002)
Founding situation	**sources**
Number of venture capital companies and branch offices	(BVK, 2003)
Public subsidiaries (Wirtschaftshilfen) per inhabitant	(INKAR, 2002)
Number of business foundations per inhabitant	(INKAR, 2002)
Economy structure	**sources**
Share of employees secondary sector	(INKAR, 2002)
Share of employees tertiary sector	(INKAR, 2002)
Share of employees in business service	(Easystat, 2002)
Sales per employee	(INKAR, 2002)
Gross value added secondary sector	(INKAR, 2002)
Gross value added tertiary sector	(INKAR, 2002)
Financial situation	**sources**
GDP per inhabitant	(INKAR, 2002)
Wage & salaries in manufacturing industry per employee	(INKAR, 2002)
Overall tax gains per inhabitant	(INKAR, 2002)
Income tax gains per inhabitant	(INKAR, 2002)
Trade tax gains per inhabitant	(INKAR, 2002)
Sales tax gains per inhabitant	(INKAR, 2002)
HC potential	**sources**
Undergraduates per 1,000 inhabitants	(INKAR, 2002)
Economics & social science graduates per inhabitant	(StBA, 2000)
Math and natural science graduates per inhabitant	(StBA, 2000)
Engineering graduates per inhabitant	(StBA, 2000)
Economics & social science graduates at technical colleges per inhabitant	(StBA, 2000)
Math and natural science graduates at technical colleges per inhabitant	(StBA, 2000)
Engineering graduates at technical colleges per inhabitant	(StBA, 2000)
Economics & social science graduates at universities per inhabitant	(StBA, 2000)
Math & natural science graduates at universities per inhabitant	(StBA, 2000)
Engineering graduates per inhabitant at universities	(StBA, 2000)

Research	sources
Employees Fraunhofer-Gesellschaft per inhabitant	(Fraunhofer-Society, 2000)
Employees Max Planck Society per inhabitant	(Max Planck Society, 2000)
Employees Helmholtz Association per inhabitant	(Helmholtz-Association, 2000)
Employees Leibniz Association per inhabitant	(Leibniz-Gemeinschaft, 2000)
Total number of research employees per inhabitant	#
Regional attractiveness	**sources**
Recreation area per inhabitant	(INKAR, 2002)
Overnight stay beds for tourists per inhabitant	(INKAR, 2002)
Places in kindergarten per inhabitant	(INKAR, 2002)
Rate of moving in	(INKAR, 2002)
Rate of moving away	(INKAR, 2002)
# Own estimations.	

Table 2: Variables, principal components, and their sources

Regional factor	Proportion of variance
Industry characteristics CHEM	0.851
Industry characteristics TRANS	0.816
Industry characteristics ELEC	0.850
Industry characteristics InSTR	0.891
Urbanization	0.635
Employment structure	0.949
Available human capital	0.940
Financial situation	0.973
Economy structure	0.968
Universities & technical colleagues	0.739
Potential human capital	0.973
Research institutes	0.647
Founding situation	0.696
Regional attractiveness	0.857

Table 3: Results of principal component analysis

CHEM_IND		ELEC_IND		HC structure		Financial situation	
Empl	0.50	Empl	0.51	Young	0.41	GDP	0.41
Firms	0.48	Firms	0.48	Female	0.42	Wage	0.41
Spec	0.51	Spec	0.52	Employed	0.42	Tax_Tot	0.41
Size	0.50	Size	0.48	Unemployed	0.38	Tax_Income	0.41
TRANS_IND		INSTR_IND		Com_In	0.41	Tax_Firms	0.40
Empl	0.51	Empl	0.51	Com_out	0.41	Tax_Sales	0.41
Firms	0.45	Firms	0.49	Economic structure		Potential HC	
Spec	0.52	Spec	0.51	Sec 2	0.40	Stud	0.34
Size	0.51	Size	0.49	Sec 3	0.41	Grad_TC_Eco	0.31
Urbanization		Universities		Service	0.41	Grad_TC_Nat	0.30
Pop_den	0.44	Eng_F_Un	0.27	Turn	0.40	Grad_TC_Eng	0.33
Collect	0.41	Nat_F_Un	0.31	VA 2	0.41	Grad_Un_Eco	0.33
Work_den	0.37	Eco_F_Un	0.30	VA 3	0.41	Grad_Un_Nat	0.35
Type	0.43	Med_F_Un	0.28	HC quality		Grad_Un_Eng	0.26
R1	0.36	Eng_F_TC	0.31	Low_Skill	0.46	Grad_Eco_Tot	0.32
R2	0.09	Nat_F_TC	0.30	High_Skill	0.44	Grad_Nat_Tot	0.31
R3	0.31	Eco_F_TC	0.28	Empl_Med	0.45	Grad_Eng_Tot	0.30
Empl_den	0.27	Med_F_TC	0.12	Adult_Edu	0.43	Research	
Regional attractivity		Eng_F_Tot	0.32	High_School	0.45	FHG	0.42
Recre	0.45	Nat_F_Tot	0.33	Founding		MPG	0.44
Beds	0.40	Eco_F_Tot	0.31	Found	0.67	LEIB	0.41
Kinder	0.44	Med_F_Tot	0.28	VC	0.38	HELM	0.40
Move_in	0.47			Eco_Sup	0.64	Research_Tot	0.55
Move_out	0.47						

Table 4: Loadings

Factor	mean	sd	median	min	max	skew	kurtosis
CHEM_R&D	403.01	712.72	200.00	9.00	4398.00	4.05	17.34
TRANS_R&D	1604.49	3443.42	460.00	3.00	27732.00	5.11	32.75
ELEC_R&D	1798.02	2629.89	942.00	9.00	15428.00	3.11	11.11
INSTR_R&D	403.01	712.72	200.00	9.00	4398.00	4.05	17.34
CHEM_Ind	1.59	0.91	1.47	0.36	6.92	2.45	10.72
TRANS_Ind	1.41	1.12	1.11	0.17	6.52	1.94	4.51
ELEC_Ind	1.54	0.99	1.34	0.18	4.87	1.26	1.81
INSTR_Ind	1.66	0.89	1.47	0.37	3.81	0.65	-0.60
Urbanization	2.21	0.40	2.11	1.67	4.70	3.59	17.03
Economy structure	2.39	0.25	2.38	1.94	3.57	1.06	3.80
Available HC	2.15	0.20	2.11	1.79	2.99	1.09	1.99
HC structure	2.36	0.24	2.41	1.74	2.82	-0.59	-0.29
Potential HC	2.06	1.74	1.68	0.00	8.91	1.06	1.38
Universities	2.31	1.87	2.05	0.00	10.06	1.20	2.27
Research institutes	0.82	1.60	0.01	0.00	9.18	3.05	10.53
Founding situation	1.38	0.40	1.29	0.88	3.71	2.86	12.21
Financial situation	2.30	0.70	2.29	1.16	4.69	0.76	1.49
Regional attractiveness	2.00	0.47	1.85	1.29	3.72	1.10	1.12

Table 5: Descriptives of regional factors

	CHEM PAT	TRANS PAT	ELEC PAT	INSTR PAT	CHEM R&D	TRANS R&D	ELEC R&D	INSTR R&D	CHEM IND	TRANS IND	ELEC IND
TRANS PAT	0.14										
ELEC PAT	0.25**	0.73***									
INSTR PAT	0.43***	0.73***	0.89***								
CHEM R&D	0.94***	0.89***	0.23**	0.38***							
TRANS R&D	0.17*	0.72***	0.63***	0.62***	0.17*						
ELEC R&D	0.15	0.13	0.87***	0.83***	0.14	0.61***					
INSTR R&D	0.94***	0.11	0.23**	0.38***	1***	0.17*	0.14				
CHEM IND	0.68***	0.4***	0.14	0.26**	0.77***	0.18*	0.13	0.77***			
TRANS IND	0.06	0.32***	0.17	0.21**	0.02	0.5***	0.16	0.02	0.19*		
ELEC IND	0.14	0.48***	0.33***	0.38***	0.1	0.41***	0.44***	0.1	0.31***	0.49***	
INSTR IND	0.29***	0.32***	0.34***	0.51***	0.2**	0.32***	0.37***	0.2*	0.35***	0.45***	0.6***
Urbanization	0.31***	0.16	0.33***	0.4***	0.26**	0.21**	0.38***	0.26**	0.06	−0.02	0.08
Economy struct.	0.43***	0.25**	0.35***	0.41***	0.41***	0.29***	0.31***	0.41***	0.34***	0.2*	0.18*
Available HC	0.33***	0.41***	0.64***	0.69***	0.3***	0.32***	0.55***	0.3***	0.16	0.15	0.16
HC structure	0.14	−0.04	−0.03	−0.08	0.16	−0.01	−0.12	0.16	0.13	−0.06	−0.17
Potential HC	0.36***	0.35***	0.57***	0.62***	0.32***	0.36***	0.53***	0.32***	0.19*	0.14	0.22**
Universities	0.35***	0.32***	0.56***	0.63***	0.31***	0.35***	0.5***	0.31***	0.15	0.18*	0.18*
Research inst.	0.25**		0.64***	0.6***	0.27***	0.32***	0.52***	0.27***	0.12	0.03	0.13
Founding sit.	0.37***		0.6***	0.6***	0.3***	0.25**	0.42***	0.3***	−0.01	−0.05	0
Financial sit.	0.5***	0.41***	0.54***	0.64***	0.46***	0.41***	0.51***	0.46***	0.37***	0.27***	0.4***
Region attract.	−0.11	−0.09	−0.1	−0.14	−0.12	−0.12	−0.19*	−0.12	−0.24**	−0.08	−0.33***

	INSTR IND	Urban.	Economy struct.	Available HC	HC structure	Potential HC	Universities	Research inst.	Founding sit.	Financial sit.
Urbanization	0.19*									
Economy struct.	0.37***	0.46***								
Available HC	0.36***	0.34***	0.46***							
HC structure	−0.21**	−0.07	−0.3***	−0.09						
Potential HC	0.35***	0.6***	0.45***	0.66***	−0.02					
Universities	0.33***	0.61***	0.35***	0.58***	0.09	0.88***				
Research inst.	0.23**	0.53***	0.34***	0.65***	0.08	0.73***	0.68***			
Founding sit.	0.26**	0.34***	0.41***	0.53***	−0.08	0.44***	0.45***	0.54***		
Financial sit.	0.56***	0.43***	0.83***	0.57***	−0.31***	0.57***	0.47***	0.4***	0.5***	
Region attract.	−0.21**	−0.16	−0.19*	−0.06	0.23**	−0.11	−0.11	0	0.13	−0.26**

Table 6: Correlation structure

Table 7: Regression results CHEM

CHEM	linear model 1			log-linear model 2			model 3
	Coef	Std. Err.	Beta	Coef	Std. Err	Beta	Coef
(Intercept)	−1690.97	1425.53		−11.76***	3.8		−12.58***
R&D	0.1***	0.02	0.93	0.03***	0	0.61	0.03***
CHEM_Ind	−4.11	8.66	-0.05	0.6*	0.35	0.13	0.63*
Urbanization	15.31	14.09	0.08	0.56	0.84	0.04	0.62
HC structure	12	13.53	0.04	1.6	1.18	0.09	1.35
Economy structure	−12.48	23.23	-0.04	1.63	1.8	0.08	2.14
Financial situation	6.55	9.16	0.06	0.19	0.72	0.03	0.20
Universities	1.32	2.99	0.03	−0.09	0.28	-0.04	0.17
HC potential	1.63	3.86	0.04	0.32	0.29	0.13	
Research instit.	−9.41*	5.15	-0.19	−0.05	0.2	-0.02	-0.03
HC available	20.29	23.34	0.05	2.68	1.7	0.12	3.15*
Founding situation	21.08	14.48	0.11	0.06	0.62	0.01	−0.04
Regional attract.	0.15	5.44	0	0.25	0.56	0.03	0.30
adj. R²	0.90			adj. R² 0.76			0.76
Max VIF	6.57			Max VIF 6.15			2.97
Sig.	***			Sig. ***			
Obs.	97			Obs. 97			
LMerr	0.849			LMerr 0.532			
LMlag	0.152			LMlag 0.144			
RLMerr	1.453			RLMerr 0.287			
RLMlag	0.632			RLMlag 0.000			
Breusch-Pegan	38.531**			Breusch-Pegan 15.582			
RESET	2.899*			RESET 3.245**			
Jarque-Bera	351.452***			Jarque-Bera 1.688			
BM test	0.012			BM -0.000			
PE	25.32**			PE 0.001*			

Signif. codes: 0.01 '***' ; 0.05 '**' ; 0.1 '*' ; [1] White's heteroskedasticity corrected standard errors

TRANS	linear model 1 Coef[1]	Std. Err.[1]	Beta	log-linear model 2 Coef	Std. Err	Beta	model 3 Coef	model 4 Coef
(Intercept)	−1281.24	3365.8		−1.69	4.14		−7.11*	−8.18*
R&D	0.03*	0.02	0.83	0.01*	0	0.17	0.01***	0.01***
TRANS_Ind	6.01	9.64	0.05	0.45*	0.24	0.13	0.42*	0.45
Urbanization	−14.19	26.66	−0.04	−0.61	0.92	−0.05	−1.12	−0.93
HC structure	−19.55	32.62	−0.04	1.08	1.26	0.06	1.11	−0.78
Economy structure	−59.04	57.4	−0.11	−6.17***	2.08	−0.33		3.32*
Financial situation	9.04	44.51	0.05	5.72***	0.91	0.89	3.51***	
Universities	4.93	13.31	0.07	0.44	0.33	0.19	0.47	
HC potential	−6.45	12.47	−0.09	−0.46	0.33	−0.2		0.14
Research inst.	−3.82	10.42	−0.05	−0.03	0.22	−0.01	−0.04	−0.15
HC available	103.68	85.37	0.16	3.44*	1.87	0.16	3.39*	5.53**
Founding situation	33.19	25.05	0.1	−1.15*	0.68	−0.13	−1.1	−0.63
Regional attract.	0.98	10.92	0	−0.35	0.58	−0.04	−0.5	−0.91
adj. R²	0.8			0.69			0.65	0.55
Max VIF	6.69			6.54			2.66	2.56
Sig.	***			***				
Obs.	97			97				
LMerr	3.402*			1.410				
LMlag	1.009			0.030**				
RLMerr	2.512			0.222				
RLMlag	0.006			3.721*				
Breusch-Pegan	59.429**			7.546				
RESET	110.682***			2.401*				
Jarque-Bera	533.411***			5.122**				
BM test	0.096***			0.000				
PE test	82.911***			0.001**				

Signif. codes: 0.01 '***' ; 0.05 '**' ; 0.1 '*' ; [1] White's heteroskedasticity corrected standard errors

Table 8: Regression results TRANS

ELEC	linear			log-linear				
	model 1			model 2			model 3	model 4
	Coef[1]	Std. Err.[1]	Beta	Coef	Std. Err	Beta	Coef	Coef
(Intercept)	−2539.35	2217.61		−6.79*	3.81		−10.6***	−13.79***
R&D	0.03***	0.01	0.69	0.38***	0.08	0.4	0.42***	0.47***
ELEC_Ind	−3.49	13.6	−0.03	0.09	0.27	0.02	0.16	0.41
Urbanization	−46.6	43.14	−0.14	−0.22	0.81	−0.02	−0.66	−0.54
HC structure	34.84	29.31	0.06	1.71	1.06	0.09	1.64	1.01
Economy structure	−13.26	55.25	−0.02	−3.98**	1.87	−0.21		3.03**
Financial situation	17.12	27.47	0.09	3.58***	0.76	0.55	2.4***	
Universities	4.01	7.16	0.06	0.35	0.28	0.15	0.14	
HC potential	−3.77	11.89	−0.05	−0.29	0.27	−0.12		0.25
Research inst.	14.31	18.13	0.17	0.06	0.19	0.03	0.02	−0.08
HC available	36.3	55.01	0.06	5.11***	1.66	0.24	5.12***	6.53***
Founding situation	68.67	51.58	0.21	−0.66	0.58	−0.07	−0.79	−0.44
Regional attract.	−5.8	11.16	−0.02	−0.6	0.51	−0.07	−0.51	−0.66
adj. R^2	0.85			0.78			0.77	0.72
Max VIF	6.57			6.2			2.71	2.69
Sig.	***			***				
Obs.	97			97				
LMerr	0.781*			0.349				
LMlag	0.806			0.416				
RLMerr	2.116			0.921				
RLMlag	2.082			1.031				
Breusch-Pegan	56.86***			19.272				
RESET	85.283***			2.420*				
Jarque-Bera	108.879***			0.318				
BM test	0.082***			0.000				
PE test	122.8***			0.000***				

Signif. codes: 0.01 '***' ; 0.05 '**' ; 0.1 '*' ; [1] White's heteroskedasticity corrected standard errors

Table 9: Regression results ELEC

INSTR	linear model 1			log-linear model 2			model 3	model 4
	Coef[1]	Std. Err.[1]	Beta	Coef	Std. Err	Beta	Coef	Coef
(Intercept)	−1460.43	1480.05		0.69	3.81		−6.28*	−4.27
R&D	0.01	0.01	0.08	0.01***	0	0.23	0.01***	0.01***
INSTR_Ind	8.17*	4.71	0.15	0.8***	0.27	0.21	1.07***	1.29***
Urbanization	2.84	13.65	0.02	0.12	0.82	0.01	−0.32	0.19
HC structure	−2.76	15.29	−0.01	−1.57	1.17	−0.09	−0.99	−2.26*
Economy structure	−62.33**	25.23	−0.32	−6.52***	1.82	−0.37	−0.99	−1.18
Financial situation	28.72***	10.33	0.41	3.41***	0.76	0.57	1.32**	
Universities	6.64**	3.29	0.25	0.51*	0.28	0.23		
HC potential	−4.4	4.13	−0.16	−0.15	0.29	−0.07	0.36*	0.42**
Research inst.	4.01	3.92	0.13	0.14	0.2	0.06	0.12	0.02
HC available	68.1**	31.91	0.29	4.66***	1.68	0.24	4.59**	5.87***
Founding situation	23.51	14.35	0.19	−0.92	0.6	−0.11	−0.92	−0.63
Regional attract.	−4.19	3.79	-0.04	0.2	0.56	0.02	0.02	0.04
adj. R²	0.67			0.72			0.67	0.65
Largest VIF	7.197			6.19			2.71	2.60
Sig.	***			***				
Obs.	97			97				
LMerr	0.175			0.447				
LMlag	1.711			0.655				
RLMerr	0.158			0.535				
RLMlag	1.661			0.873				
Breusch-Pegan	18.127*			8.124				
RESET	18.962***			0.521				
Jarque-Bera	853.772***			3.201				
BM test	0.178**			0.000				
PE test	30.332*			0.000				

Signif. codes: 0.01 '***' ; 0.05 '**' ; 0.1 '*' ; [1] White's heteroskedasticity corrected standard errors

Table 10: Regression results INSTR