Papers in Evolutionary Economic Geography

13.01

Related Variety, Unrelated Variety and Regional Functions: A spatial panel approach

Matthias Brachert, Alexander Kubis, Mirko Titze

Utrecht University
Urban & Regional research centre Utrecht

http://econ.geog.uu.nl/peeg/peeg.html

Related Variety, Unrelated Variety and Regional Functions: A spatial panel approach

by

Matthias Brachert (IWH), Alexander Kubis (IAB), Mirko Titze (IWH)

This version: January 2013*

Abstract:

The paper presents estimates for the impact of related variety, unrelated variety and the functions a region performs in the production process on regional employment growth in Germany. We argue that regions benefit from the existence of related activities that facilitate economic development. Thereby the sole reliance of the related and unrelated variety concept on standard industrial classifications (SIC) remains debatable. We offer estimations for establishing that conceptual progress can be made when the focus of analysis goes beyond solely considering industries. We develop an industry-function based approach of related and unrelated variety and test our hypothesis by the help of spatial panel approach. Our findings suggest that related variety as same as unrelated variety facilitate regional employment growth in Germany. However, the drivers behind these effects do differ. While the positive effect of related variety is driven by high degrees of relatedness in the regional “R&D” and “White-Collar”-functions, the effects of unrelated variety are spurred by “Blue Collar”-functions in this period.

* An earlier version of this papers was published under the title “Related Variety, Unrelated Variety and Regional Functions: Identifying Sources of Regional Employment Growth in Germany from 2003 to 2008“ in the discussion paper series of the Halle Institute of Economic Research (IWH), see IWH Discussion Paper 15/2011.

Related Variety, Unrelated Variety and Regional Functions: Identifying Sources of Regional Employment Growth in Germany from 2003 to 2008

Introduction

The concept of related variety has attracted increasing attention in the discussion on the nature of localized knowledge spillover and regional growth (Frenken and Boschma 2007; Frenken et al. 2007; Boschma and Iammarino 2009; Bishop and Gripiaos 2010; Eriksson 2011; Hartog et al. 2012; for criticism see Desrochers and Leppälä 2011). It questions the hypothesis that Jacobs' externalities per se generate knowledge spillover and argues that "knowledge will spill over effectively only when complementarities exist among sectors in terms of shared competences" (Boschma and Iammarino 2009, p. 290). The economic rationale behind this argument lies in the notion of sufficient cognitive proximity (Nooteboom 2000). Findings within this context show that large differences in existing and new knowledge prevent effective communications, whilst interactive learning works best when cognitive distance between partners is not too large (Nooteboom et al. 2007). Consequently, this line of thought focuses on the specific regional composition of industrial sectors and splits up the Jacobs externalities argument into the effects of related and unrelated variety (Frenken et al. 2007; Boschma and Iammarino 2009).

This paper resumes this discussion and has two objectives. First, it presents estimates for the effects of related and unrelated variety in Germany from 2003 to 2008. Following studies of Frenken et al. (2007), Boschma and Iammarino (2009), Bishop and Gripaios (2010) and Hartog et al. (2012) we test for respective effects at the level of labor market regions. Second, we pick up recent criticism on the related variety concept made by Desrochers and Leppälä (2011). They point out that sole reliance on industries in the analysis of the composition of a regional economy is debatable, and that it might be more appropriate to analyze localized knowledge spillover in terms of individual skills or know-how. In line with this thought we argue that conceptual progress can be made, when we extend the concept of related variety by the role of functions a region performs in the production process (Bade et al. 2004; Duranton and Puga 2005).[1] Koo (2005), Barbour and Markusen (2007) and Currid and Stolarick (2010) for example show that the functions a region performs in the production process can be different for different geographies. This can affect the extent of localized knowledge spillover economy in two ways. First, a high functional distance or strong functional asymmetry between industries in a region as well as a high cognitive distance prevents effective communication, thus hindering the presence of localized knowledge spillover (Maggioni and Uberti 2007; Parjanen et al. 2010; Trippl 2010; Lundquist and Trippl 2011). Second, differences in the relative importance of regional functions in the production process may limit the extent of localized knowledge spillover, as non-routine tasks usually ascribed to headquarter and R&D functions show higher potentials for the generation of knowledge spillover (Bade et al. 2004; Duranton and Puga 2005; Robert-

[1] For a discussion of functional aspects within the context of the ideal types of regional innovation see Lundquist and Trippl 2011).

Nicoud 2008). To integrate these functional aspects into the concept of related variety, we use an occupation-based approach in conjunction with the industry based analysis. This allows paying attention to the kinds of work the regional economy does as well as to the kind of products it makes (Thompson and Thompson 1985, 1987; Feser 2003; Koo 2005). Based upon the idea that two regions with similar industry mixes can show differences in the functions performed in those industries (Koo 2005), the simultaneous evaluation of cognitive and functional aspects will allow deeper insights into the nature of localized knowledge spillover and regional employment growth (Currid and Stolarick 2010).

The paper is structured as follows. The next section identifies main theoretical concepts explaining the sources of localized knowledge spillover, gives a special focus on the recent related variety debate and presents complementarities between the related variety concept and the role of functions a region performs in the production process. The third section provides insights into the methodologies and variables used to develop an industry-function based related variety concept. Section four presents the results of the model, followed by the concluding remarks.

Knowledge Spillover and the Related Variety Concept

Localized knowledge spillovers build an integral part of modern theories to explain regional economic growth (Romer 1986). Their very nature, however, has been a controversial issue (for recent reviews of the empirical literature see Rosenthal and Strange 2004; Beaudry and Schiffauerova 2009; de Groot et al. 2009; Melo et al. 2009). Theoretical literature mostly differentiates between three lines of thought. First, the localization economies approach emphasizes the sector specific role of knowledge and skills and argues that the important knowledge spillover mainly occurs within industrial sectors (Marshall 1890; for formalizations see Arrow 1962; Romer 1986). Thus, regional specialization of economic activities is supposed to be the more innovative and growth enhancing setting (Desrochers and Leppälä 2011). The second approach can be related to the urbanization economies literature. The existence of urbanization economies is traced back to external economies based upon the co-location of firms regardless of the industrial sector they belong to (Harrison et al. 1996). External economies are passed on to firms through savings from a dense environment in terms of a.o., population, universities, and public or private research institutes (Malmberg et al. 2000). The third approach can be found in the works of Jane Jacobs (1969). Jacobs puts emphasis on the positive aspects of a diversity of sectors in a region. Her main point is, that a diverse set of regional industrial sectors provides access to different knowledge bases beyond the individual industrial environment (see also Glaeser et al. 1992; Henderson et al. 1995, van Oort 2004). This diversity will spark knowledge spillover and result in more radical innovations, thus regional diversification is supposed to lead to positive effects on regional economic growth (Frenken et al. 2007; Boschma et al. 2012).

The resulting diversification vs. urbanization debate has dominated discussion on sources of knowledge spillover in regional science (Beaudry and Schiffauerova 2009). However, recent literature started advocating a more differentiated view on this classic dichotomy. Porter (2003) and Frenken et al. (2007) emphasize the role of relatedness of industries and point out that industrial sectors share commonalities in terms of technologies, knowledge bases, skills or inputs (see also Hildago et al. 2007; Boschma and Iammarino 2009; Eriksson 2011; Neffke et al. 2011). Such types of relatedness are supposed to allow knowledge to spill over more effectively with respective benefits for the regional economy. Relying heavily on the notion of "cognitive proximity" (Nooteboom 2000; Boschma 2005; Nooteboom et al. 2007) Frenken et al. (2007) argue that it is crucial to split up the generic diversity argument and analyze more deeply the specific composition of sectors within the regional economy (see also Boschma and Iammarino 2009; Boschma et al. 2012; Bishop and Gripaios 2010). To disentangle the effects of diversity, they distinguish between related and unrelated variety. Whereas the concept of unrelated variety is likely to capture a portfolio-effect and allows insights into the vulnerability of the regional economy, the related variety concept includes benefits from knowledge spillovers of different but complementary industries in a region (Essletzbichler 2005; Boschma et al. 2012; Eriksson 2011). Thus, the assumption is made that the higher the presence of related industries is in a region, the more opportunities exist for the effective transfer of tacit knowledge (Boschma and Frenken 2011; Eriksson 2011). Coming to the effects of unrelated variety, Frenken et al. (2007) assume that the higher the degree of unrelated variety is in a region, the higher is the ability to absorb sector specific shocks with likewise positive effects on regional growth.

Regarding empirical results, Frenken et al. (2007), Boschma and Iammarino (2009) and Boschma et al. (2012) indeed find that a high degree of related variety has a positive effect on regional economic growth in the Netherlands, Italy and Spain. Additional insights are presented by Bishop and Gripaios (2010) and Hartog et al. (2012). Bishop and Gripaios (2010) show that the impact of related variety is different across sectors with inconsistent signs. Within their study for Great Britain, related variety has a positive effect in only three out of 23 sectors and a negative effect in one. In their study for Finland, Hartog et al. (2012) find that related variety in general has no impact on regional growth. Instead, when controlling for differences in low-, medium- and high-tech sectors, they find that positive effects of related variety are restricted to high-tech sectors. Empirical results for the regional effects of unrelated variety are more heterogeneous. While Frenken et al. (2007) show that unrelated variety is negatively related to unemployment growth and give support to the arguments on vulnerability and shock-resistance, Boschma and Iammarino (2009) and Boschma et al. (2012) only find very little evidence for the portfolio-effect and no other economic effects of unrelated variety. In their sectoral study, Bishop and Gripaios (2010) observe positive effects of unrelated variety on employment growth for eight sectors, whereby these effects seem to be more present in manufacturing compared to the service sector. They finally conclude that the distinction between related and unrelated variety is of importance, but that the effects do differ significantly across sectors.[2]

[2] Boschma and Iammarino (2009) further shed the light on the role of the relatedness of international trade flows on the region. They find that regions benefit from extra-regional knowledge when it emanates from sectors that are complementary to those sectors in the region. However, a likewise study conducted for Spain could not confirm the results (Boschma et al. 2012). Hartog et al. (2012) do not find any significant effects of unrelated variety on annual employment growth.

The Related Variety Concept and the Role of Regional Functions

Albeit the empirical literature mentioned above has stressed the importance of controlling for the effects of related and unrelated variety, the concept has also received criticism. While focusing on the specific composition of the regional economy with industrial sectors, the related variety concept overlooks the limitations of industrial classifications schemes to reflect individual skills and know-how. Desrochers and Leppälä (2011) make the point that standard industrial classifications (SIC) alone do not capture the variety of channels, through which ideas are used and transferred between industries and suggest that it is more appropriate to analyze the effects of diversification in terms of individual skills and know-how.[3] Hartog et al. (2012) contribute to this point in showing that the effect of related variety on regional growth depends upon certain regional sector specificities such as their technological intensity.[4] However, empirical studies that concern these issues remain scarce.

We argue that conceptual progress in related and unrelated variety literature can be made, when we integrate information about skills via the functions a region performs in the production process. One way to capture individual skills is offered by the analysis of occupations and their respective classification into economic functions (Thompson and Thompson 1985, 1987; Florida 2002; Feser 2003; Bade et al. 2004; Markusen 2004; Koo 2005; Barbour and Markusen 2007; Currid and Stolarick 2010). This so called "occupational-functional approach" identifies what specific types of human capital a region possesses, thus is directing attention to the kinds of work the regional economy does (Thompson and Thompson 1985, 1987; Feser 2003; Koo 2005). With knowledge spillover being a function of people and respective skills and occupations in a region, this allows to clarify the role of differences in regional functions in understanding localized knowledge spillover.

The "occupational-functional approach" is able to contribute to the concept of related and unrelated variety in two ways. First, it allows insights into a topic addressed only rarely in the empirical discussion on localized knowledge spillover: the functional distance or proximity of industrial sectors in a region (Trippl 2010; Lundquist and Trippl 2011). Being at least partially a result of the rise of multi-unit firms increasingly taking advantage of differences in agglomeration, cost and market advantages in varying regions (Chandler 1977; Kim 1999 for theoretical approaches see within the context of the new economic geography and regional functional specialization see for Duranton and Puga 2005; Fujita and Gokan

[3] Additional criticism on SIC based measures of relatedness can be found in the strategic management literature (Bryce and Winter 2009). Albeit this type of analysis focuses on inter-industry relatedness in the context of cross-business synergies of multi-business firms with diverse business portfolios, the arguments against SIC based measures made there also hold for the related variety discussion. This body of literature criticizes the use of SIC based measures because these measures do not consistently reflect relatedness among resources, they suffer from varying degrees of breadth in SIC scheme, they implicitly assume equal dissimilarity between different SIC classes, thus perform unsatisfactory when classifying vertically related businesses, they are affected by classification errors, do not consider whether the resources shared could be accessed at an equivalent or even lower cost by non-diversifiers and exclude cases in which two industries are dynamically related (e.g., Rumelt 1984, Barney 1991, Farjoun, 1994, Montgomery and Hariharan, 1991, Markides and Williamson 1996, Fan and Lang 2000). Tanriverdi and Venkatamaran (2005) further point out that SIC based measures do not allow insights into the types of underlying relatedness as cross-business synergies can arise from the relatedness of certain different functional resources.

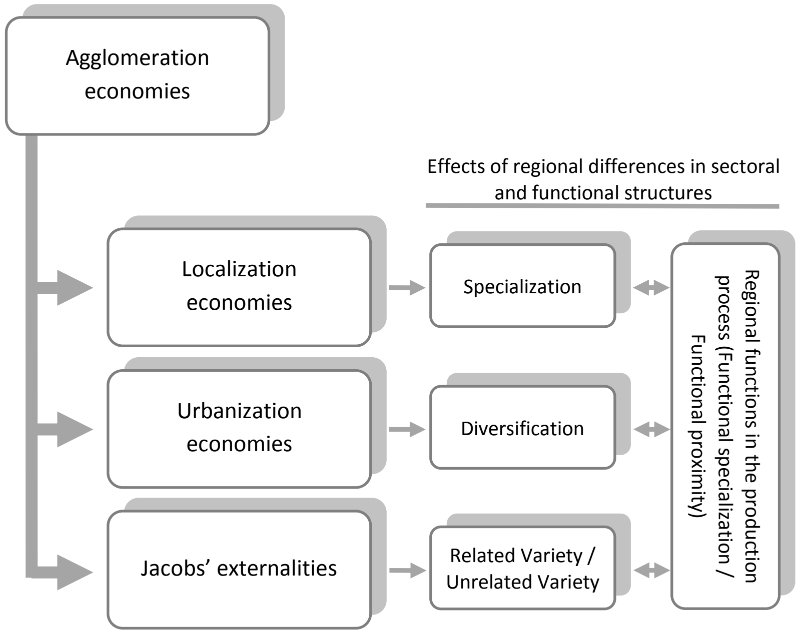
[4] In their case, the technological intensity of local sectors is indicated by the presence of low-, medium- and high-tech sectors.

2005; Fujita and Thisse 2006; Robert-Nicoud 2008), this strand of literature shows that functions for the same industry can be different for different geographies (for empirical studies see Koo 2005; Defever 2006; Markusen and Schrock 2006; Barbour and Markusen 2007; Currid and Stolarick 2010). These differences in the structure of functions in a region, however, strongly affect the nature and existence of localized knowledge spillover. Trippl (2010) and Lundquist and Trippl (2011) pick out the functional distance between industries in a region (in their context measured by differences in the innovation performance between regions, in our case more fundamental by the existence and degree of related or unrelated economic functions like R&D, managerial or production tasks) as the major issue in the discussion on ideally types of integrated innovation oriented regional innovation system. They argue that a strong functional distance or asymmetry (or the non-existence of related or unrelated R&D, managerial or production functions in a region) between industries can be seen as a factor limiting opportunities for effective communication and mutual exchange of knowledge (see also Maggioni and Uberti 2007; Parjanen 2010). When the functional distance is too large, knowledge does not flow easily, thus affecting the nature and extent of localized knowledge spillover. To conclude, functional aspects may spur the effects of related and unrelated variety (Lundquist and Trippl 2011).

A second contribution can found in the literature on the functional specialization of regions (Bade et al. 2004; Duranton and Puga 2005; Blum 2008; Robert-Nicoud 2008). This strand of literature argues that the functional specialization of regions leads to spatial differences in knowledge spillovers because headquarter functions and R&D departments show a strong affinity to metropolitan areas (Duranton and Puga see also Dohse et al 2005; Davis and Henderson 2008). Differences in the relative importance of regional functions contribute to differences in the content of tacit vs. codified information in regional transactions and thus the amount of localized knowledge spillover. This view is also advocated by Robert-Nicoud (2008). He discusses the possible range of spillovers arising from routine task (dominated by codified knowledge) and complex task (characterized by tacit knowledge) and finds it reasonable to assume that routine tasks generate fewer agglomeration economies.

Yet, we argue that the related variety concept can benefit from the integration of functional aspects of the regional economy. The combination of an occupation-based analysis with an industry-based analysis allows drawing attention to the kinds of work the regional economy does as well as to the kind of products it makes (Thompson and Thompson 1985, 1987; Feser 2003). Based upon the idea that two regions with similar industry mixes can show differences in the functions performed in those industries (Koo 2005), the simultaneous evaluation of cognitive and functional aspects in an occupational-functional approach of the related variety concept allows deeper insights into the nature of localized knowledge spillover and regional development (Currid and Stolarick 2010). Figure 1 summarizes the basic research approach.

Figure 1: Research design – Agglomeration economies and effects of regional differences in sectoral and functional structures



Source: Own illustration.

Research Design

Developing an occupational-functional approach of related and unrelated variety

To develop a framework that is able to reflect cognitive as well as functional aspects of the sectoral composition of a regional economy, we rely on a categorization of occupations by functions introduced by Bade et al. (2004). Following Duranton and Puga (2001), Bade et al. (2004) differentiate between three broad functional categories (see also Bode 1998). "White Collar" workers hold executive functions in manufacturing industries but also in service and public sectors. In addition to that, workers holding typical headquarter functions like marketing or providing services related to the existence of headquarters in region are included in this category. "R&D occupations" are reflected by occupational groups of engineers, natural scientists, agricultural engineers and consultants. "Blue Collar" workers are characterized by diverse manufacturing occupations. Table 1 summarizes the occupation groups classified into the three different categories.

Table 1: Description of the occupational groups that reflect the functions a region performs in production process

Categories of occupational functions	Number of occupational group[a]	Description of occupational group[a]
White Collar:		
Managerial and administrative functions	751	Entrepreneurs, Managers, CEOs, Business division heads
	76	Representatives, Employees with administrative or decision making authority
	881	Economists and Social Scientists
	882	Humanist Scientists
Other business-oriented services, Management consultants	752	Management consultants, Analysts
	753	Accountants, Tax consultants
	81	Lawyers, Legal advisors
Marketing	703	Advertising
	82	Publicists, Translators, Librarians
	83	Artists and related occupations
R&D Occupations:		
Technical services, R&D	032	Agricultural engineers and consultants
	60	Engineers
	61	Chemists, Physicists, Mathematicians
	883	Other natural scientists
Blue Collar:		
Manufacturing occupations	07 to 43	Diverse manufacturing occupations in all industries

[a] According to the nomenclature of occupations, compiled by Federal Statistical Office of Germany in 1970.
Source: Own compilation, basic classification developed by Bade et al. (2004). One adjustment is made in the group "White Collar" (additional group 882).

Information about the spatial distribution of occupational functions can be obtained by official statistics. Moreover, the data provided by the Federal Employment Office of Germany within its Social Insurance Statistic allow the combination of an occupation-based analysis with an industry-based analysis and thus the identification of functions performed by an industry in a region. The Social Insurance Statistic builds on the NACE classification of economic activities (Nomenclature générale des activités économiques dans les Communautés Européennes – NACE Rev.1) and combines information about the individual industrial sectoral affiliation down to the five-digit level (1041 industrial sectors), the kind of the individual occupation down to the three-digit level (369 occupational groups) and spatial attributes down to the community level. This high degree of disaggregation allows the simultaneous evaluation of cognitive and functional aspects by calculating function-specific degrees of related and unrelated variety at the regional level. For the purpose of analysis we aggregate individual data at the level of labor market regions (262 regions). The choice of labor market regions as spatial unit of analysis is based upon arguments made by Eckey et al. (1990). They point out that regions defined on behavioral settings generally perform better than administrative units, because the former do reflect economic relations.

Related variety, unrelated variety and regional functions – Calculation of the variety indices

To identify effects of functional proximity (or distance) on regional employment growth, we first calculate function-specific degrees of related and unrelated variety. In line with Frenken et al. (2007), we use entropy at the two-digit level (industrial classification) to calculate the degree of unrelated variety. Related variety is determined by the weighted sum of the entropy at the five-digit level (industrial classification) within the two-digit class.[5] Thus, we assume five-digit sectors sharing the same two-digit sector to experience commonalities fostering learning and facilitating innovative advances (see also Boschma and Iammarino 2009). Information about occupational-functions is taken into account by a division of the general variety indexes into the three categories of occupational functions as stated down in equation (1). Thus, we additionally assume that the higher the degree of functional proximity (in "White Collar", "R&D" and "Blue Collar" functions) in a region, the easier is the communication or interaction between related but also unrelated sectors and the higher is the knowledge spillover with respective effects on regional employment growth.

The formal calculation from Frenken et al. (2007) changes as follows. If all five-digit sectors *i* of a category of occupational function *j* (where *j = 1, 2, 3*) fall solely under a two-digit sector S_{g_j} (where *g= 1,…, G*), it is possible to derive two-digit shares P_{g_j} by summing the five-digit shares p_{i_j}.

$$P_{g_j} = \sum_{i \in S_{g_j}} p_{i_j} \qquad (1)$$

The degree of unrelated variety (*UV*$_j$) for each of the three categories of occupational functions *j* is calculated by the entropy at the two-digit level.

$$UV_j = \sum_{g_j=1}^{G} P_{g_j} \, log_2 \, \frac{1}{P_{g_j}} \qquad (2)$$

The degree of related variety (RVj) for each of the three categories of occupational functions is defined as the weighted sum of entropy within each two-digit sectors.

$$RV_j = \sum_{g_j=1}^{G} P_{g_j} \, H_{g_j} \qquad (3)$$

with

[5] Recent studies mostly assess diversity by the help of inverse Hirschman-Herfindahl index (Henderson et al. 1995; Combes 2000; Combes et al. 2004; Blien and Südekum 2005; for a recent application to Germany see Illy et al. (2011). However, this does not include related diversity into the analysis (Bischop and Gripaios 2010). The use of the entropy measure is preferred because of its decomposable nature. This allows introducing different digit-level degrees of related and unrelated variety into the regression analysis without causing necessarily multi-collinearity (Frenken et al. 2004) and identifying embedded relatedness of industries within the two-digit level. Avoiding controlling for these effects would contribute to an underestimation of Jacobs's externalities because they would be measured as unrelated variety (Beaudry and Schiffauerova 2009).

$$H_{g_j} = \sum_{i \in S_{g_j}} \frac{p_{i_j}}{P_{g_j}} \log_2 \frac{1}{p_{i_j}/P_{g_j}} \tag{4}$$

Dependent variable

To determine the effects of related and unrelated variety as well as the role of functions performed by regions in the production process, we use annual regional employment growth (EMPL_GROWTH) in the manufacturing sector (*Produzierendes Gewerbe*, SIC codes 10 to 41) between 2003 and 2008 as dependent variable. The analysis is conducted at the level of labor market regions. The choice of labor market regions as spatial unit of analysis is based upon arguments made by Eckey et al. (1990). Moreover, their demarcation was confirmed to be suitable in different other studies (Kosfeld and Lauridsen 2004; Kosfeld et al. 2006).

Control variables

Specialization

To test for the effects of regional specialization, we apply the Herfindahl-Index (*SPECIALIZATION*). This measure is defined as the sum of the squares of the two-digit shares P_g of a region *r.*

$$SPECIALIZATION_r = \sum_{g=1}^{G} P_{g_r}^2 \tag{5}$$

Functional specialization

The discussion above emphasizes the role of the regional functional specialization in the discussion on localized knowledge spillover *(*Bade et al. 2004; Duranton and Puga 2005). We integrate information about the functional specialization of regions by the ratio of “White Collar” (*WC*) to “Blue Collar” (*BC*) workers in region *r (FUNC_SPECIALIZATION)*.

Size of the regional economy

The size of a regional economy can affect the existence of spillover effects irrespective of the sectoral composition of the regional economy (Combes 2000). Frenken et al. (2007) for example argue that it is the dense presence of economic, social, political and cultural organizations that influence the emergence of urbanization economies. This means that the level and quality of spillovers is affected by the number of complementarities between regional organizations (Ó hUallacháin and Satterthwaite 1992; Combes 2000). Combes (2000) further points out that size effects may also negatively influence regional growth through the presence of pollution or transportation congestion. On the basis of recent studies on Germany (Illy et al. 2011), we measure the size of the regional economy by the employment density of a labor market region *r* (*SIZE*).

Average firm size and human capital

In line with other empirical studies, we integrate two additional independent variables into the regression analysis which are supposed to affect regional employment. This includes the average firm size (*AV_FIRM_SIZE*) and the regional level of human capital (*HUMAN_CAPITAL*). Whilst the first is measured by the average firm size in the manufacturing sector in the respective labor market region *r,* human capital is reflected by the regional share of R&D employees on total regional employees (see Fritsch and Slavtchev 2011 for a similar approach). As same as for the dependent variable, all independent variables are calculated for the manufacturing sector only (*Produzierendes Gewerbe*, SIC codes 10 to 41).

Model specification

To identify the effects on regional employment growth in the manufacturing sector, we apply a spatial panel approach (Elhorst 2003, Elhorst 2010). Regional employment growth is expected to be correlated over space. Thus, it has become standard to control for spatial dependence in this context (LeSage and Fischer 2008). Literature distinguishes two basic types of spatial dependence. Spatial lag dependence reflects true (economic) interactions across spatial units. Spatial error dependence refers to measurement problems as a result of the arbitrariness of administrative boundaries of spatial units (Anselin and Rey 1991). Neglecting spatial dependence may act as an omitted variable bias and produce biased results (LeSage and Pace 2009).

The static panel model that we want to estimate takes into account a spatial lag of the dependent variable and spatial autoregressive disturbances and is stated as

$$y = \lambda \ I_T \otimes W_N \ y + X\beta + u \tag{6}$$

where y describes a *NT x 1* vector of observations of the dependent variable, X is the set of explanatory variables (*NT x k* matrix*),* I_T is an identity matrix of dimension T, W_N a non-stochastic spatial weights matrix (row-standardized first order contiguity matrix in our case) and λ denotes the corresponding spatial parameter (Millo and Piras 2012). The disturbance vector u is determined by the sum of two terms:

$$u = \ \iota_T \otimes I_N \ \mu + \varepsilon \tag{7}$$

where ι_T is a column vector of ones of dimension T, I_N an *N x N* identity matrix, μ denotes vector of time-invariant individual specific effects and ε denotes an error term described by:

$$\varepsilon = \rho \; I_T \otimes W_N \; \varepsilon + \nu \tag{8}$$

Spatial specific effects can be treated as fixed or random effects (Elhorst 2012). Even though the Hausman test allows testing the appropriateness of the fixed or random effects model, recent literature emphasizes the suitability of fixed effects models when the "sample happens to be the population" (Beenstock and Felsenstein 2007, p. 178). In this case spatial specific effects are better determined by fixed effects "because each spatial unit represents itself and not sampled randomly" (Elhorst 2012, p. 10). The fixed effects models further have the attraction that they allow to control for unobserved individual heterogeneity. Such unobserved individual heterogeneity itself is a source of omitted variable bias (Cameron and Trivedi 2005).[6]

We follow the arguments made by Beenstock and Felstenstein (2007) and Elhorst (2012) an estimate a fixed effects model. This model specification also is supported by the Hausman test (see table A3). Table A4 in the appendix confirms that spatial dependence is of relevance for our analysis (significant joint test of spatial autocorrelation). The results of the LM test favor a model including a spatially lagged dependent variable. This leads us conclude that a spatial panel fixed effects lag model is the appropriate model specification for the purpose of our analysis.

Results

The regression results for the level of labor market regions are presented in table 2. We estimated two different variants of four models. However, all variants of the models show consistent results for the variables applied in this analysis. Model 1 includes only the control variables. Here it can be shown that four out five control variables contribute negatively to regional employment growth. The negative effects for SIZE and SPECIALIZATION are in line with previous research on the manufacturing sector in Germany presented by Blien and Südekum (2005). They are also supported by a recent study of Illy et al. (2011) for an almost similar period in Germany. Therein, Illy et al. (2011) find negative effects of increasing levels of SPECIALIZATION on regional employment growth at the level of planning regions. Surprisingly, HUMAN_CAPITAL and FUNC_SPECIALIZATION per se contribute negatively to regional employment growth in the manufacturing sector, a fact that will be analyzed more deeply in Model 4.

[6] Elhorst (2012) points out that spatial fixed effects can only be estimated consistently when T is large. However, the inconsistency of μ does not affect the estimator the slope coefficients β. As this study is primarily interested in β, an potential incidental parameter problem is of minor importance.

Table 2: Results of the panel regressions on annual employment growth in German labor market regions, 2003-2008

Variables	Variant 1 Fixed effects model				Variant 2 Spatial panel fixed effects lag model			
	Model 1	Model 2	Model 3	Model 4	Model 1	Model 2	Model 3	Model 4
RV		0,026**	0,029**			0,026**	0,028***	
URV			0,034***				0,034***	
RV_ WC				0,015*				0,015**
RV_R&D				0,027***				0,027***
RV_BC				-0,019				-0,019
URV_WC				-0,001				-0,001
URV_R&D				-0,010				-0,010
URV_BC				0,037***				0,037***
SPECIALIZATION	-0,176***	-0,189***			-0,179***	-0,192***		
FUNC_ SPECIALIZATION	-0,610***	-0,593***	-0,601***	-0,583***	-0,617***	-0,600***	-0,608***	-0,589***
HUMAN_CAPITAL	-1,143***	-1,041***	-1,035***	-1,090***	-1,139***	-1,038***	-1,031***	-1,088***
Log(SIZE)	-0,208***	-0,205***	-0,208***	-0,208***	-0,201***	-0,205***	-0,208***	-0,208***
Log(AV_FIRM_SIZE)	-0,005	-0,009	-0,010	0,003	-0,005	0,009	0,010	0,003
λ					-0,054	-0,053	-0,051	-0,039
N	262	262	262	262	262	262	262	262
T	5	5	5	5	5	5	5	5

Note: ***, **, * indicate statistical significance on the 1%, 5% or 10% level. Estimations are done with splm package by Millo and Piras (2012). The fixed effects models include individual and time specific effects. Due to the high correlation between the variables SPECIALIZATION and URV (-0,941), we decided to enter variables separately in the models.
Source: Authors own calculation.

Models 2 and 3 stepwise include both general variety variables (RV and URV). We find that related variety (RV) as same as unrelated variety (URV) positively affect regional employment growth. This is in also line with previous results for effects of diversity in general on regional employment growth in Germany (Blien and Südekum 2005, Illy et al. 2011, Fuchs 2011). However, this is the first study for Germany that explicitly splits up the generic diversity argument introduced by Jacobs (1969) and analyses more deeply differences in regional variety structures. The results give support to the argument that the distinction between related and unrelated variety is of importance (Frenken et al. 2007, Bishop and Gripaios 2010). Furthermore the results confirm the effects of related variety in likewise studies by Frenken et al. (2007), Boschma and Iammarino (2009), Bishop and Gripaios (2010) and Hartog et al. (2012). In contrast to these studies we also find unrelated variety to have a positive effect on regional employment growth (Bishop and Gripaos 2010).

Model 4 allows deeper insights into the drivers behind the positive effects of related and unrelated variety. It presents the decomposed variety indices that can be differentiated into “White Collar” (RV_WC, URV_WC), “R&D” (RV_R&D; URV_R&D) and “Blue Collar” (RV_BC, URV_BC) functions. The results show, that the drivers behind the effects of related and unrelated variety differ. We find that high levels of related variety in “White Collar” (RV_WC) and “R&D” (RV_R&D) functions have positive effects on regional employment in the manufacturing sector. In contrast to this, the effects of unrelated variety are found to be significant for “Blue Collar” functions (URV_BC). The results of RV_WC and RV_R&D can be set in relation the negative results for the HUMAN_CAPITAL and FUNC_SPECIALIZATION variables. It is not the share of engineers on regional manufacturing employment that per se positively effects regional employment growth but rather a high level of relatedness within this functional employment category. The same argument holds for the functional specialization variable. It is not the relative importance of “White Collar” to “Blue Collar” functions that exerts positive effects on regional employment growth but rather a high level of relatedness within the “White Collar” function. This gives support to the arguments made Trippl (2010) and Lundquist and Trippl (2011). The higher is the level of relatedness in non-routine tasks performed in a region, the higher is the content of tacit information in regional transactions and thus the amount of localized knowledge spillover with respective positive effects on regional employment growth. Coming to the effects of high levels of unrelatedness in “Blue Collar” or manufacturing functions, the results indicate that regions benefit from diverse “Blue Collar” functions. Theoretical reasons for that can be traced back to arguments such as a large diversified pool of qualified labor as source of knowledge spillover and regional growth. Such spatial patterns are advantageous to firms as same as workers when workers can move among employers without retooling and firms gain access to wide set of labor with skills they need (Ellison et al. 2010).

Conclusions

This paper had two main goals, first to present estimates of the effects of related and unrelated variety on regional growth in Germany from 2003 to 2008 and second to develop an occupational-functional approach of the related variety concept to control for effects of functions a region performs in the production process. Functional aspects are integrated into the analysis by a decomposition of related and unrelated variety indices into three categories of occupation functions (“White Collar”, “R&D” and “Blue Collar” workers). Previous studies only applied an undifferentiated view on the effects of related and unrelated variety or did not test for their effects (Glaeser et al. 1992; Frenken et al. 2007; Boschma and Iammarino 2009 with an exception in Hartog et al. 2012).

Our results support the need for a more differentiated view on variety in the discussion on regional employment growth and highlight the importance of controlling for regional functions in the production process in this context. We find that both related variety and unrelated variety positively affect regional employment growth in the manufacturing sector in Germany between 2003 and 2008. However, it is necessary to shed further attention to the kinds of work a region does in the production process to get deeper insights into the drivers behind these effects. “White Collar” and “R&D” functions are characterized by a non-routine nature and thus offer much more potential for localized knowledge spillover (Robert-Nicoud 2008). Our results indicate that related variety acts as an accelerator in this context. The driver behind the effect of unrelated variety is different from those of related variety and can be found in the “Blue Collar” function. This can be traced back to arguments such as positive effects of regional labor market pooling.

This research approach opens up a number of different other issues that further research should shed more light on. First of all, the application of SIC based measures alone does not sufficiently present insights into the nature of potentials for localized knowledge spillover. They assume that the functions performed in an industry are similar for different geographies. This is not necessary the case (Koo 2005, Barbour and Markusen 2007, Currid and Stolarick 2010). Future studies could attempt to refine this classification of occupations to achieve more specific insights into the effects of functional proximity/distance or interactions of functions on regional growth. Furthermore, more advanced measures of relatedness are needed. The discussion in the strategic management literature proposes co-occurrence approaches as an appropriate tool in this context (Bryce and Winter 2009). First approaches that integrate these insights into regional science literature can be found in Neffke and Henning (2012). However, relatedness is a multi-dimensional construct and relatedness patterns might be different in different contexts (Bryce and Winter 2009). Thus, future research needs to consider different types of relatedness. While relatedness of products is of importance, for example skill relatedness (Neffke and Henning 2012) is crucial when coping with increasing needs for flexibility in regional structural change and enabling cross-sectoral knowledge spillover.

Literature

Anselin, L. 2006. Spatial Econometrics. In *Palgrave Handbook of Econometrics*, eds. T.C. Mills, and K. Patterson, 901-969, Basingstoke: Palgrave Macmillan.

Anselin, L., and Florax, R. 1995. *New Directions in Spatial Econometrics*. Berlin: Springer.

Anselin, L., and Rey, S. 1991. Properties of tests for spatial dependence in linear regression models. *Geographical Analysis* 23: 112-31

Arrow, K. 1962. The Economic Implications of Learning by Doing. *The Review of Economic Studies* 29: 155-173

Bade, F.-J.; Laaser, C.; and Soltwedel, R. 2004. Urban specialization in the internet age — empirical findings for Germany. Kiel Working Paper no. 1215, Kiel Institute for World Economics.

Barbour, E., and Markusen, A. 2007. Regional Occupational and Industrial Structure: Does One Imply the Other? *International Regional Science Review* 30: 72-90

Barney, J. 1991. Firm resources and sustained competitive advantage. *Journal of Management* 17: 99-120

Beaudry, C., and Schiffauerova, A. 2009. Who's right, Marshall or Jacobs? The localization versus urbanization debate. *Research Policy* 38: 318-337

Beenstock, M. and Felsenstein, D. (2007) Spatial vector autoregressions. Spatial Economic Analysis 2: 167-196

Bishop, P., and Gripaios, P. 2010. Spatial Externalities, Relatedness and Sector Employment Growth in Great Britain. *Regional Studies* 44: 443-454

Blien, U., and Suedekum, J. 2005. Local Economic Structure and Industry Development in Germany, 1993-2001. *Economics Bulletin* 17: 1-8

Blum, U. 2008. Der lange Schatten des Sozialismus: Folgen für die Wirtschaftspolitik in Ostdeutschland. *List Forum für Wirtschafts- und Finanzpolitik* 34: 216-229.

Bode, E. 1998. *Lokale Wissensdiffusion und regionale Divergenz in Deutschland*. Tübingen: Mohr.

Boschma, R. 2005. Proximity and innovation: A critical assessment. *Regional Studies* 39: 61-74

Boschma, R., and Iammarino, S. 2009. Related Variety, Trade Linkages, and Regional Growth in Italy. *Economic Geography* 85: 289-311

Boschma, R.; Minondo, A.; and Navarro, M. 2012. Related variety and regional growth in Spain. Papers in Regional Science, 91: 241–256

Bryce, D., and Winter, S. 2009. A General Interindustry Relatedness Index. *Management Science* 55: 1570-1585

Cameron, C., and Trivedi, P. 2005. *Microeconometrics: Methods and Applications*. New York: Cambridge University Press.

Chandler, A. 1977. *The Visible Hand.* Cambridge: Belknap.

Combes, P. 2000. Economic Structure and Local Growth: France, 1984-1993. *Journal of Urban Economics* 47: 329-355

Combes, P.; Magnac, T.; and Robin, J. 2004. The Dynamics of Local Employment in France. *Journal of Urban Economics* 56: 217-243

Currid, E., and Stolarick, K. 2010. The Occupation-Industry Mismatch: New Trajectories for Regional Cluster Analysis and Implications for Economic Development. *Urban Studies* 47: 337-362

Davis, J., and Henderson, J. 2008. The Agglomeration of Headquarters. *Regional Science and Urban Economics* 38: 445-460

De Groot, H.; Poot, J.; and Smit, M. 2009. Agglomeration externalities, innovation and regional growth: theoretical perspectives and meta-analysis. In *Handbook of Regional Growth and Development Theories*, eds. R. Capello, and P. Nijkamp, 256-281. Northampton MA: Edward Elgar

Debarsy, N., and Ertur, C. 2010. Testing for spatial autocorrelation in a fixed effects panel data model. *Regional Science and Urban Economics* 40: 453-470

Defever, F. 2006. Functional fragmentation and the location of multinational firms in the enlarged Europe. *Regional Science and Urban Economics* 36: 658-677

Desrochers, P., and Leppälä, S. 2011. Opening up the 'Jacobs Spillovers' black box: local diversity, creativity and the processes underlying new combinations. *Journal of Economic Geography* 11: 843-863

Dohse, D.; Laaser, C.; Soltwedel, R.; and Schrader, J. 2005. Raumstruktur im Internetzeitalter: Tod der Distanz? Eine empirische Analyse. Kieler Diskussionsbeiträge 416/417. Kiel Institute for World Economics, Kiel, Germany.

Duranton, G., and Puga, D. 2001. From Sectoral to Functional Urban Specialisation. CEPR Discussion Paper 2971. Centre for Economic Policy Research (CEPR).

Duranton, G., and Puga, D. 2005. From Sectoral to Functional Urban Specialization. *Journal of Urban Economic* 57: 343-70

Eckey, H.-F.; Horn, K.; and Klemmer, P. 1990. *Abgrenzung von regionalen Diagnoseeinheiten für die Zwecke der regionalen Wirtschaftspolitik*. Bochum: Brockmeyer.

Elhorst, J. 2003. Specification and estimation of spatial panel data models. *International Regional Science Review* 26: 244-268

Elhorst, J. 2010. Spatial panel data models. In Handbook of applied spatial analysis, eds. M. Fischer and A. Getis, 377-407, Berlin, Heidelberg and New York: Springer, Berlin, Heidelberg and New York.

Elhorst, J. 2012. Dynamic spatial panels: models, methods, and inferences. *Journal of Geographical Systems* 14: 5-28

Ellison, G.; Glaeser, E.; and Kerr, W. 2010. What causes industry agglomeration? Evidence from coagglomeration patterns. *American Economic Review* 100: 1195-1213

Eriksson, R. 2011. Localized Spillovers and Knowledge Flows: How Does Proximity Influence the Performance of Plants? *Economic Geography* 87: 127-152

Essletzbichler, J. 2005. Diversity, stability and regional growth in the U.S. (1975-2002). Papers in Evolutionary Economic Geography 05.13. Utrecht University.

Fan, J. and Lang, L. 2000. The Measurement of Relatedness: An Application to Corporate Diversification. *The Journal of Business* 73: 629-660

Farjoun, M. 1994. Beyond industry boundaries: Human expertise, diversification and resource-related industry groups. *Organization Science* 5: 185-199

Feser, E. 2003. What regions do rather than make: A proposed set of knowledge-based occupation clusters. *Urban Studies* 40: 1937-1958

Florida, R. 2002. *The Rise of the Creative Class*. New York: Basic Books.

Frenken, K., and Boschma, R.A. 2007. A theoretical framework for evolutionary economic geography: industrial dynamics and urban growth as a branching process. *Journal of Economic Geography* 7: 635-649

Frenken, K.; van Oort, F.; and Verburg, T. 2007. Related variety, unrelated variety and regional economic growth. *Regional Studies* 41: 685-697

Fritsch, M., and Slavtchev, V. 2011. Determinants of the Efficiency of Regional Innovation Systems. *Regional Studies* 45: 905-918

Fuchs, M. 2011. The determinants of local employment dynamics in Western Germany. *Empirical Economics* 40: 177-203.

Fujita, M., and Gokan, T. 2005. On the evolution of the spatial economy with multi-unit·multi-plant firms: the impact of IT development. *Portuguese Economic Journal* 4: 73-105

Fujita, M., and Thisse, J. 2006. Globalization and the evolution of the supply chain: Who gains and who looses? *International Economic Review* 47: 811-836

Glaeser, E., and Saiz, A. 2004. The rise of the skilled city. *Brookings-Wharton Papers on Urban Affairs* 5: 47-94

Glaeser, E.; Kallal, H.D.; Schinkmann, J.A.; and Shleifer, A. 1992. Growth in cities. *Journal of Political Economy* 100: 1126-1152

Harrison, B.; Kelley, M.; and Gant, J. 1996. Innovative Firm Behaviour and Local Milieu: Exploring the Intersection of Agglomeration, Firm Effects, and Technological Change. *Economic Geography* 72: 233-258.

Hartog, M.; Boschma, R.; and Sotarauta, M. 2012. The Impact of Related Variety on Regional Employment Growth in Finland 1993–2006: High-Tech versus Medium/Low-Tech. *Industry and Innovation* 19: 459-476

Henderson, J.; Kuncoro, A.; and Turner, M. 1995. Industrial Development in Cities. *Journal of Political Economy* 103: 1067-1090

Hidalgo, C.; Klinger, B.; Barabási, A.; and Hausmann, R. 2007. The Product Space Conditions the Development of Nations. *Science* 317: 482-487

Illy, A.; Schwartz, M.; Hornych, C.; and Rosenfeld, M. T. 2011. Local Economic Structure and Sectoral Employment Growth in German Cities. *Tijdschrift voor economische en sociale geografie* 102: 582-593

Jacobs, J. 1969. *The Economy of Cities*. New York: Vintage.

Kim, S. 1999. The Rise of Multiunit Firms in U.S. Manufacturing. *Explorations in Economic History* 36: 360-86

Koo, J. 2005. How to Analyze the Regional Economy with Occupation Data. *Economic Development Quarterly* 19: 356-372

Kosfeld, R., and Lauridsen, J. 2004. Dynamic spatial modelling of regional convergence processes. *Empirical Economics* 29: 705-722

Kosfeld, R.; Eckey, H.-F.; and Dreger, C. 2006. Regional productivity and income convergence in the unified Germany, 1992-2000. *Regional Studies* 47: 755-767

LeSage, J., and Fischer, M. 2008. Spatial Growth Regressions: Model Specification, Estimation and Interpretation. *Spatial Economic Analysis* 3: 275-304

LeSage, J., and Pace, K. 2009. *Introduction to Spatial Econometrics*. Boca Raton: Chapman and Hall/CRC.

Lundquist, K.-J., and Trippl, M. 2011. Distance, Proximity and Types of Cross-border Innovation Systems: A Conceptual Analysis. *Regional Studies* (forthcoming)

Maggioni, M., and Uberti, E. 2007. Inter-Regional Knowledge flows In Europe: An Econometric Analysis. In *Applied Evolutionary Economics and Economic Geography,* ed. K. Frenken, 230-255. Cheltenham: Edward Elgar.

Malmberg, A.; Malmberg, B.; and Lundequist, P. 2000. Agglomeration and firm performance: economies of scale, localisation, and urbanisation among Swedish export firms. *Environment and Planning A* 32: 305-321

Markides, C. and Williamson, P. 1996. Corporate diversification and organizational structure: a resource-based view. *Academy of Management Journal* 39: 340-69

Markusen, A. 2004. Targeting occupations in regional and community economic development. *Journal of the American Planning Association* 70: 253-268

Markusen, A., and Schrock, G. 2006. The distinctive city: Divergent patterns in American urban growth, hierarchy and specialization. *Urban Studies* 43: 1301-23

Melo, P.; Graham, D.; and Noland, R. 2009. A Meta-analysis of Estimates of Urban Agglomeration Economies. *Regional Science and Urban Economics* 39: 332-342

Millo, G. and Piras, G. 2012. splm: Spatial Panel Data Models in R. *Journal of Statistical Software* 47: 1-38

Montgomery, C. and Hariharan, S. 1991. Diversified expansion by large established firms. *Journal of Economic Behavior & Organization* 15: 71-89

Neffke, F., and Henning, M. 2009. Skill-relatedness and firm diversification. Papers on Economics and Evolution 2009-06. Max Planck Institute of Economics Jena.

Neffke, F.; Henning, M.; and Boschma, R. (2011), How Do Regions Diversify over Time? Industry Relatedness and the Development of New Growth Paths in Regions. Economic Geography, 87: 237–265.

Nooteboom, B. 2000. *Learning and Innovation in Organizations and Economies*. Oxford: Oxford University Press.

Nooteboom, B.; Van Haverbeke, W.; Duysters, G.; Gilsing, V.; and Van Den Oord, A. 2007. Optimal cognitive distance and absorptive capacity. *Research Policy* 36: 1016-1034

Ó hUallacháin, B., and Satterthwaite, M. 1992. Sectoral growth patterns at the metropolitan level: An evaluation of economic development incentives. *Journal of Urban Economics* 31: 25-58

Parjanen, S.; Harmaakorpi, V.; and Frantsi, T. 2010. Collective Creativity and Brokerage Functions in Heavily Cross-Disciplined Innovation Processes. *Interdisciplinary Journal of Information, Knowledge, and Management* 5: 1-21

Porter, M. 2003. The Economic Performance of Regions. *Regional Studies* 37: 549-578

Robert-Nicoud, F. 2008. Offshoring of routine tasks and (de)industrialisation: Threat or opportunity – and for whom? *Journal of Urban Economics* 63: 517-535

Romer, P. 1986. Increasing returns and long-run growth. *Journal of Political Economy* 94: 1002-1037

Rosenthal, S., and Strange, W. 2004. Evidence on the Nature and Sources of Agglomeration Economies. In *Handbook of Regional and Urban Economics: Cities and Geography,* eds. V. Henderson, and J. Thisse, 2119-2171. Amsterdam: Elsevier.

Rumelt, R. 1984. Towards a strategic theory of the firm. In *Competitive Strategic Management*, ed. R. Lamb, 556-570, Englewood Cliffs: Prentice Hall.

Tanriverdi, H. and Venkatraman, N. 2005. Knowledge relatedness and the performance of multibusiness firms. *Strategic Management Journal* 26: 97-119

Thompson, W., and Thompson, P. 1985. From industries to occupations: Rethinking local economic development. *Economic Development Commentary* 9: 12-18

Thompson, W., and Thompson, P. 1987. National industries and local occupational strengths: the cross-hairs of targeting. *Urban Studies* 24: 547-560

Trippl, M. 2010. Developing cross-border regional innovation systems: key factors and challenges. *Tijdschrift voor economische en sociale geografie* 101: 150-160.

Appendix 1 – Descriptive statistics of independent variables (pooled, n=1310)

Variables	Mean	SD	Min	Max
RV	1.85	0.40	0.50	2.71
URV	3.47	0.42	0.89	4.16
RV_ WC	1.51	0.45	0.15	2.51
RV_R&D	1.17	0.48	0.00	2.43
RV_BC	1.79	0.41	0.53	2.77
URV_WC	3.31	0.48	0.37	4.18
URV_R&D	2.70	0.57	0.22	3.93
URV_BC	3.34	0.41	0.86	4.02
SPECIALIZATION	0.14	0.08	0.07	0.79
FUNC_ SPECIALIZATION	0.06	0.04	0.01	0.41
HUMAN_CAPITAL	0.04	0.02	0.01	0.16
SIZE*	26.66	37.13	1.36	375.83
AV_FIRM_SIZE*	30.46	16.86	10.64	201.01

* SIZE and AV_FIRM_SIZE enter the regression analysis log transformed.

Source: Authors own calculations.

Appendix 2 – Correlation matrix of independent variables (pooled, n=1310)

Variables	RV	URV	RV_ WC	RV_R&D	RV_ BC	URV_ WC	URV_R&D	URV_BC	SPECIALI-ZATION	FUNC_ SPECIALI-ZATION	HUMAN_ CAPITAL	SIZE	AV_FIRM _SIZE
RV	1												
URV	0,473	1											
RV_ WC	0,858	0,427	1										
RV_R&D	0,832	0,309	0,776	1									
RV_BC	0,960	0,401	0,804	0,805	1								
URV_WC	0,432	0,818	0,389	0,315	0,368	1							
URV_R&D	0,453	0,752	0,392	0,337	0,385	0,704	1						
URV_BC	0,431	0,958	0,398	0,273	0,382	0,734	0,680	1					
SPECIALIZATION	-0,437	-0,941	-0,363	-0,261	-0,364	-0,787	-0,679	-0,889	1				
FUNC_ SPECIALIZATION	0,085	0,025	0,093	0,055	0,163	-0,253	-0,012	0,116	0,054	1			
HUMAN_CAPITAL	-0,036	-0,079	0,081	-0,035	0,085	-0,227	-0,274	-0,000	0,138	0,708	1		
SIZE	0,119	-0,162	0,256	0,198	0,184	-0,144	-0,091	-0,140	0,195	0,240	0,365	1	
AV_FIRM_SIZE	-0,393	-0,594	-0,232	-0,201	-0,292	-0,528	-0,465	-0,518	0,683	0,172	0,343	0,356	1

Source: Authors own calculations.

Appendix 3 – Results of the Hausman test for spatial models

	Model 3		Model4	
	Fixed effects	Random effects	Fixed effects	Random effects
Hausman's χ^2	-	126.4	-	154.6
df	-	7	-	11
p-value	-	0.000	-	0.000

Notes: Tests are done with splm package by Millo and Piras (2012)..

Source: Own calculation.

Appendix 4 – LM tests for spatial dependence (fixed effects panel model)

LM tests (Dubarsy and Ertur 2010)	Model 3		Model4	
	LM-Statistic	p-value	LM-Statistic	p-value
Joint test of spatial correlation (H0: absence of spatially correlated residuals and spatial correlation of the dependent variable)	67.64	< 0.01	59.85	< 0.01
Spatial correlation in residuals (H0: absence of spatial correlation in residuals)	27.80	< 0.01	31.02	< 0.01
Spatial correlation of the dependent variable (H0: absence of spatial correlation of the dependent variable)	40.30	< 0.01	41.93	< 0.01
Spatial correlation in residuals when spatial correlation of the dependent variable is accounted for (H0: absence of spatial correlation in residuals)	1.85	0.17	1.51	0.22
Spatial correlation of the dependent variable when spatial correlation in residuals is accounted for (H0: absence of spatial correlation of the dependent variable)	491.87	< 0.01	444.32	< 0.01

Notes: A 262x262 row standardized contiguity matrix is used. The tests developed in Dubarsy and Ertur 2010 are performed via the MATLAB code provided by Debarsy and Ertur for the Econometrics toolbox of LeSage (http://www.spatial-econometrics.com).

Source: Own calculation.