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Cooperation and Innovation Performance in Rural, Low-Technology Regions*

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Abstract

This paper assesses the extent to which cooperation impacts innovation performance of firms in rural regions characterized by a solid economic performance despite a low-technology industrial structure. Particular emphasis is placed on the spatial and functional dimension of cooperation. Generic results for the German region of Lower Bavaria show that firms do not profit primarily from R&D-intensive forms of cooperation, but that other forms of cooperation are more important for regional firms. For policymakers, this implies that an exclusive focus on R&D-based regional innovation policies may be neither appropriate nor sufficient for stimulating innovativeness in this type of region.

Keywords: innovation, connectivity, low-tech industries, rural regions, R&D, Germany

JEL Classification: R11, O18, O31, L25

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1 Introduction

Following new growth theory, R&D inputs and high shares of human resources in science and technology are seen as preconditions for economic growth and innovativeness of a region and the technological intensity of the regional industries is frequently conceived as primary cause of differences in economic growth, with rural, low-tech regions seen to be lagging behind (e.g. FAGERBERG, 2002). This implies that metropolis areas and densely populated urban agglomerations with large shares of high-tech industries, high levels of R&D expenditure and a highly educated workforce are more innovative and reveal a better economic performance overall (MEYER-KRAHMER, 1985; COPUS and SKURAS, 2006; CRESCENZI and RODRIGUEZ-POSE, 2011). However, case-specific empirical evidence indicating that some regions perform well in economic terms, independently of their rural and low-technology industrial structure. One of these regions is the German region of Lower Bavaria, located in the south-east corner of Germany at the German-Austrian-Czech border. Despite its rural, low-tech industrial structure and low shares of human resources in science and technology, the region performs well above the German average in terms of economic growth and employment. Furthermore, almost two-thirds of regional firms report that they have introduced some form of innovation in the past three years, suggesting that the relation between regional R&D inputs and economic growth might not be as straightforward and R&D might not stimulate innovativeness and thus, economic growth in every region in the same way. This paper draws on this puzzling findings and asks to what extent the absorption capacity of regional firms, enabling them to profit from cooperation and to acquire innovation inputs from external knowledge sources (COHEN and LEVINTHAL 1990), can explain the empirical evidence.

Overall, the principle that cooperation strengthens the innovation performance of firms particularly in regions with a low-tech industrial structure is widely acknowledged and has become a fundamental element of many regional innovation policies, not least reflected by the regional innovation strategy of the European Commission (see, for example, CAMAGNI and CAPELLO 2013; MCCANN and ORTEGA-ARGILES, 2013). However, while several studies have shown that firms in non-core regions indeed profit from regional cooperation (see, for instance, VARIS and LITTUNEN, 2012; FITJAR and RODRIGUEZ-POSE, 2011; HIGGINS and JOHNSTON, 2009), the underlying *spatial* and *functional* dimensions of cooperation driving these results have not yet been fully understood. This paper contributes to the literature by investigating how cooperation impacts the innovation performance of firms in a rural and low-tech region and how the relation between cooperation and innovation is driven by the underlying *spatial*

and *functional* dimension of cooperation. Moreover, by considering both technological and non-technological forms of innovation, the paper contemplates a further aspect that has been largely neglected in previous works. The empirical analysis is carried out on the basis of empirical micro-level survey data of Lower Bavarian firms. Because of its high economic and innovation performance despite a low-tech industrial structure and low values of the traditional innovation indicators, Lower Bavaria serves as a particularly suitable and interesting case study for these research questions.

The remainder of this paper is structured as follows: the next section provides a brief overview of the state of research and sketches the main regional features of the study region. Section 3 states the empirical hypotheses. The data and the estimation strategy are described in Section 4. The results from the empirical analysis are provided and discussed in Section 5. The paper closes with a critical discussion of the main results and their implications.

2 Does Cooperation Impact Innovation in Rural, Low-Tech Regions?

2.1 Theoretical Background

Innovation is commonly perceived as the result of an interactive process, requiring the combination of various competencies, skills and technologies. Therefore, firms have to acquire external knowledge in order to innovate (STERNBERG, 2000; BROEKEL *et al.*, 2011). On the regional level, agglomeration theories (see DURANTON and PUGA, 2004 for an overview) and integrated concepts such as the regional innovation system (see NELSON, 1993; LUNDVALL, 1992; BRACZYK *et al.*, 1997; CRESCENZI and RODRIGUEZ-POSE, 2011) stress the benefits that the embeddedness in regional cooperation networks provides for the innovation potential of regional firms. They suggest that regional embeddedness is necessary for knowledge exchange, as face-to-face contact and mutual trust support regional knowledge spill-over (MASKELL and MALMBERG, 2007; CRESCENZI and RODRIGUEZ-POSE, 2011). However, particularly firms in non-core regions with a limited knowledge base have to acquire knowledge, skills and competencies from outside the region in order to innovate and to avoid regional lock-in (BOSCHMA, 2005; MORRISON *et al.*, 2013; IAMMARINO, 2005). Furthermore, recent studies suggest that the geographic diversity of partners is an innovation-supporting factor. Firms can exploit a greater variety of knowledge sources which may lead to more opportunities to learn and to acquire innovation-related skills (VAN BEERS and ZAND, 2013).

The majority of empirical studies that assess the relation between cooperation and innovation support the positive relation. However, many studies focus exclusively on R&D cooperation and examine firms in high-tech industries or firms located in urban agglomerations with knowledge-intensive industries and a distinct innovation infrastructure. Studies that explicitly consider the relation between cooperation and innovation in non-core regions are less frequent and generally inconsistent with regard to their results and methodological approaches. Among the studies with a quantitative approach, VARIS and LITTUNEN (2012) find that innovating firms perceive the importance of inter-regional cooperation with actors outside the region to be greater than non-innovating firms. In the same line, FITJAR and RODRIGUEZ-POSE (2011) indicate that particularly firms with cooperation linkages that reach outside the region are successful in developing new products. The benefits of inter-regional networks for firms in low-tech regions are also highlighted by HUGGINS and JOHNSTON (2009), who assess the regional scope of firm networks in two British regions. Their results indicate that more innovative SMEs possess denser networks with actors both within and outside the region. Further empirical evidence is provided by LAGENDIJK and LORENTZEN (2007), who found that firms in remote regions depend heavily on non-local forms of interaction. In the same line, VIRKKALA (2007) shows for a Finnish region that the leading regional firms acquire knowledge from external knowledge sources, while VALE and CALDEIRA (2007) depict for the low-tech region of Northern Portugal that the most innovative regional firms develop distant cooperation-linkages. This brief overview of the related literature shows that firms in non-core regions benefit particularly from inter-regional cooperation.

2.2 The Regional Context of the Empirical Case

In contrast to the studies outlined above, this paper assesses the relation between connectivity and innovation in a region that is economically successful, despite a disadvantageous industrial structure and low levels on the traditional R&D indicators. Here, the German region of Lower Bavaria serves as the empirical example. As outlined above, the region represents an interesting case for economic geographers, as it is successful in terms of innovation and economic growth, despite a rural and low-technology industrial structure.

Altogether, the region encompasses an area of 10,320 km², of which 5,608 km² (i.e. 54.3%) are agricultural production land. The rural structure is also underlined by the comparatively high share (5.4%) of employees in the agricultural sector, which exceeds the share of any other Bavarian region. Geographically, the region is located at the south-easternmost corner of Germany on the Austrian and Czech border (see Figure 1). Hence, at least from a German perspective,

the region can be conceived as a peripheral region. In 2012, the regional population density amounted to 115.38 inhabitants per km², and was lower than in any other Bavarian region. Furthermore, the region lacks any urban agglomeration. The two largest cities in the region are Landshut with 64,763 inhabitants (in 2012) and Passau with 50,458 inhabitants (in 2012). Given the lack of any major city with more than 100,000 inhabitants and the low population density, Lower Bavaria qualifies as a rural region according to the classification of the German Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR) (2014).

Figure 1: Map of Lower Bavaria and Surrounding Regions ^a



^a Map of Lower Bavaria and the surrounding German, Austrian and Czech regions, whereby Lower Bavaria is depicted by a dark coloring and Bavaria by a grey coloring.

Politically, Lower Bavaria belongs to the federal state of Bavaria. In terms of economic growth, Bavaria has undergone a very successful development in the past 60 years (SCHIFFERS, 2013). While the state was one of the poorest regions in West Germany after World War II, characterized by a rural and backward economic structure, since 1960, Bavaria has risen to become one of the most successful German states. However, it has mainly been the metropolitan area of Munich and the surrounding region of Upper Bavaria that have profited intensely from the successful development, with multiple high-tech firms clustering around the universities and research facilities in Munich (KUJATH, 2002). In contrast, Lower Bavaria – which may be conceived as a second tier region vis-a-vis Munich – has attracted far fewer high-tech firms. During the time of the Cold War, the location directly alongside the “*iron curtain*” was particularly disadvantageous for the region.

The regional economic structure is still characterized today by a dominance of low and medium-

tech industries. When taking the sector-based classification of technology intensity proposed by the OECD (2011) as a basis, low and medium-tech industries represent over three quarters of the regional manufacturing sector, whereas high-tech industries are entirely lacking (see Table 1).¹

Table 1: Technology Intensity of Regional Manufacturing Industries^a

Technology Intensity	Share of Regional Manufacturing Industries
Low-technology industries	35.5%
Medium-low-technology industry	40.7%
Medium-high-technology industry	23.8%
High-technology-industries	00.0 %

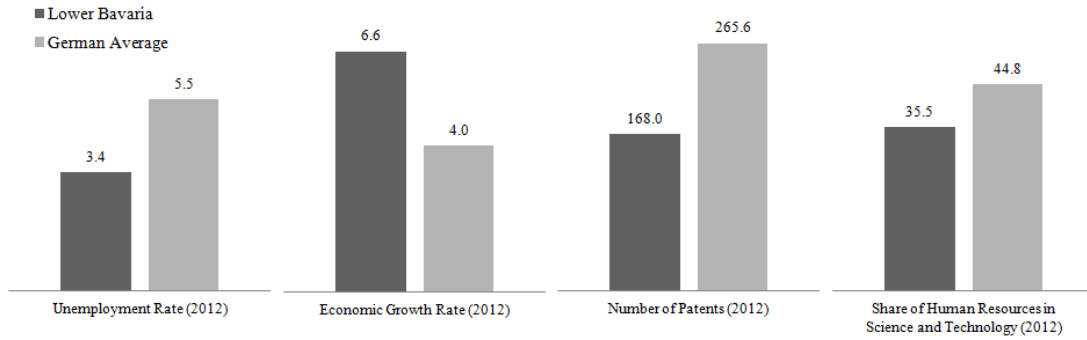
^a Share of regional manufacturing firms (by the number of establishments) by technological intensity based on the classification of the OECD Directorate for Science, Technology and Industry, 2011. Own calculation based on data obtained from IHK NIEDERBAYERN and HWK NIEDERBAYERN-OBERPFALZ (2012).

Regarding the economic structure according to industry, the location of a major automotive plant in the region in 1969 particularly contributed to the establishment of various suppliers, especially in the vehicle manufacturing, engine building and plant construction industries. These industries still prevail today, reflected also by their large number of employees. In 2012, over 25% of employees in the manufacturing sector worked in the automotive industry, while another 15% worked in both the engine building and the plant construction industries respectively (IHK NIEDERBAYERN and HWK NIEDERBAYERN-OBERPFALZ, 2012). Overall, this distribution again underlines the dominance of low and medium-tech industries. With respect to the firm size, small and medium-sized enterprises (SME) dominate, a pattern that can be observed in many rural, low-technology regions.

In summary, the region of Lower Bavaria is certainly disadvantaged by its low-tech industrial structure, its low share of human resources in science and technology and its peripheral location on the German-Czech-Austrian border. Yet, the region is successful in terms of economic growth, not least reflected by the strong regional GDP per capita, and the low unemployment rate within the region (see Figure 2). Furthermore, even though the number of patents is below the German average, two-thirds of regional firms have introduced some form of innovation in the past three years. Given these seemingly contradicting regional features, Lower Bavaria serves as a good example for a specific type of European region located at the second tier of a major innovative city that is economically successful despite low levels of R&D.

To illustrate the comparability of Lower Bavaria, Table 2 lists 8 regions within the EU-15 that share similar regional characteristics to Lower Bavaria in terms of location, the lack of a regional

Figure 2: Lower Bavarian Economic Performance and Innovativeness Indicators



agglomeration center, their economic performance and their regional R&D. This list illustrates that it may be reasonable to conceive Lower Bavaria as an archetype for a specific type of European region that has not been conclusively examined in previous research.

Table 2: Comparable 2nd tier regions around most innovating EU cities ^a

Core City	Second Tier Region	GDP	HRST	Largest City (Inhabitants)
Vienna	Upper Austria	126	36.1	Linz (191.501)
Munich	Lower Bavaria	117	37	Landshut (65.322)
Copenhagen	Southern Denmark	114	40.2	Vejle (52.449)
	Middle Denmark	116	42.8	Vilborg (38.261)
Amsterdam	Friesland	104	40.5	Leeuwarden (96.568)
Frankfurt	Giessen	107	41.2	Giessen (76.680)
Stockholm	Smaland	108	39.6	Joenkoeping (89.369)
Stuttgart	Tuebingen	124	46.1	Tuebingen (84.496)
Brussels	West Flanders	112	43.6	Bruegge (117.170)

^a Based on Eurostat Data, 2014. GDP=Regional GDP (PPS per inhabitant in % of the EU27 average); HRST= Share of Human Resources in Science and Technology (in % of total workforce).

3 The Impact of the Space and Form of Cooperation on Innovation

3.1 Hypotheses Regarding the *Spatial Dimension* of Cooperation

The description of Lower Bavaria has shown that the region might serve as an interesting case when assessing the relation between cooperation and innovation in non-core regions that are successful in terms of economic growth and innovativeness, despite several disadvantageous regional characteristics. Drawing from the existing literature (see, Section 2), one reason for this seemingly contradicting finding might be the fact that regional firms exploit external knowledge

bases through inter-regional cooperation and that regions with a low-tech industrial structure profit particularly from acquiring innovation-related knowledge and skills from cooperation with partners in external regions. Hence, in accordance with the above-mentioned literature, two hypotheses regarding the spatial scope of cooperation can be formulated.

- *Hypothesis 1: The larger the spatial scope of a firm's cooperation linkages, the more likely it is to innovate.*
- *Hypothesis 2: Inter-regional cooperation has a larger positive effect on a firm's likelihood of innovating than intra-regional cooperation.*

Given the presumption that firms in rural regions with a low-tech industrial structure profit particularly from inter-regional cooperation, the question remains as to which regions provide the most innovation-related skills and competences for firms in this type of region. Building on the global pipeline concept illustrated by BATHELT *et al.* (2004) and MORRISON *et al.* (2013), the assumption is that firms in regions with a low-tech industrial structure and low R&D may profit particularly from cooperation with partners in globally connected core regions. Conferring this view to the Lower Bavarian context, it is assumed that regional firms benefit particularly from cooperation linkages with partners in nearby Munich, as the city is one of the most innovative European metropolises.

- *Hypothesis 3: Cooperation with Munich as the nearest core region has a positive effect on the likelihood of a firm innovating.*

A further factor that potentially influences the impact of cooperation might be the geographical distance between the regional firm and its cooperation partners. Here, the literature is divided over the effect. On the one hand, several studies suggest that transaction costs arising from cooperation with distant partners might exceed the benefits, while on the other hand, firms might only choose cooperation partners in distant regions when they can exploit important external knowledge from these cooperation linkages (VAN BEER and ZAND, 2013). Empirically, CRESCENZI and RODRIGUEZ-POSE (2011) find evidence for a distant-decay effect, suggesting that distant cooperation is only beneficial up to a certain tipping point. Hence, cooperation with distant partners who are more than a daytrip (i.e. 200 km) away does not yield a beneficial effect.

- *Hypothesis 4: Cooperation with geographically distant regions does not affect the likelihood of a firm innovating.*

While the previous hypotheses focus on the spatial (i.e. geographical) dimension of distance, other dimensions have not been taken into account, yet. Building on the multidimensionality of distance outlined by BOSCHMA (2005), geographical distance might, however, not be the only significant dimension, with cognitive and institutional proximity also being of potential importance. Cooperation with German partners is thus potentially exposed to fewer institutional barriers than cross-border cooperation with partners in Austria or in the Czech Republic. This is in line with the reasoning of TÖDTLING and TRIPPL (2005), who argue that firms entering into cross-border cooperation face additional barriers originating from different customs, habits and institutions. Altogether, this evidence suggests that institutional distance negatively affects the relation between cooperation and innovation.

- *Hypothesis 5: Cooperation with cross-border regions does not affect the likelihood of a firm innovating.*

3.2 Hypotheses Regarding the *Functional* Dimension of Cooperation

Along with the *spatial dimension* of cooperation, the *functional dimension* of cooperation might further affect the extent to which firm's cooperation relates to its innovativeness. Following the neoclassical R&D-based innovation paradigm, suggesting that R&D plays the leading role in the innovation process, R&D cooperation in particular should increase a firm's likelihood of innovating (SAVOTTI and NOTEBOOM, 2000). This idea is also supported by the resource-based theory perspective, suggesting that R&D cooperation is one of the most valuable resources in the innovation process (VAN BEERS and ZAND, 2013). Therefore, particularly in regions with low internal R&D, firms have to acquire innovation-related skills and competences from external sources. Therefore, firms in Lower Bavaria should profit particularly from R&D cooperation. Conversely, other forms of cooperation might only indirectly affect the innovation process of a firm, and are hence presumed to be of lower relevance.

- *Hypothesis 6: R&D cooperation has a positive effect on the likelihood of a firm innovating.*

The empirical evidence for this hypothesis, however, is extremely scarce in the existing literature. By differentiating between the impact of various cooperation areas (i.e. procurement cooperation, production cooperation, sales cooperation and R&D cooperation), the paper assesses a further dimension of cooperation that has received little attention in previous research.

4 Data, Variables and Measurements

To test the hypotheses stated above, original micro-level data from a survey of regional firms conducted between February and April 2013 are used. The advantage of these data compared to standard innovation surveys (e.g. Community Innovation Survey) is that they provide detailed information on both the *spatial dimension* and the *functional dimension* of firm's cooperation. Furthermore, they allow a distinction between technological and non-technological forms of innovation. The sample of firms is drawn from the firm database of the regional Chamber of Commerce and Industry (IHK Niederbayern) and the regional Chamber of Handicrafts (HWK Niederbayern-Oberpfalz). Due to the compulsory membership of German firms in one of the two chambers, the joint database can be regarded as comprehensive. Overall, 5,347 firms were asked to participate in the survey, reflecting all regional firms with an annual turnover of more than 17,500 Euro. This boundary was implemented to exclude the large number of micro-firms, which are not suitable for our analysis and would potentially bias the results. In the survey, firms were contacted either by email or post. Overall, 732 Lower Bavarian firms participated in the survey, reflecting a return rate of 13.7%. However, due to item-non response, only 399 firms (i.e. 7.46%) are included in the subsequent analysis. Regarding the sector and size of firms, the distribution in the final sample is outlined in Table 3. From the statistics, it becomes evident that small firms with fewer than 50 employees and firms in the manufacturing sector dominate, a pattern that reflects the actual distribution of Lower Bavarian firms. Hence, in terms of sector and size, the sample is representative for the entire population of regional firms.

Table 3: Distribution of Firms in the Sample according to Size and Sector

Sector	Firm Size						
	<10	<50	<100	<250	<1000	≥ 1000	
Construction Sector	56	43	10	2	1	1	113
Manufacturing Sector	81	75	21	22	14	4	217
Service Sector	31	33	4	0	1	0	69
	168	151	35	24	16	5	399

4.1 Dependent Variable: Innovation

With respect to *innovation*, firms were asked to indicate what kind of innovations they have introduced in the past three years. The definition of innovation thereby follows the guidelines for interpreting innovation data outlined by the OECD and Eurostat in the *Oslo Manual* (OECD and EUROSTAT, 2005). Hence, firms could differentiate between product innovation, process

innovation, organizational innovation and marketing innovation. Subsequently, the information was aggregated to one binary innovation variable, indicating whether or not a firm has introduced any *innovation* in the past three years. Furthermore, separate binary variables for *technological innovations* (i.e. product and process innovation) and *non-technological innovations* (i.e. organizational innovations and marketing innovations) were created. This distinction is in accordance with the guidelines of the *Oslo Manual* (2005) as well as other empirical studies (e.g. PIPPEL, 2014). It allows a consideration of the effect of cooperation separately for technological innovation and for non-technological innovation. The latter is of importance due to the perception that in regions with a low-tech industrial structure, low-threshold innovations may play a crucial role for the regional prosperity.

The descriptive statistics of innovation are depicted in Table 4. The statistics reveal that 60.4% of Lower Bavarian firms have introduced some form of innovation in the past three years. This is lower than the German average, which amounted to 79.9% in 2008, but higher than the average in all other EU countries except Luxembourg (RAMMER, 2013). With respect to technological and non-technological innovations, results show that the share of firms that have introduced technological innovations (i.e. product and process innovations) is slightly higher than the share of firms that have introduced non-technological innovations (i.e. marketing innovations or organizational innovations) in the past three years. As multiple answers were possible, the two categories (i.e. technological and non-technological innovations) are not mutually exclusive.

Table 4: Innovation in Lower Bavaria^a

	Yes		No		n
Technological innovations	178	(44.61%)	221	(55.39%)	399
Non-technological innovations	164	(41.10%)	235	(58.90%)	399
Any Innovation	241	(60.40%)	158	(39.60%)	399

^a Number and share (in parantheses) of Lower Bavarian firms that have or have not introduced technological, non-technological or any innovation in the past three years.

4.2 Explanatory Variable: Cooperation

To analyze the *spatial* and the *functional* dimension of cooperation, firms were asked to indicate their cooperation linkages in a two-dimensional matrix. The first dimension (i.e. the *functional dimension*) includes the area of cooperation (i.e. procurement cooperation, production cooperation, sales cooperation and R&D cooperation), while the second dimension (i.e. the *spatial dimension*) includes the geographic distribution of cooperation linkages. In this dimension, firms could indicate out of a list of 26 different regions where their cooperation linkages are

geographically located. A complete list of regions is presented in the Appendix (Table A.1).

With respect to the *spatial dimension* of cooperation, the first explanatory variable is the geographic scope of cooperation. The scope of cooperation is defined as the number of regions a particular firm cooperates with. Values range from 0 (indicating that a firm does not maintain any cooperation linkages) to 26 (indicating that the firm maintains cooperation linkages with all 26 regions inquired about in the firm survey). The average number of cooperation regions is 3.3, meaning that on average, Lower Bavarian firms cooperate with actors in approximately three regions (see Table 5).

Regarding intra and inter-regional cooperation linkages, two dummy variables are generated. They indicate whether a firm maintains cooperation linkages with partners within Lower Bavaria (intra-regional cooperation) and with partners outside Lower Bavaria (inter-regional cooperation). Overall 60.1% of the surveyed firms maintain intra-regional cooperation linkages, whereas merely 46.9% of firms maintain inter-regional cooperation linkages (see Table 5).²

Further spatial cooperation variables include a binary variable for cooperation with partners in Munich as the nearest core region, and a binary variable for cooperation with partners in distant regions (i.e. with partners from outside Germany, Austria and the Czech Republic). Furthermore, additional dummy variables for cooperation with partners in Bavaria, Austria and the Czech Republic are generated. These regions are located within a 200 km radius around Lower Bavaria. Hence, they do not require an overnight stay.

With regard to the *functional dimension* of cooperation, the paper differentiates between procurement cooperation, production cooperation, sales cooperation and R&D cooperation. Again, binary variables for each area of cooperation are generated, indicating whether or not a firm maintains cooperation linkages in the specific area. As the descriptive statistics in Table 5 show, input and output cooperation are most common among Lower Bavarian firms, while R&D cooperation is less common.

4.3 Control Variables: Innovation-Supporting Firm Characteristics

Along with the cooperation variables, a parsimonious set of further *control variables* is included in the analysis. The control variables are chosen in accordance with the factors that have been identified in the literature as (potentially) influencing the relationship between cooperation and innovation in rural regions. The set comprises the size and the sector of a firm as well as a firm's R&D expenditure, which have been shown to affect firms' likelihood of innovating in regions with a low-tech industrial structure (Barge-gil, 2010).³ The *size* of a firm is measured by the number

Table 5: Summary Statistics Explanatory Variables and Control Variables ^a

	N	Mean	St.D.	Min.	Max.
Main Explanatory Variables: Cooperation					
Scope of Cooperation	399	3.286	4.452	0	26
Intra-Regional Cooperation	399	.607	.489	0	1
Inter-Regional Cooperation	399	.469	.500	0	1
Cooperation with Partners in Munich	399	.185	.389	0	1
Cooperation with Partners in Distant Regions	399	.133	.340	0	1
Cooperation with Partners in Bavaria	399	.376	.485	0	1
Cooperation with Partners in Austria	399	.153	.360	0	1
Cooperation with Partners in the Czech Republic	399	.065	.247	0	1
Input Cooperation	399	.383	.487	0	1
Production Cooperation	399	.316	.465	0	1
Output Cooperation	399	.333	.472	0	1
R&D Cooperation	399	.163	.370	0	1
Control Variables					
Number of Employees (Categorical)	399	1.935	1.174	0	6
R&D Expenditure	399	.286	.452	0	1
Manufacturing Sector	399	.544	.499	0	1
Construction Sector	399	.283	.451	0	1
Service Sector	399	.173	.397	0	1

^a Summary statistics of independent variables included in the multivariate models.

of employees or, alternatively, by the annual turnover. However, as the results of the empirical analyses do not change significantly depending on whether firm size is measured by the number of employees or the annual turnover, only the results for number of employees are reported. Both variables constitute categorical variables, with the categories approximating the common EU classification (EUROPEAN COMMISSION, 2006).⁴ Overall, small and medium-size enterprises (SME) dominate in Lower Bavaria, a pattern that is characteristic for low-technology regions.

With respect to the *sector*, three binary sectoral variables are created. They indicate (1) the manufacturing sector, (2) the construction sector (which also includes the large regional crafts sector) and (3) the service sector.⁵ Regarding firms' R&D expenditure, a dummy variable, indicating whether or not a firm devotes extra money to R&D, is generated. The summary statistics (see Table 5) show that about one-fourth of Lower Bavarian firms use extra money for R&D.

5 Impact of Cooperation on the Likelihood of Innovating

To empirically investigate the impact of cooperation on innovation – while controlling for different firm-specific confounding factors – a binary regression model with various specifications is estimated. The likelihood of a firm innovating is thereby regressed on the various cooperation

variables, on the size and the sector of the firm and on firm's R&D expenditure. The baseline model can be described as follows:

$$P(\text{innov.} = 1) = (\alpha_i + \beta_1(C_i) + \beta_2(S_i) + \beta_3(B_i) + \beta_4(RD_i)),$$

where i denotes the specific firm and α_i the intercept for each firm i . The parameters β_1 to β_4 denote the estimated parameters for the independent variables included in the model. Here, C depicts the various forms of cooperation, S depicts the firm size (measured via the number of employees or, alternatively, via the annual turnover). Furthermore, B denotes the firm branch (i.e. sector), included as various sectoral binary variables with the service sector serving as the reference category, and RD denotes firms' R&D expenditure.

5.1 Spatial Dimension - Scope of Cooperation

Estimated by a logit model, the corresponding results presented in Table 6 indicate that firms with a more spatially diverse set of cooperation partners have a greater likelihood of innovating (column 1). The positive and statistically significant average marginal effect remains stable when controlling for the size and the sector of the firm as well as for the firm's R&D expenditures. Regarding the control variables, R&D expenditure and the number of employees reveal a statistically significant positive effect, whereby the effect of R&D expenditure is particularly large. In accordance with previous studies, it shows that large firms and firms that devote extra money to R&D have a higher likelihood of innovating. On the other hand, in the region of Lower Bavaria, the sector has no significant effect.

Overall, the results (column 1) support the first hypothesis that firms with a spatially more diverse set of cooperation partners have a greater likelihood of innovating. To give a more explicit interpretation of the estimated average marginal effects, Figure 3 displays the increase in the predicted probability of a firm innovating dependent on the number of cooperation regions, while controlling for size, sector and R&D expenditure. As the graphic illustrates, the average predicted probability of innovating monotonically increases with the number of cooperation regions. Altogether, these results provide evidence for the accentuated role that a spatially diverse set of cooperation partners plays for the innovation potential of a firm.

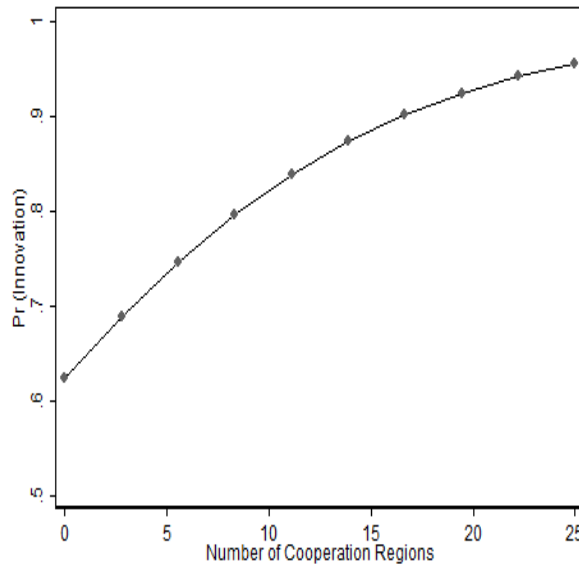
The results clearly suggest that in accordance with the second hypothesis, inter-regional cooperation is beneficial for the innovativeness of Lower Bavarian firms. To test whether inter-regional cooperation indeed has a larger effect on firm's likelihood of innovating compared to cooperation

Table 6: Impact of the Geographical Scope of Cooperation (Logit Estimates, Marginal Effects) ^a

	(1)	(2)	(3)	(4)
Cooperation Variables				
Scope of Cooperation	.018** (.006)			
Intra-Regional Cooperation		.052 (.044)		.006 (.048)
Inter-Regional Cooperation			.106* (.042)	.104* (.047)
Control Variables				
Number of Employees	.058* (.024)	.063** (.024)	.061* (.024)	.061* (.024)
R&D Expenditures	.514*** (.075)	.529*** (.077)	.495*** (.078)	.496*** (.078)
<i>Economic Sector (Reference: Service Sector)</i>				
Manufacturing Sector	.102 (.058)	.094 (.059)	.104 (.058)	.104 (.059)
Construction Sector	.031 (.063)	.012 (.064)	.024 (.063)	.023 (.063)
Model Statistics				
Observations	399	399	399	399
Mc Fadden's R ²	.230	.213	.222	.222

^a Table entries denote average marginal effects. Dependent variable: Innovation in the past three years. Standard errors in parentheses. Stars denote significance of the estimates as follows: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Figure 3: Impact of the Scope of Cooperation



limited to partners within the region of Lower Bavaria, the baseline specification is extended and the likelihood of a firm innovating is regressed on both intra and inter-regional cooperation

linkages. As before, the size and sector of the firm as well as R&D expenditure are included as control variables.

The results presented in Table 6 (column 2 to 4) show that inter-regional cooperation (i.e. cooperation with partners outside Lower Bavaria) indeed has a larger effect on firms' likelihood of innovating than intra-regional cooperation (i.e. cooperation within Lower Bavaria). Furthermore, the effect of inter-regional cooperation is statistically significant, whereas the effect of intra-regional cooperation is not. The results remain stable when controlling for the size and the sector of the firm and for firms' R&D expenditure. Moreover, estimation results remain robust, regardless of whether the two variables (i.e. inter-regional cooperation and intra-regional cooperation) are included separately in two different models or simultaneously in one and the same model. Overall, the results underline the importance that inter-regional cooperation has for the likelihood of firms in rural, low-tech regions innovating. The results are thus in line with the empirical evidence from previous studies (see Section 2). Moreover, they provide empirical evidence for the integrity of the EC regional innovation strategy emphasizing regional connectivity as a key element for stimulating innovation, particularly in regions with a low-tech industrial structure (see, for example, CAMAGNI and CAPELLO, 2013 or MCCANN and ORTEGA-ARGILES, 2013).

5.2 Spatial Dimension - Cooperation Regions

While the previous model specifications reveal that inter-regional cooperation tends to be important, the question remains as to which cooperation regions are especially beneficial. As indicated above, expectations are that regional firms profit particularly from cooperation with partners in Munich (as the nearest core region) when it comes to the acquisition of innovation-related knowledge and skills. Besides, it is assumed that both the geographical and institutional distance from the cooperation partners affects the extent to which cooperation impacts innovation. To assess the effect of cooperation with geographically distant partners, the average marginal effects for cooperation with partners in distant regions (i.e. cooperation with partners outside Germany, Austria and the Czech Republic) are estimated. In the same way, the average marginal effects for cooperation with partners in the surrounding region of Bavaria as well as in the cross-border regions in Austria and in the Czech Republic are estimated. As before, the size and the sector of the firm as well as firms' R&D expenditure serve as control variables.

The results (Table 7) indicate that the effect of cooperation with partners in Munich is – in contrast to expectations – not statistically significant. This means that whether or not a firm

cooperates with partners in Munich has no statistically significant effect on the likelihood of a firm innovating. This is of course not to say that firms cooperating with partners in Munich do not innovate. However, contrary to what is expected from the literature (see, for example, BATHELT *et al.*, 2004 or MORRISON *et al.*, 2013), cooperation with partners in Munich does not affect the innovation behavior of the firm when keeping all other variables constant. Instead, the positive and statistically significant average marginal effects of cooperation with partners in the remaining parts of Bavaria and in Austria suggest that cooperation with partners in these surrounding regions is important for the innovativeness of Lower Bavarian firms. This indicates that the spatial proximity is indeed relevant and the exploitation of location effects may indeed play a role. The relevance of geographical proximity is also underlined by the fact that cooperation with partners in geographically distant regions does not have a significant effect on firms' likelihood of innovating.

Table 7: Impact of the Cooperation Region (Logit Estimates, Marginal Effects) ^a

	(5)	(6)	(7)	(8)	(9)
Cooperation Variables					
Cooperation in Munich	.079 (.057)				
Cooperation in Bavaria		.173** (.043)			
Cooperation in Austria			.172** (.065)		
Cooperation in Czech Republic				-.010 (.102)	
Cooperation in Distant Regions					.120 (.091)
Control Variables					
Number of Employees	.059* (.024)	.062** (.024)	.062* (.024)	.061* (.024)	.060* (.024)
R&D Expenditures	.530*** (.077)	.508*** (.074)	.523*** (.076)	.533*** (.077)	.512*** (.078)
<i>Economic Sector (Reference: Service Sector)</i>					
Manufacturing Sector	.097 (.058)	.118 (.058)	.106 (.059)	.099 (.059)	.105 (.059)
Construction Sector	.019 (.063)	.030 (.062)	.049 (.064)	.020 (.064)	.032 (.064)
Model Statistics					
Observations	399	399	399	399	399
Mc Fadden's R ²	.214	.237	.223	.211	.214

^a Table entries denote average marginal effects. Dependent variable: Innovation in the past three years. Standard errors in parentheses. Stars denote significance of the estimates as follows: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Regarding the impact of cross-border cooperation, results are mixed. The negative (but not statistically significant) effect of cooperation with Czech partners suggests that institutional

distance might indeed be important. At the same time, the positive effect that cross-border cooperation with Austrian partners has on innovation suggests that spatial effects may only be one factor that explains the choice of cooperation regions. Instead, a similar industrial structure as well as a common language and culture (see TÖDTLING and TRIPPL, 2005) may likewise be beneficial for exploiting innovation-related knowledge and skills for firms in low-tech regions. In conclusion, regarding the spatial dimension of cooperation, results suggest firstly that inter-regional cooperation with a spatially diverse set of cooperation regions is positively related to the likelihood of a firm innovating, secondly that cooperation with Munich as the nearest core region does not have a significant effect, and thirdly that cooperation with the surrounding Bavarian and Austrian regions is particularly beneficial for Lower Bavarian firms.

5.3 Functional Dimension of Cooperation

With respect to the *functional dimension* of cooperation, four cooperation areas are distinguished, namely procurement cooperation, production cooperation, sales cooperation and R&D cooperation. According to the neoclassic R&D-based innovation paradigm, R&D cooperation in particular should positively affect firms' likelihood of innovating. To test this hypothesis, firms' likelihood of innovating is now regressed on the different cooperation areas. Size and sector of the firm as well as R&D expenditure are again included as control variables.

The results presented in Table 8 indicate that in Lower Bavaria, in contrast to expectation, it is not R&D cooperation that significantly affects the likelihood of a firm innovating. Rather, production cooperation has the largest and most statistically significant average marginal effect when controlling for the size and sector of a firm as well as for firms' R&D expenditure.

This result is surprising at first glance, yet it fits well with the insignificant effect that cooperation with partners from Munich has on the likelihood of a firm innovating. Hence, the results by and large suggest that in Lower Bavaria, as a rural region characterized by a dominance of SME in low and medium-tech industries, innovation-promoting knowledge is not primarily transmitted through R&D-intensive forms of cooperation. Rather, other forms of knowledge transmitted through more applicable forms of cooperation seem to be of greater relevance for regional firms. This indicates that Lower Bavarian firms have a lower demand for R&D and that R&D inputs may only be one part of the story. For policymakers and regional stakeholders, this implies that an exclusive focus of R&D cooperation may not be appropriate for stimulating the innovativeness, as R&D inputs do not affect regional innovation in all regions in the same way.

Table 8: Impact of the Functional Dimension of Cooperation (Logit Estimates, Marginal Effects)^a

	(10)	(11)	(12)	(13)
Cooperation Variables				
Input Cooperation	.019 (.046)			
Production Cooperation		.107* (.047)		
Output Cooperation			.059 (.047)	
R&D Cooperation				.064 (.094)
Control Variables				
Number of Employees	.062* (.024)	.064** (.024)	.064** (.024)	.060* (.024)
R&D Expenditures	.532*** (.077)	.513*** (.076)	.524*** (.077)	.510*** (.083)
<i>Economic Sector (Reference: Service Sector)</i>				
Manufacturing Sector	.093 (.061)	.080 (.059)	.090 (.060)	.098 (.059)
Construction Sector	.013 (.066)	-.004 (.064)	.007 (.064)	.021 (.063)
Model Statistics				
Observations	399	399	399	399
Mc Fadden's R ²	.211	.220	.213	.211

^a Table entries denote average marginal effects. Dependent variable: Innovation in the past three years. Standard errors in parentheses. Stars denote significance of the estimates as follows: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

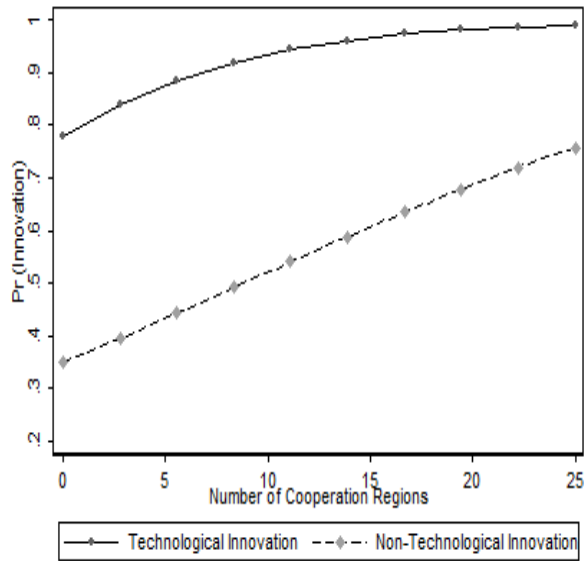
Thus, in rural, low-tech regions with a strong economic performance, other forms of knowledge might be of greater importance.

5.4 Technological vs. Non-Technological Innovation

A further explanation for the insignificant effect of R&D-intensive forms of cooperation might be that in this type of region, cooperation especially stimulates non-technological innovations that require less R&D-intensive forms of knowledge. To elaborate on this point, the impact of cooperation is now assessed separately for technological innovations (i.e. product and process innovation) and non-technological innovations (i.e. organizational and management innovations). Results displayed in Figure 4 show that even though cooperation affects both technological and non-technological innovation, the effect is particularly visible for non-technological innovation. Hence, in this region, cooperation relates especially to non-technological innovation.

In summary, the empirical analysis shows that in Lower Bavaria, as one example of an economically successful rural region, cooperation is indeed important for innovation. However, it is

Figure 4: Impact of the Scope of Cooperation by Type of Innovation



not the R&D-intensive forms of cooperation that are relevant; instead, the results suggest that geographically diverse cooperation partners and applicable forms of cooperation are particularly important for the innovation potential of regional firms.

6 Discussion and Conclusion

The paper has studied the relation between connectivity and innovation performance of firms in the German region of Lower Bavaria. This region serves as an interesting case study, as it represents a rural region located at the second tier of Munich, a major innovative city. Furthermore, the region is characterized by strong economic performance indicators despite a low-tech industrial structure and low values for the traditional innovation indicators. Building on the existing literature, six hypotheses regarding the impact of cooperation on innovation in this type of region have been developed and tested on the basis of original firm-level data. Special emphasis has thereby been devoted to both the *spatial* and *functional* dimension of cooperation.

The results show that cooperation linkages are an important element. However, the extent to which cooperation impacts innovation differs between the various *spatial* and *functional* dimensions. Most surprisingly, R&D cooperation and cooperation with partners from a highly innovative core region do not have a significant effect on the innovativeness of firms. Hence, the results reject the presence of an automatic link between R&D inputs and innovation in this

region. Overall, six major findings can be summarized.

(1) Regarding the *spatial dimension* of cooperation, results indicate that inter-regional cooperation with a geographically diverse set of cooperation partners is particularly beneficial for the innovativeness of regional firms. This result is in line with evidence from other empirical works, indicating that firms in non-core regions profit in particular from cooperation-linkages with a variety of regions that provide a greater scope of learning opportunities (e.g. CRESCENZI and RODRIGUEZ-POSE, 2011). Integrated into the political discourse, the result suggests that locally bounded cluster and network policies may not be sufficient to stimulate regional innovativeness. Instead, policies should also consider the benefits arising from spatially diverse, inter-regional cooperation when designing regional policies suited for rural low-tech regions.

(2) With respect to the distinct cooperation regions, results show that cooperation with Munich as the nearby core region does not stimulate the innovativeness of firms. This contradicts the presumption outlined in the innovation diffusion literature (e.g. BATHELT *et al.* 2004; MORRISON *et al.*, 2013), suggesting that firms in low-tech regions profit especially from cooperation with core regions that are integrated into the global knowledge pipelines. One possible explanation for this unexpected finding is that regional low-tech firms might be unwilling or unable to exploit and absorb the knowledge provided by high-tech firms or research institutions located in core regions. Therefore, as suggested by COHEN and LEVINTHAL (1990), the absorption capacity might indeed be important.

(3) Cooperation with partners in the surrounding Bavarian and Austrian regions is especially beneficial when it comes to the likelihood of a firm innovating. This might stem from the creation of (cross-border) agglomeration or location effects, suggesting that spatial proximity is indeed important for the cooperation benefits. This reasoning is also underlined by the fact that cooperation with distant partners (i.e. partners outside Germany, Austria and the Czech Republic) does not reveal a significant effect. The results thus confirm a distant-decay effect, similar to that found in other empirical works (e.g. ASHEIM *et al.*, 2011).

(4) With respect to cross-border cooperation, results indicate that cooperation with Czech partners does not have a significant effect, while cross-border cooperation with Austrian partners is positively related to firms' likelihood of innovating. Without engaging in cultural studies, one *ad hoc* explanation for this finding might be the cultural proximity between Germany and Austria, not least reflected by a common language and history. As TÖDTLING and TRIPPL (2005) have pointed out, a common culture helps to overcome cooperation barriers arising through national borders. Moreover, regional similarities in terms of sectoral markets

might contribute to the beneficial effect that cooperation with Austrian partners has on firms' innovativeness. To further elaborate on the factors that determine the impact of cooperation with one particular region, it might be interesting to examine which region-specific and firm-specific factors can explain the choice of a firm to cooperate with partners in one specific region. Here, regional factors such as the share of firms in the high-technology industry, the regional GDP, the number of universities, or the institutional quality potentially influence the choice of firms to engage in cooperation with partners in the respective regions.

(5) As well as the geographical dimension, the *functional dimension* of cooperation is also relevant. This is reflected by the fact that in Lower Bavaria, contrary to what is expected from the literature, it is not primarily R&D cooperation that affects the likelihood of a firm innovating. Instead, more applicable forms of cooperation (i.e. production cooperation) have the largest effects. For policymakers, this implies that an exclusive focus on R&D-based cooperation might neither be appropriate nor sufficient for stimulating the innovativeness of firms in low-tech regions. Instead, policymakers and regional stakeholders should also consider policy instruments designed to foster other forms of cooperation with partners in the surrounding regions. This is not to say that R&D inputs are not relevant. The contrary is the case, as the results from the various specifications clearly reveal, firms' R&D expenditure is highly significant for their innovativeness. However, when it comes to cooperation, it is not the R&D cooperation that have the largest effect.

(6) The importance of less R&D-intensive forms of cooperation is also supported by the fact that cooperation significantly increases the likelihood of a Lower Bavarian firm introducing non-technical innovations.

Even though the paper adds multiple new aspects to the academic debate on how cooperation impacts innovation, there are some limitations to be noted. The paper uses micro-data of firms in Lower Bavaria, which limits the overall external validity of the results. There may be certain unobserved, idiosyncratic regional factors that drive the results in this particular region and consequentially impede a transfer of results to other regions. However, Lower Bavaria is not that atypical compared to other regions. Located at the second tier of a major city and characterized by a relatively strong economic performance, despite low levels of internal R&D, Lower Bavaria integrates well into a list of regions with similar regional characteristics. As indicated above, at least 8 such regions within the EU-15 can be found. All these regions display regional characteristics similar to those of Lower Bavaria in terms of similar location, internal R&D and economic performance. Due to this high degree of similarity, it may be reasonable to assume that the region of Lower Bavaria constitutes a valid and typical example

for a specific type of European region.

However, owing to the lack of comparable survey data for these regions, this presumption cannot be tested empirically. The extension of the database to further regions is therefore worth aspiring to. Moreover, a comparison of Lower Bavaria with regions that share similar structural characteristics, but are less successful in economic terms, may be an interesting endeavor. It would allow an investigation of whether firms in these economically less successful regions lack cooperation linkages or whether cooperation linkages are also present, but do not affect firms' innovativeness. Finally, the paper only analyzes correlations between cooperation and innovation. Hence, the results do not claim a causal interpretation of the relevant associations. Nevertheless, knowing these correlation patterns already provides important insights for a better understanding of the modes of knowledge transmission and the role played by cooperation on innovation explicitly in regions with low internal R&D that are nonetheless economically successful.

Notes

¹This sector-based distinction is not indisputable (see, for example, KIRNER *et al.* (2009)).

²Multiple answers were possible, meaning that the answer categories are not mutually exclusive and the percentages do not add up to 100%.

³The literature suggests that the size of a firm and firms' R&D expenditure both have a positive effect; regarding the sector, export-oriented industries and high-tech industries in particular positively affect firms' likelihood of innovating (Barge-gil, 2010). A further variable frequently mentioned is the presence of a distinct R&D department. However, as this variable highly correlates with R&D expenditure, it is not included in the analysis.

⁴In our analysis, we apply the following thresholds: for the *number of employees* (0) 0 employees, (1) 1-9 employees, (2) 10-49 employees, (3) 50-99 employees, (4) 100-249 employees, (5) 250-999 employees, (6) more than 1000 employees; for the *annual turnover* (1) less than 1 million Euro, (2) 1-5 million Euro, (3) 5-50 million Euro, (4) more than 50 million Euro.

⁵Here, the sector is based on self-indication of firms and may deviate from the classification reported in the official statistics.

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A Appendix

Table A.1: List of Potential Cooperation Regions of Lower Bavarian Firms^a

Lower Bavaria	Germany
Straubing	Remaining Germany
Regen	Austria
Deggendorf	Upper-Austria
Freyung-Grafenau	Salzburg
Passau	Remaining Austria
Rottal-Inn	Czech Republic
Dingolfing-Landau	Southern-Bohemia
Kelheim	Western-Bohemia
Bavaria	Middle-Bohemia
Regensburg	Remaining Czech Republic
Munich	Europe / World
Nuremberg, Fürth, Erlangen	Remaining Western Europe
Upper-Palatinate	Remaining Eastern Europe
Upper Bavaria	Remaining World
Remaining Bavaria	

^a List of potential cooperation regions of Lower Bavarian firms and classification along the dichotomy core and peripheral regions. Own classification.