Berlemann, Michael; Jahn, Vera

Conference Paper

Regional importance of Mittelstand firms and innovation performance

Beiträge zur Jahrestagung des Ausschusses für Wirtschaftssysteme und Institutionenökonomik im Verein für Socialpolitik: "Marktwirtschaft im Lichte möglicher Alternativen", 27.-29. September 2015, Bayreuth

Provided in Cooperation with:

Ausschuss für Wirtschaftssysteme und Institutionenökonomik, Verein für Socialpolitik

Regional Importance of Mittelstand Firms and Innovation Performance

MICHAEL BERLEMANN[*] and VERA JAHN[†]

ABSTRACT

Despite of the deeply rooted belief of politicians from all over the world in the important role of Mittelstand firms, there has been surprisingly little empirical research on this issue, yet. This article contributes to the literature by studying whether the relative regional importance of Mittelstand firms has an effect on regional innovation performance. Using a cross section of German NUTS-3-regions, a significantly positive relation between the relative importance of owner-managed SMEs and patent applications is identified. This finding is highly robust when controlling for spatial correlations as they often occur in highly disaggregated regional analyses.

JEL: O31; C21; D23

Keywords: Innovation, Mittelstand firms, Owner-management, SMEs, Germany

[**]*Helmut Schmidt University Hamburg, Faculty of Economics and Social Sciences, Holstenhofweg 85, 22043 Hamburg, Germany.*
Email: michael.berlemann@hsu-hh.de
[†]*Helmut Schmidt University Hamburg, Faculty of Economics and Social Sciences, Holstenhofweg 85, 22043 Hamburg, Germany.*
Email: vera.jahn@hsu-hh.de

INTRODUCTION

One remarkable specialty of the German economy is the comparatively large economic importance of owner-managed small and medium sized firms (SMEs).[1] These so-called Mittelstand firms[2] are said to have been the key to Germany's postwar economic miracle (BERGHOFF, 2006). It is also argued that the strength of the German Mittelstand firms allowed Germany to cope with huge external shocks such as (the costs of) German Reunification (STUDZINSKI, 2013) or the worldwide recession of 2009 (BLACKSTONE and FUHRMANS, 2011; GIOTRA and NETESSINE, 2013). The strength of the German economy throughout the recent years made the German Mittelstand model interesting for other countries which aim at emulating it (IFM BONN, 2013a; FEAR, 2014).

Even among German politicians the belief in the Mittelstand model is deeply rooted. The report "German Mittelstand: Engine of the German economy" published by the FEDERAL MINISTRY OF ECONOMICS AND TECHNOLOGY, 2013, argues "The German economy is doing well in comparison with many other countries. This is causing people all around the world to take a particularly keen look at Germany, and especially at the 'German Mittelstand' and its longstanding record of high employment and productivity". Similar views are expressed in many political speeches. Often, German politicians praise the German Mittelstand as the "backbone of the German economy" (see, e.g., MERKEL, 2009) which is responsible for a large share of aggregate output and employment. Politicians also often claim that Mittelstand firms are highly engaged in providing apprenticeship training positions, thereby contributing to the relatively low rate of youth unemployment in Germany (MINISTRYOF ECONOMIC AFFAIRS OF NORTH RHINE WESTPHALIA, 2014). Mittelstand firms are also said to be overly innovative. The FEDERAL MINISTRY OF ECONOMICS AND TECHNOLOGY, 2013, argues "The 'German Mittelstand' companies are some of the most innovative in Europe: 54% of them launched an innovation onto the market in the 2008-2010 period". Similarly, STUDZINSKI, 2013, argues that Mittelstand companies are "readier to innovate, and invest a larger proportion of their revenues in R&D. There are Mittelstand

companies that file more patents in a year than do some entire European countries. It is one of the underlying reasons for their exporting success, even when their goods seem expensive".[3]

Somewhat surprisingly, the deeply rooted belief in the important role of Mittelstand firms is yet not adequately backed by empirical evidence. While there are numerous studies claiming to study the role of Mittelstand firms, almost all of them fail to qualify the relevant firms in an adequate way. This is primarily due to the fact that official statistics typically deliver no joint information on firm size, ownership and governance issues. In the absence of this information, most studies alternatively use the definition of SMEs, which solely recurs on firm size and fails to take the second and not least important feature of owner-management into account (WOLTER and HAUSER, 2001). A prominent example for this procedure is the earlier mentioned report of the FEDERAL MINISTRY OF ECONOMICS AND TECHNOLOGY, 2013, which claims to report on Mittelstand firms but factually relies on a pure SME definition. Similarly, the *Institut für Mittelstandsforschung Bonn* provides the following definition on its internet page: "An enterprise belongs to Mittelstand if management, liability and risk are in the responsibility of the owners (unity of ownership)".[4] However, due to unavailable data on onwership and management structure, the Mittelstand statistics provided by the institute exclusively report on SMEs.[5] While these studies deliver interesting information on the role of SMEs in general, it is far from being clear in how far their conclusions can be transferred to Mittelstand firms.

This paper aims at contributing to fill the described gap in the empirical literature on owner-managed SMEs. It examines the relation between the relative importance of owner-managed SMEs and innovation performance on the regional level (NUTS-3) in a cross section approach. In order to do so, patent data from OECD's REGPAT database are combined with data on firm ownership, governance and size from the largest German firm database maintained by *Creditreform*.[6] The analysis identifies a significantly positive and sizeable influence of the relative importance of owner-managed SMEs on relative regional innovation activity, even when controlling for a large number of potential covariates. Moreover, this finding proves to be highly robust when controlling for various sorts of spatial

correlation.

The remainder of this paper is organized as follows. The next section briefly discusses theoretical arguments supporting the view that owner-managed SMEs are overly innovative. The third section outlines the estimation approach and introduces the employed datasets. The fourth section presents the empirical results for the baseline regression. The fifth section allows for non-linearities in the relation between innovation activity and importance of Mittelstand firms. The sixth section studies the existence of spatial correlation and delivers further estimation results taking these correlations into account. The final section summarizes the main results and draws some conclusions.

THEORETICAL CONSIDERATIONS

Before turning to the empirical analysis, it seems to be useful to discuss briefly which arguments might support the view that Mittelstand firms are more innovative than others.

According to principal agent theory, owner-managed firms have financial advantages over manager-led enterprises in innovation competition and might also be more dynamic. Firms have to bear agency costs whenever strategic decisions are not made by the firm owners. In this case, owners have to spend resources on monitoring and disciplining managers. Especially the agency costs connected with innovations tend to be high. Firstly, due to the risky nature of innovation projects, principals need to observe the agents' activities intensively because output is a poor indicator of agents' effort. Secondly, risk averse agents prefer low-risk tasks instead of working in intrinsically erratic projects. Finally, innovations often are long-term projects whereas agents favor tasks influencing the present value of the firm and thus partially the agents' salaries in the short run (HOLMSTROM, 1989). Owner-managed firms have not to bear these agency costs and might use the referring resources for research and development which finally might result in innovations. Because owners decide themselves, owner-managed firms can make innovation decisions faster, which provides a time advantage in innovation competition

(PUTTERMAN, 2009; JENSEN and MECKLING, 2009; IFM BONN, 2013a). In fact, KRAFT, 1989, and IFM BONN, 2013a, find empirical evidence in favor of these theoretical considerations, discovering German owner-managed firms to show higher innovation activities than their manager-led counterparts.

Additionally, the theoretical literature considers small and medium sized enterprises to outperform large companies in terms of innovations due to less bureaucracy, short lines of communication and great agility (PARKER, 2011). Bureaucracy might counteract innovations by restricting experimentation as it often struggles with new and extraordinary projects and often does not tolerate failures in the innovation process. Extended bureaucracy might also screen out innovative personalities (HOLMSTROM, 1989). Since smaller firms tend to be less bureaucratic, they invest more likely in revolutionary innovations (which are in general characterized by high risk) than larger companies (BAUMOL, 2010). Additionally, large decision-making hierarchies tend to stick to the status quo rather than choosing a risky innovation (AUDRETSCH and KEILBACH, 2007, 2008). In expanded hierarchies a larger number of layers decide whether to initiate an innovation. However, innovation projects might counteract the interests of individual layers and thus will not be implemented. Furthermore, small firms often concentrate on few activities and hence promote innovations. The more tasks with different risk characteristics risk averse agents can engage in, the more incentives have to be provided to make them work on the risky innovation project (HOLMSTROM, 1989). Firm size also directly influences the way how firms innovate. SMEs are often active on niche markets and develop individual products together with their customers (ARVANITIS, 1997; BIZER and THOMÄ, 2013; IFM BONN, 2013b). ACS *et al.*, 2002, find empirical evidence in favor of these theoretical considerations, detecting SMEs in the U.S. to be more innovative than their larger counterparts.

According to FAMA and JENSEN, 1983, owner-management especially makes sense in small non-complex firms, thereby strengthening the advantages of small enterprises. One might therefore expect that owner-managed SMEs outperform other sorts of firms in terms of innovations. However, to the best of the authors' knowledge, the case of Mittelstand firms has yet not been studied empirically.

BAUMOL, 2010, argues that the optimal amount (and type) of innovations occurs in economies which consist of a healthy mix of large market players and SMEs.[7] This line of argument is driven by the idea of a division of labor between larger and smaller companies, which BAUMOL, 2010, also refers to as David-Goliath partnership. SMEs and large companies tend to specialize in different but complementary components of the innovation process, both necessary to generate the optimal amount of innovations. While smaller firms on average generate the more promising and radical but also more risky innovations, large enterprises minimize their risk by specializing in incremental innovations. For example, larger companies often aim at increasing reliability and user-friendliness in mass production of basic innovations, originally invented by SMEs (BAUMOL, 2010; BAUMOL *et al.*, 2007). Whenever this line of argument holds true, one might expect a somewhat non-linear relationship between the regional importance of Mittelstand firms on the one hand and regional innovation activity on the other.

METHODOLOGY AND DATA

Methodology

This paper aims at studying whether there is a systematic relation between the level of innovations which occurs in a region and the relative importance of owner-managed firms of small or medium size. The estimation approach consists of regressing an indicator of regional innovation activity on the relative importance of locally operating owner-managed SMEs and a number of additional, potentially meaningful control variables. As explained later in more detail, regional importance is measured by the share of Mittelstand firms in all economically active firms in a region. As the relative importance of owner-managed SMEs is available only for the year 2008, the subsequent analysis focuses on the referring cross section.[8] In order to have enough degrees of freedom for the estimation, the analysis is conducted on the NUTS-3-level.[9] The empirical approach thus consists of estimating the following regression

$$Inn_i = \alpha + \beta\ OMSME_i + \gamma X_i + \epsilon_i \quad (1)$$

with Inn being a proxy for regional innovation performance,$OMSME$ being the relative importance of owner-managed SMEs and X being a vector of control variables. The index i denotes the region, an observation comes from, ϵ is the error term and α, β and γ are the parameters to be estimated. In the baseline version of the model the regression is estimated using the OLS technique and assumes the relationship of central interest between regional innovation performance and relative importance of Mittelstand firms to be linear. In the second step of the analysis the relation is allowed to be non-linear and is estimated using non-parametric estimation techniques. Finally, as the regressions are estimated on the NUTS-3-level and might therefore be confronted with spatial dependencies as a consequence of commuting behavior and spillover effects, a detailed analysis of spatial correlation is conducted.

Regional Innovation Activity

In line with most of the existing literature (see, e.g., GRILICHES, 1990; LYBBERT and ZOLAS, 2014; GOTO *et al.*, 2010; MOSER and VOENA, 2012), the analysis in this paper employs patents as intermediate output measure for innovations. In order to measure German regional innovation activity, patent applications to the European Patent Office from applicants located in Germany are used. The patent data were extracted from the REGPAT database (January 2013 edition) maintained by the OECD. However, using patent applications as indicator of regional innovation performance has several problems to be solved. First, not all inventions are patentable or should be patented according to the will of the inventors (GOTO *et al.*, 2010; GRILICHES, 1990). Therefore, the absolute number of patent applications would underestimate the factual number of innovations. Second, the share of inventions, inventors choose to protect by applying for patenting, differs widely across industries. Thus, regions with differing sector structures, like the German NUTS-3-regions, are hardly comparable on the basis of simple patent counts. Therefore, as GRILICHES, 1990, argues, when evaluating regional innovation activity, industrial structure should be

taken into account. Third, the share of patented inventions might change in the course of time (MOSER, 2013). However, since the subsequent analysis only uses a cross section of data this problem is obviously absent in the analysis. In order to deal adequately with the first two problems, the analysis proceeds as follows. Since there is no reliable information on the share of patented innovations, no attempt is made to try to construct an indicator of absolute innovation activity. Instead, a measure of relative innovation activity is derived. In addition, the measure controls for the industrial structure of German regions.[10] However, German NUTS-3-regions do not only differ in their industrial structures, but also in the total number of locally operating enterprises. Therefore, the indicator controls for the number of enterprises on the regional level as well. Data on the total number of economically active enterprises per region were extracted from the *Creditreform* database. *Creditreform* is the largest German company information service, collecting data on economically active firms in Germany. The database contains 3,954,721 economically active firms located in Germany at the end of the year 2008.[11] The database includes information on the location of firms' headquarters and on the industrial sector in which an enterprise generates its largest turnover.

The indicator of relative innovation activity of German NUTS-3-regions is calculated by comparing the expected number of patents per region with the number that actually occurs.[12] A region is judged to be overly (insufficiently) innovative whenever a region generates more (less) patents per enterprise than an imaginary German region with the same sector structure. Let I be the number of regions, J the number of sectors, $P_{i,j}$ the number of patents in region i and sector j and $N_{i,j}$ the number of firms in region i and sector j. Factual patent density in region i is then given by

$$D_i := \sum_{j=1}^{J} \frac{P_{i,j}}{N_{i,j}} * \frac{N_{i,j}}{N_i} \tag{2}$$

with N_i being the number of firms in region i, i.e.

$$N_i = \sum_{j=1}^{J} N_{i,j} \tag{3}$$

Whenever firms within the same sector perform similarly in terms of generating innovations in all

regions, patent density should vary one to one with the structure of the regional economy. Expected patent density can be calculated as

$$D_i^e := \sum_{j=1}^{J} D_j * \frac{N_{i,j}}{N_i} \quad (4)$$

with D_j being average patent density in sector $j$over all regions i, i.e.

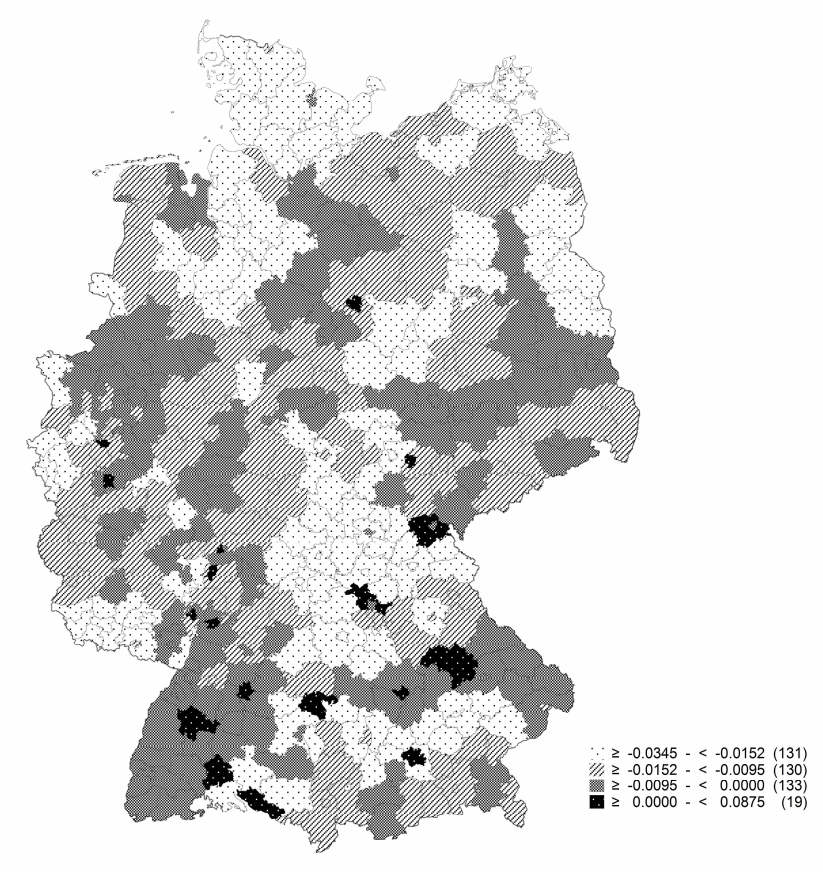
$$D_j = \frac{\sum_{i=1}^{I} P_{i,j}}{\sum_{i=1}^{I} N_{i,j}} \quad (5)$$

Relative innovation performance of region i is then defined as

$$R_i := D_i - D_i^e \quad (6)$$

Positive values of R_i go along with overly innovative regions, while negative values indicate underperforming regions.[13] Figure 1 shows the results on the NUTS-3-level.

Figure 1: Relative regional innovation activity by NUTS-3-regions in Germany, 2008

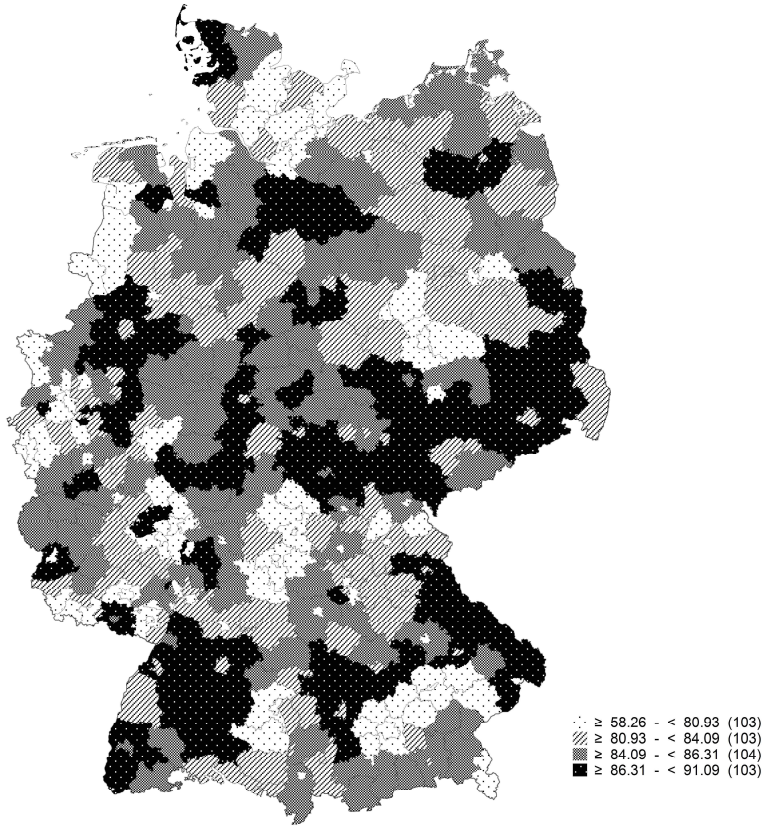


Regional Importance of Owner-Managed SMEs

In order to measure the relative importance of owner-managed SMEs on the NUTS-3-level, the earlier mentioned *Creditreform* database is employed. This database allows classifying enterprises by management structure as well as by firm size. More precisely, the database contains information on the legal form, the owners and the chief operating officers of an enterprise. Moreover, the database reports the companies' turnover and the number of employees which are subject to social insurance contribution (minijobs are thus excluded). Using this information owner-managed SMEs can be adequately identified. Firms are considered to be owner-managed whenever the chief operating officers of an enterprise also own (at least parts of) the enterprise. However, as the advantage of owner-managed firms tends to diminish with an increasing number of decision makers, this paper follows BERLEMANN *et al.*, 2007, and restricts the maximum number of chief operating officers, which are considered to be classified as owner-managed firms, to four.[14] Since the analysis focuses on owner-managed SMEs only, the definition of SMEs is applied to the identified owner-managed firms. When doing so, the valuesof the definition of the *Institut für Mittelstandsforschung Bonn* are used. Thus, SMEs are classified as firms with less than 500 employees or an annual turnover of less than 50 million Euros.[15]

By applying this procedure, 3,228,778 German firms are classified as owner-managed SMEs, 81.64 percent of total enterprises. Note that the share of owner-managed SMEs in all firms is still large but considerably lower than in the statistics published by the *Institut für Mittelstandsforschung Bonn* as this statistics is factually based solely on the SME definition. Note also that there are practically only very few large firms which are owner-managed. In order to measure the relative importance of owner-managed SMEs on the regional level, the number of owner-managed SMEs is divided by the total number of all economically active firms on the NUTS-3-level.[16] Figure 2 shows the relative regional importance of owner-managed SMEs.

Figure 2: Relative regional importance of owner-managed SMEs by NUTS-3-regions in Germany in percent, 2008



Additional Control Variables

Besides the relative importance of owner-managed SMEs, various additional factors might affect regional innovation activity.

In line with the existing literature, firms' expenditures for research and development are expected to have a positive impact on innovation activity (CÁCERES *et al.*, 2011; JAFFE, 1986; FRANKE and FRITSCH, 2004). Therefore, internal investments in research and development per enterprise by NUTS-3-regions are used as control variable. In order to take potentially decreasing marginal returns into account, investments are added as a quadratic polynomial to the regression equation as well (ARVANITIS, 1997).[17] Data on absolute investments in research and development on the regional level were provided

on request by *Stifterverband*.[18] In order to calculate investments per enterprise, the total number of enterprises on the regional level from the *Creditreform* database is used.[19]

Moreover, regional knowledge spillovers from universities to enterprises might positively affect innovation activity (see, e.g., PIERGIOVANNI and SANTARELLI, 2001; BAUMERT *et al.*, 2010; AUDRETSCH and VIVARELLI, 1996). According to BAUMOL, 2010, universities play an essential role in the innovation process. Universities provide highly risky basic research that serves as a basis for applied research in private companies. Additionally, universities are also active in applied research. However, when universities leave applied research uncommercialized as a result of the uncertainty inherent in new ideas, this knowledge might serve as a basis for starting a new enterprise in order to exploit that knowledge (AUDRETSCH and KEILBACH, 2007). Thus, the absolute number of scientists at universities and universities of applied sciences by NUTS-3-regions is included into the regression equation to control for knowledge spillovers from research institutions to the local economy. The referring data were provided by the Federal Statistical Office on request.

However, innovating companies might not only benefit from research institutions in terms of knowledge spillovers. Additionally, universities provide skilled human capital necessary for innovation activities in firms (BAUMERT *et al.*, 2010; AUDRETSCH and VIVARELLI, 1996; BRENNER and BROEKEL, 2011). Thus, one might expect the regional supply of skilled human capital to have a positive influence on innovation activity (BAUMERT *et al.*, 2010). Theestimation approach therefore also controls for the regional share of employees with a degree in professional schools, universities of applied sciences or universities in all employees subject to social insurance contribution. The necessary data were provided by the Statistical Office of Lower Saxony.

In line with the existing literature (AUDRETSCH *et al.*, 2012; BAUMERT *et al.*, 2010; PFIRRMANN, 1994), regional indicators like economic prosperity and population density are included in the regression analysis. Economic prosperity may be an indicator for a high level of domestic demand for high quality consumer goods (BAUMERT *et al.*, 2010) as well as for the availability of capital for investments in

innovation processes (BRENNER and BROEKEL, 2011). One might therefore expect economic prosperity to have a positive influence on innovations. Regional economic prosperity is measured by GDP per capita. Data were extracted from the databases of the Statistical Offices of the Länder. Population density is measured by population per square kilometer. The referring data were provided by the Federal Institute for Research on Building, Urban Affairs and Spatial Development.

In the case of Germany, it might also play a role in which part of Germany a region is located. One might suspect a systematic difference of innovative performance in East and West Germany, which were reunified not before 1990 and therefore still might differ to some extent (AUDRETSCH *et al.*, 2012; FRANKE and FRITSCH, 2004). Thus, a dummy variable expressing whether a region is located in the former East or West Germany is added to the estimation equation.

Numerous empirical studies on innovation activity also control for the regional industrial structure (see, e.g., SCHWALBACH and ZIMMERMANN, 1991; BRENNER and BROEKEL, 2011). However, the subsequent analysis refrains from doing so as the dependent variable already accounts for the regional industry structure. For a detailed description of the employed variables see Table 1. Descriptive statistics of the used variables are shown in Table 2.

Table 1. Description of employed variables

Variable	Description	Source
Inn	Relative regional innovation activity by NUTS-3-regions, Germany, 2008 $Factual\ patent\ density - Expected\ patent\ density$	Calculations from BERLEMANN and JAHN, 2013, based on the OECD REGPAT database, January 2013 edition, and on the *Creditreform* database, 2008 [a]
OMSME	Number of owner-managed SMEs relative to all enterprises by headquarters by NUTS-3-regions in percent, Germany, December 31, 2008 $\frac{Number\ of\ owner-managed\ SMEs}{Number\ of\ all\ firms}$	*Creditreform* database, 2008 [a]
RD	Internal investments in research and development per enterprise in thousand Euros by headquarters by NUTS-3-regions, Germany, average over 2007 and 2009 [b] $\frac{Investments\ in\ research\ and\ development}{Number\ of\ all\ firms}$	*Stifterverband* [a]
RD^2	Squared RD	
Univ	Number of academic and artistic personnel at universities and universities of applied sciences by NUTS-3-regions, Germany, 2008. In order to deal adequately with scientists working part-time, full-time equivalent values are reported.	German Federal Statistical Office [a]
Edu	Share of employees with degree in professional school, university of applied sciences or university in all employees subject to social insurance contribution at place of work by NUTS-3-regions in percent, Germany, June 30, 2008 $\frac{Number\ of\ skilled\ employees}{Number\ of\ all\ employees}$	Statistical Office of Lower Saxony, 2010
GDP	GDP per capita at current prices in thousand Euros by NUTS-3-regions, Germany, 2008	Statistical Offices of the Länder, 2010
PD	Population density measured as population per square kilometer, Germany, 2008	Federal Institute for Research on Building, Urban Affairs and Spatial Development
East	East Germany dummy variable (including Berlin)	

[a] Special analysis on request.

[b] Value for 2007 of Schweinfurt is missing.

Table 2. Descriptive statistics of dataset

Variable	Min	1st Quantile	Median	Mean	3rd Quantile	Max	Width	Standard deviation
Inn	-0.0345	-0.0169	-0.0112	-0.0116	-0.0078	0.0875	0.1219	0.0105
OMSME	58.26	80.9	84.1	83.1	86.3	91.09	32.83	4.809
RD	0.0203	1.0	2.8	9.1	6.8	588.9621	588.9417	34.28
Univ	0	0	0	416	152	12,350	12,350	1,196
Edu	2.8142	5.35	6.97	7.82	9.17	25.3362	22.5220	3.652
GDP	13.263	21.6	25.8	28.5	31.6	85.403	72.1	10.86
PD	38.2	114	199	522	674	4,274.5	4,236.3	674
N = 413								
N East = 87								

BASELINE RESULTS

Table 3 reports the results of the baseline regression approach, explaining relative innovation activity (*Inn*) of German NUTS-3-regions[20] by the share of owner-managed SMEs (*OMSME*) and the described control variables in the 2008 cross section. The second column displays the estimated coefficients, the third column the resulting standard errors, and the fourth column the p-values. The fifth column informs on the standardized coefficients.[21] The coefficients are estimated using the OLS method. The table reports White-corrected standard errors. The regression explains 53.4 percent of the observed variation in relative regional innovation performance.

Table 3. Determinants of relative regional innovation activity (*Inn*)

	Coefficients	Standard errors	p-values	Standardized coefficients
(Intercept)	-0.1251	0.0099	0.0000	
OMSME	0.0012	0.0001	0.0000	0.5533
RD	0.0003	0.0001	0.0067	
RD^2	-0.0004	0.0002	0.0107	
Univ	0.0000	0.0000	0.0417	0.1002
Edu	0.0004	0.0002	0.0110	0.1422
GDP	0.0002	0.0001	0.0007	0.2170
PD	0.0000	0.0000	0.0065	0.1492
N	413			
adj. R^2	0.534			
F-value	68.3 (0.0000)			

Since the coefficient of the East German dummy variable turns out to be insignificant, the dummy variable is excluded from the baseline regression and the following empirical analyses. All other employed control variables seem to perform well in the sample. The estimated coefficients turn out to be significant at least on the 90-percent confidence level, most of them on even higher levels. Moreover, the coefficients turn out to have the expected sign.

An analysis of bivariate correlations and variance inflation factors indicate that the estimations do not suffer from any multicollinearity problems.

Concerning firms' investments in research and development, a positive non-linear impact on innovation performance is found. This result confirms the empirical findings of ARVANITIS, 1997, suggesting diminishing returns to research and development expenditures. However, just as in ARVANITIS, 1997, concentrating on the practically relevant part of the function, the impact of investments in research and development turns out to be linear. Running the regression without the Wolfsburg region, which might be classified as an outlier with respect to investments in research and development, the coefficient of RD^2 is no longer significant while the remaining estimates remain virtually unchanged. One might therefore argue that research and development expenditures in general

have a significantly positive linear influence on innovations. This result is in line with most of the existing literature.

According to the estimation results, the total number of scientists at universities and universities of applied sciences in a region tends to promote regional innovation activity. This result is even consistent with the existing literature, indicating knowledge spillovers from universities to enterprises within the same region.

Furthermore, a significantly positive impact of the regional supply of skilled human capital on innovation performance is detected. This finding indicates skilled employees to be a necessary input factor to innovation activities in firms.

Moreover, the analysis shows a significantly positive impact of economic prosperity and population density on regional innovation activity. The influence of economic prosperity on innovations is the second largest among the explanatory variables. Regions with high population density on average tend to be more innovative than less densely populated regions.

The variable of central interest, the share of owner-managed SMEs ($OMSME$) turns out to have a positive impact on a region's relative innovation activity. Hence, regions possessing a relatively large amount of owner-managed SMEs tend to be more innovative than regions having a relatively small number of owner-managed SMEs. The estimated coefficient is highly significant and sizeable as it has a larger standardized coefficient than all other included control variables. A regression without the relative importance of owner-managed SMEs as independent variable delivers an adjusted R-squared of only 33.8 percent. Thus, the share of owner-managed SMEs in all economically active firms explains a considerable part of relative regional innovation performance.

Altogether, the results of the baseline regression are thus supportive to the hypothesis that owner-managed SMEs generate above-average levels of innovations. Interestingly enough, the results remain highly stable when extending the analysis to all owner-managed firms, regardless of their sizes. However, this finding can be attributed to the fact that there are only very few large owner-managed

firms. Thus, the relative regional importance of owner-managed companies is very similar to the one of owner-managed SMEs.

In order to check the stability of the results, the existence of possible outliers is examined. Three regions might be classified as outliers: First, the urban district Ludwigshafen exhibits a relatively high regional innovation activity. In Ludwigshafen (hosting the large chemical producer *BASF*) the relative number of patent applications per enterprise exceeds the German average by 0.0875. Second, the urban region Wolfsburg in Lower Saxony shows a relatively high amount of investments in research and development as well as a relatively large GDP per capita. These findings can be attributed to the large *Volkswagen Company* located in Wolfsburg. Third, the German capital Berlin hosts a relatively large number of scientists at universities and universities of applied sciences. However, Berlin is not only Germany's capital but also the largest German city. Running regressions without these three potential outliers leads to similar outcomes as in the analysis including all 413 German regions, at least with respect to direction and significance of the OMSME-coefficient. Therefore, all regions are kept in the sample in the following empirical analysis.

IS THE RELATION BETWEEN INNOVATIONS AND IMPORTANCE OF MITTELSTAND FIRMS NON-LINEAR?

The empirical approach employed in the previous section assumed the relation between regional innovation activity and relative importance of Mittelstand firms to be linear. In the next step of the analysis this assumption is relaxed, as the relationship between both variables might also be non-linear. As discussed in the second section one might suspect that there is an optimal mixture of owner-managed SMEs and large and/or outside managed firms. In this case one should expect an inverse U-shaped relation between regional innovation activity and relative importance of Mittelstand firms.

In order to study this question, a semi-parametric additive mixed model (see, e.g., WOOD, 2006;

ZUUR *et al.*, 2008) of the type

$$Inn_i = \alpha + \beta\, f(OMSME_i) + \gamma X_i + \epsilon_i \qquad (7)$$

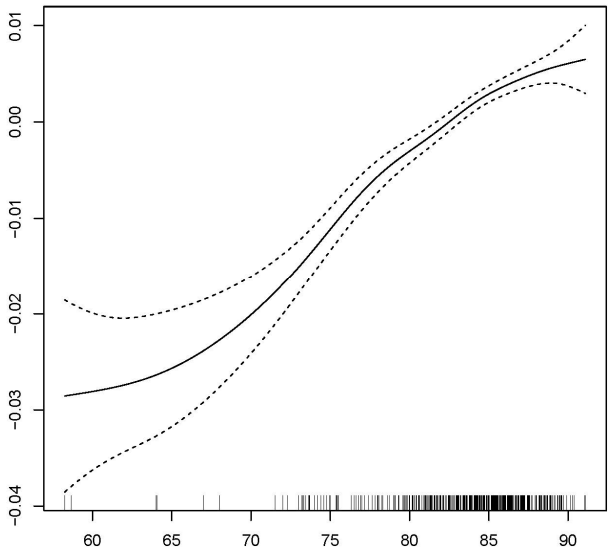
is estimated. The major difference to the earlier estimated model is that $f(OMSME_i)$ is now a sufficiently smooth but a-priori unspecified function in the corresponding range of the covariate which is estimated from the data. Due to the large number of parametric components of the estimation equation, using the maximum likelihood technique would lead to "badly biased" estimators (see WOOD, 2006). The model is therefore estimated using the restricted maximum likelihood (REML) technique (see FAHRMEIR *et al.*, 2013) using penalized spline smoothing to generate a sufficiently smooth function.[22]

Table 4 reports the estimation results of the parametric part of the estimation. Obviously, the results are very similar as those reported in the previous section. All control variables have the expected sign and are significant on at least the 95-percent-level.

Table 4. Semi-parametric regression of determinants of regional innovation activity (*Inn*)

	Coefficients	Standard errors	p-values
(Intercept)	-0.0245	0.0015	0.0000
RD	0.0003	0.0000	0.0000
RD^2	-0.0004	0.0001	0.0000
Univ	0.0000	0.0000	0.0155
Edu	0.0004	0.0001	0.0060
GDP	0.0002	0.0000	0.0000
PD	0.0000	0.0000	0.0031
N	413		
adj. R^2	0.545		

Figure 3: Non-parametric influence of *OMSME* on *Inn*



The estimation results for the regional importance of owner-managed SMEs, entering the estimation equation as a-priori unspecified function, are visualized in Figure 3. The solid line shows the functional effect, which is, for reasons of identifiability, centered around zero (see Fahrmeir *et al.*, 2013). The dashed lines depict the 95-percent point-wise confidence bands. As it is easily visible, the marginal effect of *OMSME* is positive over the entire estimation interval. While the effect is not completely linear, at least for the area including the vast majority of observations (roughly 71 percent to 90 percent) the effect is very close to being linear.[23] Thus, little evidence for non-linearities in general and thus also no supporting evidence in favor of the hypothesis of an inverse U-shaped relationship is found. Of course, it cannot be ruled out completely that for very high levels of *OMSME* the marginal effect becomes negative as there are too less observations to estimate the effect in this range reliably. However, it can be concluded that sticking to the earlier applied linear estimation approach is appropriate for the dataset at hand.

SPATIAL CORRELATIONS

While using data on the NUTS-3-level allows estimating the relationship between innovation activity and the importance of owner-managed SMEs on the basis of 413 observations, this comes at the price that the underlying data might exhibit a significant degree of spatial correlation. In the presence of spatial correlation, OLS in many cases does not deliver best linear unbiased estimators (KEILBACH, 2000; LERBS and OBERST, 2014; ECKEY *et al.*, 2007). Since the previously conducted analysis relied on the OLS procedure, it is necessary to study whether the estimations are suffering from spatial correlation. Moreover, whenever indications of spatial correlations are found, it is necessary to study whether the results from the baseline regression hold even when controlling for the relevant form of spatial correlation.

The idea of spatial correlation goes back to Tobler's first law of geography, stating that everything is interacting but interaction weakens with increasing space (ANSELIN, 1988a). Three types of spatial dependencies might occur in linear regressions.

First, the error terms might be correlated in space. In this case the innovation performance of the referring region depends not only on a set of observed characteristics of the same region but also on unobserved characteristics omitted from the model that neighboring regions have in common (ELHORST, 2014). In the presence of spatial residual autocorrelation, OLS no longer leads to efficient estimates (LERBS and OBERST, 2014). Hence, spatial error models of the type

$$Y = \alpha + \beta X + u, \;\; u = \lambda W u + \epsilon, \;\; \epsilon \sim N(0, \sigma^2) \tag{8}$$

have to be used. Y is the dependent variable, X is a vector of independent variables, W is the contiguity matrix describing the spatial arrangement of the relevant area, u is the spatially dependent and ϵ a normally distributed error term. The parameters to be estimated are α, β and λ.

Second, there might be spatial autocorrelation in the dependent variable. In the context of this paper, innovation performance of a region might be influenced by innovation activities of the

neighboring regions. In the presence of spatial autocorrelation in the dependent variable, OLS estimators are biased (LERBS and OBERST, 2014; KEILBACH, 2000). In this case, a spatial lag model of the form

$$Y = \rho WY + \alpha + \beta X + \epsilon, \;\; \epsilon \sim N(0, \sigma^2) \tag{9}$$

should be implemented. Here, the parameters to be estimated from the data are α, β and ρ.

Third, the explained variable might not only depend on the explanatory variables of the same region but also on their spatial lags. As an example, innovation activity of a region might be related to the number of scientists at universities located in neighboring regions as well. In the presence of spatially lagged independent variables, the appropriate spatial lag model to be estimated becomes

$$Y = \alpha + \theta WX + \beta X + \epsilon, \;\; \epsilon \sim N(0, \sigma^2) \tag{10}$$

with θ being the vector of coefficients of the spatial lags of the explanatory variables to be estimated from the data.

However, the three described forms of spatial correlation might also occur in combination. The spatial Durbin model allows for spatially autocorrelated dependent variables together with spatially lagged independent variables (ELHORST, 2010).

In the following it is studied whether and which of the described forms of spatial correlation turn out to exist in the dataset. The estimation strategy follows the general-to-specific approach and starts with the OLS model. Afterwards it is tested whether the model needs to be extended with spatially lagged variables and/or error terms (ELHORST, 2010). In order to test for spatial dependence, first the contiguity matrix has to be defined. As this type of contiguity matrix is recommended in the literature (see, e.g., KEILBACH, 2000), the subsequent analysis uses a row standardized contiguity matrix of style *queen* including only regions next to the one under consideration. Row standardization means that a neighbor's impact on the referring region is equal to the average of all neighbors' influences.

In order to test whether spatial interactions exist, a Moran's I-test is used (KEILBACH, 2000; ANSELIN, 1988a). Moran's I identifies weak but significant spatial autocorrelation in the OLS residuals.[24] As the OLS baseline regression does not explicitly control for spatial dependencies, they are reflected in

the residuals. In order to extend the OLS model by spatial correlations, a model with spatially lagged independent variables is estimated (ELHORST and VEGA, 2013). However, Moran's I still shows highly significant spatial autocorrelation in the residuals (0.1840). Therefore, Lagrange-Multiplier-tests are applied to discover whether a spatial error model or a model with a spatially lagged dependent variable might be appropriate to capture the existing spatial dependencies (ANSELIN, 1988b). The Lagrange-Multiplier-tests find both models to be potentially adequate and therefore robust Lagrange-Multiplier-tests have to be used. The robust tests support the spatial error model, whereas the hypothesis of no spatially lagged dependent variable can no longer be rejected (ELHORST, 2014; ANSELIN and FLORAX, 1995; SELDADYO, 2010). The referring results are summarized in Table 5.

Table 5. Results of Lagrange-Multiplier-tests

	LM test	p-values
LMerr	30.82	0.0000
LMlag	22.4	0.0000
RLMerr	8.648	0.0033
RLMlag	0.2276	0.6333

Hence, a spatial error model is estimated instead of a model with spatially lagged dependent variable. However, the spatial error model might suffer from omitted variable bias since it does not contain spatially lagged dependent and explanatory variables. In this case, the spatial Durbin model would be appropriate, nesting the spatial error model (FISCHER and LESAGE, 2008). Although a Likelihood-ratio-test technically detects the spatial error model to be sufficient to describe the underlying data (ANGULO and MUR, 2012), a spatial Durbin model is estimated in order to protect against omitted variable bias. The spatial Durbin model produces unbiased coefficient estimates even when the data generating process follows another spatial regression specification with one or two types of spatial dependence (ELHORST, 2010; LESAGE and PACE, 2009).

Table 6. OLS and spatial models of regional innovation activity (*Inn*)

				Spatial Durbin		
	OLS	OLS with spatially lagged explanatory variables	Spatial error	Direct effects	Indirect effects	Total effects
(Intercept)	-0.1251***	-0.1354***	-0.1224***			
OMSME	0.0012***	0.0012***	0.0012***	0.0012***	0.0002	0.0014***
RD	0.0003***	0.0003**	0.0003***	0.0003***	-0.0000	0.0002**
RD^2	-0.0004**	-0.0004**	-0.0004***	-0.0004***	0.0001	-0.0003
Univ	0.0000**	0.0000**	0.0000**	0.0000*	-0.0000	0.0000
Edu	0.0004**	0.0006**	0.0005***	0.0006***	-0.0004	0.0002
GDP	0.0002***	0.0002**	0.0002***	0.0002***	0.0002*	0.0004***
PD	0.0000***	0.0000**	0.0000***	0.0000**	0.0000	0.0000*
OMSME.lag		0.0001				
RD.lag		0.0000				
RD^2.lag		0.0001				
Univ.lag		0.0000				
Edu.lag		-0.0004				
GDP.lag		0.0002*				
PD.lag		0.0000				
adj. R^2	0.534	0.532				
F-value	68.3***	34.4***				
Nagelkerke			0.5752		0.58	
ρ					0.3799***	
λ			0.387***			

*** 1%, ** 5%, * 10%

The results from these estimations are shown in Table 6.[25] Again, the table reports White-corrected standard errors in the OLS regressions. The regression coefficients of the spatial Durbin model, as a model containing a spatially lagged dependent variable, should not be interpreted because they fail to take feedback effects into account (LeSage and Pace, 2009; Gleditsch and Ward, 2007; Elhorst, 2014). Feedback effects result from the spatial interaction of the dependent variable and describe impacts that affect the dependent variable of a particular region, pass on to surrounding regions and back to the referring region (Elhorst, 2014; Gleditsch and Ward, 2007; Fischer and LeSage, 2008). Since the regression coefficients of the spatial Durbin model do not take feedback effects into

account, the coefficients of the spatial Durbin model are not interpreted, here.Instead, direct, indirect and total effects that include feedback effects are calculated. Direct effects describe the influence of an explanatory variable on the dependent variable within the same region. Indirect effects, also referred to as spillover effects, measure the change in the explained variable of a particular region due to an increase in an explanatory variable in all other regions. Total effects are the sum of the direct and indirect impacts (LeSage and Pace, 2009; Fischer and LeSage, 2008). Total effects describe the overall effect on the dependent variable of the referring region due to nationwide changes in an explanatory variable.

Interestingly enough, the model with spatially lagged explanatory variables as well as the spatial error model show nearly the same results as the simple OLS approach employed in the baseline regression. Even the spatial Durbin model, combining spatial correlations in various variables, leads to very similar findings. Especially the influence of the relative importance of owner-managed SMEs turns out to perform highly robust across all applied estimation approaches both in direction and size. Hence, although controlling for various forms of spatial dependence, a significantly positive impact of the regional share of owner-managed SMEs on innovation performance within regions is found.[26] Moreover, the spatial Durbin model finds this effect even to increase when surrounding regions are taken into account. Thus, the relative number of owner-managed SMEs tends to influence innovation activity significantly positive on the regional as well as on the national level.

LIMITATIONS AND CONCLUSIONS

The empirical analysis in this paper is concerned with the model of owner-managed SMEs, the so called Mittelstand firms, which are especially common in Germany and which are often praised for being overly innovative. Based on a macroeconomic analysis on the regional level for Germany, regions with a high share of Mittelstand firms are found to generate more patent applications than comparable regions with less owner-managed SMEs. Moreover, this relation is found to be linear rather than non-linear.

While it seems to be natural to attribute the surplus in regional patent applications to the regionally operating Mittelstand firms, it cannot be ruled out this to be the false conclusion as it is also possible that large or not owner-managed firms are more innovative in the presence of a high share of regionally competing owner-managed SMEs. In order to proof that in fact the additional innovations occur in Mittelstand firms, a firm level analysis would be necessary, which was infeasible with the dataset at hand. While this issue has to be left open for future research, the result is less important for policy conclusions to be drawn. Whenever regions with a higher relative importance of Mittelstand firms perform better in innovation activity, supporting policies for such a firm structure tend to be justified, regardless in which firms the additional innovations occur.

NOTES

[1]For an international comparison of the importance of owner-managed SMEs see TCHOUVAKHINA and SCHWARTZ, 2013.

[2] The term "Mittelstand" is not always used consistently in the literature. In Germany, the term Mittelstand goes well beyond the dimension of firm size. While there is some discussion on the most adequate definition of Mittelstand firms even in Germany (see, e.g., BERGHOFF, 2006), there is consensus that the most remarkable characteristic of Mittelstand firms is unity of ownership and management of an enterprise (IFM BONN, 2015). Outside Germany, the term Mittelstand is often used as a synonym for SMEs. However, as the analysis in this paper is interested in the performance of the German specialty of small and medium sized owner-managed firms, it sticks to the German definition.

[3] Similar views are expressed by the GERMAN INSTITUTE FOR ECONOMIC RESEARCH, 2012, the FEDERATION OF GERMAN INDUSTRIES, 2012, and PAUST, 2014.

[4]IFM BONN, 2015.

[5]Other examples for this procedure are, e.g., AUDRETSCH and ELSTON, 1997, ICKS, 2006, and MAAß and

FÜHRMANN, 2012.

[6]While the microdata in the REGPAT database were fully accessible, this holds not true for the *Creditreform* database. While this database contains data on the micro level, we were not given full access to the dataset. Instead, the *Creditreform* company assembled the necessary data for us on the regional level. As a consequence, matching on the micro level was impossible. The present paper therefore has to rely on a macro approach on the regional level.

[7]FEHL, 1988, also argues in favor of a healthy mix of large and small market players in economies, however without referring explicitly to innovation.

[8]As no obvious instrument variable is available for owner-managed SMEs there are little possibilities to control for endogeneity. However, there is neither a credible theoretical argument for reverse causality nor empirical evidence pointing in this direction (see, e.g., CZARNITZKI and KRAFT, 2004).

[9]This methodology is also used by BLOCK and SPIEGEL, 2013, analyzing the relation between the relative regional importance of medium- to large-scale family firms and regional innovation output.

[10]Instead of controlling for industrial structure by transforming the left-hand variable one might also think of adding variables measuring regional sector importance on the right-hand side of the estimation equation. However, as detailed data on almost 90 sectors are employed in the analysis, doing so would lead to a large loss in degrees of freedom for the estimation. The situation becomes even worse when studying spatial lags of the independent variables. The dependent variable is therefore corrected for sectoral structure.

[11]For a small number of firms, no information on the location was available. These observations were dropped from the sample.

[12]For a more detailed elaboration see BERLEMANN and JAHN, 2013.

[13]Note that the applied procedure has some similarities to the well-established shift-share analysis (see DUNN, 1960, and ESTEBAN-MARQUILLAS, 1972). As in shift-share analysis, this paper assumes that

regional industrial structure has an impact on regional (innovation) performance. To make the regions comparable, the measure of regional performance is corrected for industrial structure.

[14]Obviously, firms with one owner-manager are clearly owner-managed firms. However, sticking to this very narrow definition would rule out many family firms, which have more than one but only a few owner managers and thus still follow the model of the classic Mittelstand firm. The same holds true for many start-ups in which a few owner-managers found a firm, thereby exploiting their differing job background. However, it seems not to be useful to extend the number of owner-managers by too much as then the typical advantage of owner-managed firms - flat hierarchies, little organizational slack and quick decisions - are typically lost.

[15] When applying this definition, most owner-managed firms are classified as Mittelstand firms. However, a significant share of SMEs turns out not to be owner-managed.

[16]As the *Creditreform* database contains information on turnover and employment one might think of measuring the regional importance by the turnover (employment) share of Mittelstand firms. However, for many small but also for a considerable number of medium sized firms, the turnover and employment data are missing while for large firms the dataset contains no missings at all. While owner-managed SMEs are thus classified correctly (based on the earlier described definition), there is no adequate information on the turnover or employment share of Mittelstand firms. The regional importance of Mittelstand firms is therefore measured by the share of owner-managed SMEs in all regionally operating firms.

[17]Alternatively, we experimented with using the logarithm of research and development expenditures in order to test for potentially diminishing marginal returns. However, since the regression results remained broadly unaffected by doing so, we decided to stick to the quadratic polynomial for research and development expenditures.

[18]*Stifterverband* is a community initiative of the German economy supporting academic institutions in

Germany.

[19]Alternatively, we experimented with firms' internal investments in research and development as a share of absolute turnover by NUTS-3-regions as control variable. Again, this variable was also included as a quadratic polynomial in the regression equation. However, both coefficients turned out to be insignificant. Therefore, sticking to absolute investments in research and development per enterprise as control variable seems to be reasonable.

[20]According to the territorial boundaries of 31.12.2008, Germany consisted of 413 NUTS-3-regions.

[21]The table does not report standardized coefficients for R&D investments as this variable enters the estimation equation in a linear-quadratic fashion. When estimating the model only with a linear R&D variable the standardized coefficient is in a similar range but slightly below the GDP coefficient.

[22]For a more detailed discussion of penalized spline smoothing see WONG and KOHN, 1996, and WOOD, 2000. For the analysis the R-package mgcv (see WOOD, 2011) is used, which allows for a computationally stable and reliable estimation.

[23]Note that those parts of the estimated function, which are based on relatively few observations, have to be interpreted with great care, which is already indicated by the quickly widening confidence bands in these areas.

[24]Moran's I is positive (0.1851) and highly significant (0.0000).

[25]The presented spatial models are based on a contiguity matrix including only regions with direct borders. Additionally, spatial models based on a contiguity matrix of second order were estimated as robustness check. Again, the empirical findings are similar to the reported.

[26]While the model fits of all spatial models estimated in this paper cannot be compared, the results of an F-Test indicate that the model with spatially lagged independent variables is not a significant improvement over the simple OLS model. Thus, while spatial effects seem to play a role in this context, the effects seem to be comparatively unimportant.

REFERENCES

ACS Z. J., ANSELIN L. and VARGA A. (2002) Patents and Innovation Counts As Measures of Regional Production of New Knowledge, *Research Policy* **31**, 7, 1069-1085.

ANGULO A. M. and MUR J. (2012) The Likelihood Ratio Test of Common Factors under Non-Ideal Conditions, *Investigaciones Regionales* **21**, 37-52.

ANSELIN L. (1988a) *Spatial econometrics: methods and models. Studies in operational regional science.* Kluwer Academic Publishers, Dordrecht.

ANSELIN L. (1988b) Lagrange Multiplier Test Diagnostics for Spatial Dependence and Spatial Heterogeneity, *Geographical Analysis* **20**, 1, 1-17.

ANSELIN L. and FLORAX R. (1995) Small Sample Properties of Tests for Spatial Dependence in Regression Models: Some Further Results, in ANSELIN L. and FLORAX R. (Eds) *New Directions in Spatial Econometrics*, pp. 21-74. Springer, Berlin/Heidelberg.

ARVANITIS S. (1997) The Impact of Firm Size on Innovative Activity - an Empirical Analysis Based on Swiss Firm Data, *Small Bus. Econ.* **9**, 473-490.

AUDRETSCH D. B. and ELSTON J. A. (1997) Financing the German Mittelstand, *Small Bus. Econ.* **9**, 97-110.

AUDRETSCH D. B., HÜLSBECK M. and LEHMANN E. E. (2012) Regional Competitiveness, University Spillovers, and Entrepreneurial Activity, *Small Bus. Econ.* **39**, 3, 587-601.

AUDRETSCH D. B. and KEILBACH M. (2007) The Theory of Knowledge Spillover Entrepreneurship, *Journal of Management Studies* **44**, 7, 1242-1254.

AUDRETSCH D. B. and KEILBACH M. (2008) Resolving the Knowledge Paradox: Knowledge-spillover Entrepreneurship and Economic Growth, *Research Policy* **37**, 1697-1705.

AUDRETSCH D. B. and VIVARELLI M. (1996) Firm Size and R D Spillovers: Evidence From Italy, *Small Bus. Econ.* **8**, 249-258.

BAUMERT T., BUESA M. and HEIJS J. (2010) The Determinants of Regional Innovation in Europe: A

Combined Factorial and Regression Knowledge Production Function Approach, *Research Policy* **39**, 722-735.

BAUMOL W. J. (2010) *Microtheory of Innovative Entrepreneurship*. Princeton University Press, Princeton.

BAUMOL W. J., LITAN R. E. and SCHRAMM C. J. (2007) *Good Capitalism, Bad Capitalism, and the Economics of Growth and Prosperity*. Yale University Press, New Haven/London.

BERGHOFF H. (2006) The End of Family Business? The Mittelstand and German Capitalism in Transition, 1949-2000, *Business History Review* **80**, 263-295.

BERLEMANN M., ENGELMANN S., LESSMANN C., SCHMALHOLZ H., SPELSBERG H. and WEBER H. (2007) Unternehmensnachfolge im sächsischen Mittelstand, *ifo Dresden berichtet* **14**, 1, 15-28.

BERLEMANN M. and JAHN V. (2013) Relative innovative capacity of German regions: Is East Germany still lagging behind?, *CESifo Forum* **14**, 4, 42-50.

BIZER K. and THOMÄ J. (2013) To Protect or Not to Protect? Modes of Appropriability in the Small Enterprise Sector, *Research Policy* **42**, 35-49.

BLACKSTONE B. and FUHRMANS V. (2011) The Engines of Growth, Wall Street Journal, 27th June.

BLOCK J. H. and SPIEGEL F. (2013) Family Firm Density and Regional Innovation Output: An Exploratory Analysis, *Journal of Family Business Strategy* **4**, 270-280.

BRENNER T. and BROEKEL T. (2011) Regional Factors and Innovativeness: an Empirical Analysis of Four German Industries, *The Annals of Regional Science* **47**, 1, 169-194.

CÁCERES R., GUZMÁN J. and REKOWSKI M. (2011) Firms as Source of Variety in Innovation: Influence of Size and Sector, *International Entrepreneurship and Management Journal* **7**, 3, 357-372.

CZARNITZKI D. and KRAFT K. (2004) Management Control and Innovative Activity, *Review of Industrial Organization* **24**, 1-24.

DUNN JR. E. S. (1960) A statistical and analytical technique for regional analysis, *Papers and Proceedings of the Regional Science Association* **6**, 1, 97-112.

ECKEY H.-F., KOSFELD R. and TUERCK M. (2007) Regionale Entwicklung mit und ohne räumliche Spillover-Effekte, *Jahrbuch für Regionalwissenschaft* **27**, 1, 23-42.

ELHORST J. P. (2014) *Spatial Econometrics. From Cross-Sectional Data to Spatial Panels*. Springer, Berlin/Heidelberg.

ELHORST J. P. (2010) Applied spatial econometrics: Raising the bar, *Spatial Econometric Analysis* **5**, 1, 9-28.

ELHORST J. P. and VEGA S. H. (2013) On Spatial Econometric Models, Spillover Effects, and W, ERSA conference papers No. ersa13p222.

ESTEBAN-MARQUILLAS J. M. (1972) Shift and Share Analysis Revisited, *Regional and Urban Economics* **2**, 3, 249-261.

FAHRMEIR L., KNEIB T., LANG S. and MARX B. (2013) *Regression - Models, Methods and Applications*. Springer, Heidelberg.

FAMA E. F. and JENSEN M. C. (1983) Separation of Ownership and Control, *Journal of Law and Economics* **26**, 301-325.

FEAR J. (2014) The secret behind Germany's thriving 'Mittelstand' businesses is all in the mindset, The Conversation, 28th April.

FEDERAL MINISTRY OF ECONOMICS AND TECHNOLOGY (2013) *German Mittelstand: Engine of the German economy. Facts and Figures About Small and Medium-sized German firms*. Berlin.

FEDERATION OF GERMAN INDUSTRIES (2012) *The industrial 'Mittelstand' in Germany. For growth and employment in Europe*. Berlin.

FEHL U. (1988) Optimale Unternehmensgröße versus Vielfalt von Unternehmensgrößen. Einige grundsätzliche Überlegungen zu einem alten Thema, in KLAUS J. and KLEMMER P. (Eds) *Wirtschaftliche Strukturprobleme und soziale Fragen - Analyse und Gestaltungsaufgaben. J. Heinz Müller zum 70. Geburtstag*, pp. 343-353. Duncker & Humblot, Berlin.

FISCHER M. M. and LESAGE J. P. (2008) Spatial Growth Regressions: Model Specification, Estimation and Interpretation, *Spatial Economic Analysis* **3**, 3, 275-304.

FRANKE G. and FRITSCH M. (2004) Innovation, Regional Knowledge Spillovers and R D Cooperation, *Research Policy* **33**, 245-255.

GERMAN INSTITUTE FOR ECONOMIC RESEARCH (DIW) (2012) Forschungsstarker Mittelstand stützt die deutsche Konjunktur, Press Release of 27th September. Berlin.

GIOTRA K. and NETESSINE S. (2013) Extreme Focus and the Success of Germany's Mittelstand, Harvard Business Review, 12th February.

GLEDITSCH K. S. and WARD M. D. (2007) An Introduction to Spatial Regression Models in the Social Sciences, University of Washington, University of Essex.

GOTO A., MOTOHASHI K. and NAGAOKA S. (2010) Patent Statistics as an Innovation Indicator, in HALL B. H. and ROSENBERG N. (Eds), *Handbook of the Economics of Innovation, Vol. 2*, pp. 1083-1127. North-Holland, Amsterdam et al..

GRILICHES Z. (1990) Patent Statistics as Economic Indicators: A Survey, *Journal of Economic Literature* **28**, 4, 1661-1707.

HOLMSTROM B. (1989) Agency Costs and Innovation, *Journal of Economic Behavior and Organization* **12**, 3, 305-327.

ICKS A. (2006) Der Mittelstand in Deutschland, Speech on the Meeting of the Group "Mittelstand" of the Initiative Neue Qualität der Arbeit (INQA) on 12th June 2006 in Berlin.

IFM BONN (2013a) Innovationstätigkeit von Familienunternehmen, IfM-Materialien Nr. 225. Bonn.

IFM BONN (2013b) Der deutsche Mittelstand: Ein Konglomerat verschiedenartiger Unternehmen, IfM Standpunkt 1. Bonn.

IFM BONN (2015) SME-definition of IfM Bonn, http://en.ifm-bonn.org/definitions/sme-definition-of-ifm-bonn/.

JAFFE A. B. (1986) Technological Opportunity and Spillovers of R D: Evidence from Firms' Patents, Profits, and Market Values, *Am. Econ. Rev.* **76**, 5, 984-1001.

JENSEN M. and MECKLING W. (2009) Theory of the Firm: Managerial Behavior, Agency Costs, and Ownership Structure, in KROSZNER R. S. and PUTTERMAN L. (Eds) *The Economic Nature of the Firm, 3rd edition*, pp. 283-303. Cambridge University Press, New York.

KRAFT K. (1989) Market Structure, Firm Characteristics and Innovative Activity, *The Journal of Industrial Economics* **37**, 3, 329-336.

KEILBACH M. C. (2000) *Spatial knowledge spillovers and the dynamics of agglomeration and regional growth*. Physica Verlag, Heidelberg.

LERBS O. W. and OBERST C. A. (2014) Explaining the Spatial Variation in Homeownership Rates: Results for German Regions, *Regional Studies* **48**, 5, 844-865.

LESAGE J. P. and PACE R. K. (2009) *Introduction to Spatial Econometrics*. CRC Press, Boca Raton.

LYBBERT T. J. and ZOLAS N. J. (2014) Getting Patents and Economic Data to Speak to Each Other: An 'Algorithmic Links with Probabilities' Approach for Joint Analyses of Patenting and Economic Activity, *Research Policy* **43**, 3, 530-542.

MAAß F. and FÜHRMANN B. (2012) Innovationstätigkeit im Mittelstand, IfM-Materialien Nr. 212, IfM Bonn.

MERKEL A. (2009) Mittelstand - Rückgrat der Sozialen Marktwirtschaft, Video-Podcast, 18th July 2009, http://www.bundeskanzlerin.de/Content/DE/Podcast/2009/2009-07-18-Video-Podcast/2009-07-18-video-podcast.html.

MINISTRY OF ECONOMIC AFFAIRS OF NORTH RHINE WESTPHALIA (2014), Daten und Fakten, http://www.wirtschaft.nrw.de/mittelstand/mittelstandspolitik/ daten_und_fakten/index.php.

MOSER P. (2013) Patents and innovation: evidence from economic history, *Journal of Economic Perspectives* **27**, 23-44.

MOSER P. and VOENA A. (2012) Compulsory Licensing: Evidence from the Trading-with-the-Enemy-Act, *Am. Econ. Rev.* **102**, 396-427.

PARKER S. C. (2011) Small Firms and Innovation, in AUDRETSCH D. B., FALCK O., HEBLICH S. and LEDERER A. (Eds), *Handbook of Research on Innovation and Entrepreneurship*, pp. 357-364. Edward Elgar, Cheltenham (UK).

PAUST S. (2014) The German Mittelstand - a model for Asia's emerging economies?, Asia Pathways, posted on 20th June.

PFIRRMANN O. (1994) The Geography of Innovation in Small and Medium-Sized Firms in West Germany, *Small Bus. Econ.* **6**, 1, 41-54.

PIERGIOVANNI R. and SANTARELLI E. (2001) Patents and the Geographic Localization of R D Spillovers in French Manufacturing, *Reg. Studies* **35**, 8, 697-702.

PUTTERMAN L. (2009) Ownership and the Nature of the Firm, in KROSZNER R. S. and PUTTERMAN L. (Eds) *The Economic Nature of the Firm, 3rd edition*, pp. 353-361. Cambridge University Press, New York.

SCHWALBACH J. and ZIMMERMANN K. F. (1991) A Poisson Model of Patenting and Firm Structure in Germany, in ACS Z. J. and AUDRETSCH B. (Eds) *Innovation and Technological Change. An International Comparison*, pp. 109-120. University of Michigan Press, Ann Arbor.

SELDADYO H., ELHORST J. P. and DE HAAN J. (2010) Geography and Governance: Does Space Matter?, *Papers in Regional Science* **89**, 3, 625-640.

STUDZINSKI J. (2013) Germany is right: there is no right to profit, but the right to work is essential, The Guardian, 6th February.

TCHOUVAKHINA M. and SCHWARTZ M. (2013) Auf die Vielfalt kommt es an: Deutscher Mittelstand im europäischen Vergleich, Fokus Volkswirtschaft Nr. 24, KfW Bankengruppe. Frankfurt.

WOLTER H.-J. and HAUSER H.-E. (2001) Die Bedeutung des Eigentümerunternehmens in Deutschland - Eine Auseinandersetzung mit der qualitativen und quantitativen Definition des Mittelstands, in *Jahrbuch*

für Mittelstandsforschung 1/2001, Schriften zur Mittelstandsforschung Nr. 90 NF, pp. 25-77. Deutscher Universitätsverlag, Wiesbaden.

WONG C. and KOHN R. (1996) A Bayesian Approach to Additive Semiparametric Regression, *Journal of Econometrics* **74**, 209-235.

WOOD S. (2000) Modelling and Smoothing Parameter Estimation with Multiple Quadratic Penalties, *Journal of the Royal Statistical Society: Series B (Statistical Methodology)* **62**, 2, 413-428.

WOOD S. (2006) *Generalized Additive Models: An Introduction with R*. Chapman & Hall/CRC, Boca Raton.

WOOD S. (2011) mgcv: GAMs with GCV/AIC/REML Smoothness Estimation and GAMMs by PQL, R Package Version 1.7-11.

ZUUR A. F., IENO E. N., WALKER N. J., SAVELIEV A. A. and SMITH G. M. (2008) *Mixed Effects Models and Extensions in Ecology with R*. Springer, New York.