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How and Why does the Efficiency of Regional Innovation Systems Differ?

FREIBERG WORKING PAPERS
FREIBERGER ARBEITSPAPIERE

05
2002

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Revised version of a paper prepared for presentation at the International Workshop on "Innovation Clusters and Interregional Competition", Kiel, November 12./13. 2001

ISSN 0949-9970

Contents

Abstract

Literature suggests that location should matter for R&D activities. However, attempts to empirically detect differences in innovation activity between regions have so far been rather unsuccessful. Using a unique data set which contains comparable information about manufacturing enterprises in eleven European regions, a number of significant regional differences in the efficiency of innovation activities can be found. This variation is in correspondence with a center-periphery pattern indicating that agglomeration economies are conducive to R&D activities. The paper investigates whether the differences in efficiency of regional innovation systems can be explained by differences in R&D-cooperation behavior.

JEL classification: D21, L6, O32, R30
Keywords: Innovation, R&D productivity, R&D cooperation, regional innovation systems, knowledge production function

Zusammenfassung

“Inwiefern und warum sind regionale Innovationssysteme unterschiedlich effizient?“

In der Literatur finden sich vielfältige Hinweise darauf, dass von den Standortbedingungen ein Einfluss auf Innovationsaktivitäten ausgeht. Allerdings haben entsprechenden empirische Untersuchungen bisher nur recht schwache Evidenz hierzu erbracht. Auf der Grundlage von Daten über Industriebetriebe in elf europäischen Regionen können eine ganze Reihe von signifikanten interregionalen Unterschieden hinsichtlich der Effizienz von Innovationsaktivitäten identifiziert werden. Dass diese Unterschiede tendenziell einem Zentrum-Peripherie-Muster entsprechen deutet darauf hin, dass für FuE-Aktivitäten bestimmte Agglomerationsvorteile bestehen. In dem Aufsatz wird der Frage nachgegangen, inwieweit die feststellbaren Unterschiede der Effizienz regionaler Innovationssysteme mit entsprechenden Unterschieden im Kooperationsverhalten erklärt werden können.

JEL-Klassifikation: D21, L6, O32, R30
Schlagworte: Innovation, FuE Produktivität, FuE Kooperation, Regionale Innovationssysteme, Wissensproduktionsfunktion

1. Introduction

The question "Do Regions Matter for R&D?" (Kleinknecht and Poot, 1992) has a long tradition in the regional economics literature. While a number of hypotheses suggest that location has a strong impact on innovation activity, the available empirical evidence is not at all persuasive (Section 2). This paper investigates differences in innovation behavior in a sample of eleven European regions (Section 3). The analysis reveals a number of differences in the input and output of innovation processes (Section 4). Regions also differ with regard to the efficiency or productivity of innovation activities that can be considered indicate the quality of a regional innovation system (Section 5). Based on such efficiency estimates, which are derived from a knowledge production function, the question is whether the interregional differences can be explained by R&D cooperation behavior (Section 6). Section 7 contains some final remarks.

2. A review of hypotheses and empirical evidence

According to a widely accepted hypothesis, the level as well as the success or efficiency of innovation activity should be higher in easily accessible locations, i.e., densely-populated regions – the center – than in more remote areas or regions that are characterized by a relatively low degree of agglomeration – the periphery (for a brief review of the literature see Fritsch, 2000, 410f.).[1] Two main reasons for such a geographical pattern are given in the literature. First, spatial clustering of innovation activities of a certain type or in a certain technological field is in many cases associated with a well-developed regional supply of needed inputs. Among these are differentiated markets for labor and innovation-related services, the presence of institutions (e.g., universities) whose research activities focus on the particular

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[1] In a broad sense, a region in the 'center' may be defined as an easily accessible location characterized by relatively high density of population and economic activity. A center has a relatively high rank in the spatial hierarchy. In contrast, regions in the 'periphery' are lacking these properties. They are characterized by relatively low density, poor accessibility, and rank relatively low.

technological field as well as the easy availability of relevant information. Secondly, it is argued that knowledge spillovers generated by innovation activities are concentrated in the area near the source (cf. Acs, Audretsch and Feldman, 1992; Anselin, Varga and Acs, 1997; Jaffe, Trajtenberg and Henderson, 1993). Actors in spatial proximity to many such sources in a cluster or a densely populated area, therefore, benefit from a higher level of spillover than actors in regions with a relatively low density of innovation activities or at a more remote location. Based on these arguments, one may expect innovation activities to operate at a higher level and with higher productivity at the center as compared to the periphery. Therefore, a certain degree of agglomeration or clustering of innovators within a particular area should be conducive to innovation activities (Baptista and Swann, 1998; Porter, 1998).

A number of empirical investigations concerning the regional distribution of R&D have indeed shown that innovation activities in a particular technological field tend to be clustered regionally (Almeida and Kogut, 1997; Baptista and Swann, 1998, 1999; Feldman, 1994; Audretsch and Feldman, 1996; Porter, 1998). However, there is nearly no empirical evidence showing a significant effect of location on innovation activities of firms or establishments (for a brief review see Fritsch, 2000). A possible reason for the difficulty in finding evidence of the interregional differences in innovation activities may be that a clear measurement concept and appropriate data has been lacking.

Recent attempts to explain the level and the success of regional innovation activities, such as the network approach[2] or the concept of 'innovative milieux'[3], emphasize the role of cooperative relationship between innovative actors and firms or institutions. According to these approaches, the availability of inputs and the spatial proximity to other innovators constitutes only a necessary condition for agglomeration economies to become effective. Of crucial importance is how the innovative actors make use of these possible

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[2] Cf. Saxenian (1994) and the contributions in Pyke, Beccatini and Sengenberger (1990), Camagni (1991) and in Grabher (1993).

advantages, such as by maintaining R&D cooperation and implementing an effective division of innovative labor. Some regional case studies suggest that spatial clustering or density of innovation activities does not necessarily lead to a higher level of cooperation between the firms or research institutions in a particular region (e.g. Sabel, Herrigel, Deeg and Kazis, 1989; Saxenian, 1994). Yet, when firms in a region cooperate on R&D, it may have a great effect on the result of their innovation activities. However, empirical evidence on regional peculiarities with regard to R&D cooperation is rather poor, based mainly on the 'impressions' the authors received while conducting case studies. We do not really know the significance of interregional differences in R&D cooperation behavior. It is, therefore, interesting to ask if significant variations in R&D-cooperation behavior between regions exist and to what degree such differences contribute to explain diverging levels and efficiency in innovation activity.

3. Data

The empirical analyses reported here are based on data gathered from questionnaires mailed to manufacturing enterprises in eleven European regions (Figure 1). This survey was done in two phases between 1995 and 1998. It resulted in a data set consisting of approximately 4,300 usable questionnaires. The questions concentrated on innovation-related issues, but it also gathered general information on each enterprise, such as the number of employees, the amount of turnover, characteristics of the product program, etc. (for a more detailed description of the data set see Sternberg, 2000).

Four of the eleven regions included in the survey are dominated by large cities of international importance. These regions are Barcelona, Rotterdam, Stockholm, and Vienna, with the latter two cities serving as national capitals. Two of the regions in our sample, Saxony and Slovenia, were under socialist

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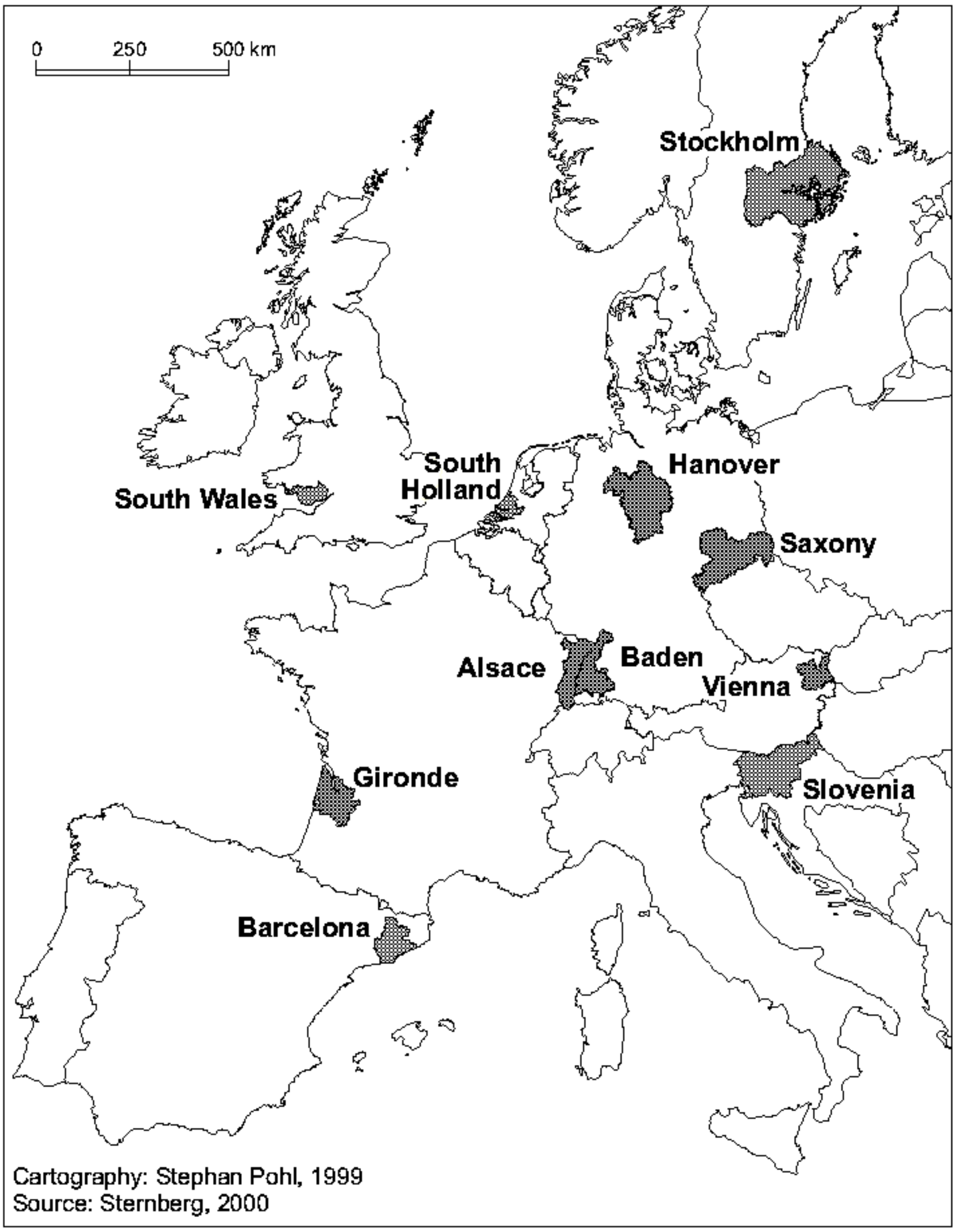
[3] See Crevoisier and Maillat (1991) and the contributions to Aydalot and Keeble (1988).

Figure 1: Case study areas



regime until 1990/1991 and have to a greater or lesser degree had to completely reorganize their innovation system. Baden, one of the two West German regions in the sample, is said to have a relatively well-functioning innovation system (Cooke, 1996; Heidenreich and Krauss, 1998). The other West German region, Hanover, has a relatively high share of large-scale industries (e.g., automobiles, steel) while the proportion of employment in new innovative industries is comparatively low. The French border region of Alsace, which is adjacent to the Baden region in Germany, represents a relatively rural area. The second French region, Gironde, has a significant share of employment in high-tech industries most of which are well-integrated into the global division of labor. Finally, South-Wales represents an old industrialized region that has experienced a considerable employment shift from 'old' declining industries to 'new' high-tech industries in recent years (cf. Cooke, 1998). Due to the great variation in economic development and location conditions of the regions in our sample, we may expect location to have an impact on R&D. We should then find such differences in the data.[4]

4. Interregional differences with regard to innovation input and innovation output

Careful analysis of the data has revealed a number of differences with regard to innovation activities between the regions under examination (see Fritsch, 2000 for details). Information concerning Barcelona, Rotterdam, Stockholm, and Vienna, the four regions that are dominated by large urban areas, is always grouped in the upper part of the tables to make identification of the special characteristics of these regions easier. Looking at the input to the innovation process, we find the highest proportion of establishments with R&D employment in the two metropolitan areas of Barcelona and Rotterdam. Alsace and South-Wales, two regions characterized by a relatively low population density, have the lowest share of establishments that perform R&D (Table 1). In the two regions that are making a transition to a market economy, Saxony and

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4 For an overview of economic conditions and innovation activities in the different regions see Fritsch (2000).

Slovenia, the proportion of establishments with R&D employees was in the middle range. Using the proportion of R&D employees (including establishments without R&D) as an indicator of the intensity of R&D activities in a region, the Saxony again has a middle position while Slovenia is at the lower end. In all case-study regions, R&D employment increased more than overall employment (or showed a smaller decline compared to the fall in overall employment) so that the share of R&D employment rose. The amount of R&D expenditure per R&D employee was at a relatively low level in Slovenia and South-Wales. Quite strikingly, the enterprises in Vienna not only had by far the highest share of R&D employment, but also the highest R&D expenditure per R&D employee.

Table 1: Indicators for inputs for innovation processes (percentages)

	Share of firms with R&D employees (%)	Share of R&D employees (%)[+]	Changes in R&D employment in preceding 3 years (%)[+]	R&D expenditure per employee[++]	R&D expend-iture per R&D employee[++]
Barcelona	89.8	6.2	15.2	3.50	62.21
Rotterdam	83.2	5.3	16.9	2.80	56.08
Stockholm	74.6	8.4	21.5	5.29	82.21
Vienna	74.7	10.7	-2.8	4.19	104.21
Alsace	61.1	4.7	7.2	3.56	93.87
Baden	70.2	6.6	0.4	5.00	85.39
Gironde	67.8	4.0	32.6	3.75	72.49
Hanover	77.7	3.7	7.6	4.46	89.84
Saxony	74.9	5.9	-2.5	3.69	53.37
Slovenia	79.4	3.2	-0.7	1.13	32.08
South-Wales	61.2	3.6	49.0	3.10	44.48

Notes: [+] All enterprises; [++] median, thousands ECU per year, innovative enterprises only.

The proportion of manufacturing enterprises that have introduced at least one significant product or process innovation during the preceding three years represents a rather broad indicator for the output of innovation activities in a regional economy. The highest share of innovating establishments according to this measure is found in Barcelona, followed by South-Wales and Rotterdam (Table 2). In Saxony and Slovenia, the two regions that are undergoing a transition from a socialist system to a market economy, the share of innovators tends to be relatively high, but the figures belie the expectation that there would be a special urgency to modernize given the backwardness of production processes and product programs. With the exception of Barcelona, the share of enterprises with at least one product innovation tends to be higher than the proportion of enterprises that have implemented at least one process innovation. The ratio of new products[5] to the total number of products supplied by an enterprise indicates the amount of product innovation activity. The relatively high values for this indicator found in Slovenia and Saxony are very likely caused by the special necessity to modify the products supplied that accompanies the transition to a market economy (cf., Fritsch and Werker, 1999). Compared to these high shares of new products, the proportion of turnover that was achieved with the new products (another questionnaire topic) was relatively low in Saxony and Slovenia. This could indicate that these firms had particular problems in marketing their product innovations.

Table 2: Indicators for the results of the innovation process

	Share of enterprises (%) with at least one			Ratio of new products to total number of products (%)+	Share of turnover with new products (%)+	Share of enterprises that registered for patenting in preceding 3 years (%)	Patents per enterprise (mean, enterprises with patents only)
	innovation	process innovation	product innovation				
Barcelona	93.5	79.3	79.1	33.3	20	28.9	6.4
Rotterdam	80.2	56.1	64.3	26.5	15	21.9	2.2
Stockholm	72.3	57.8	66.2	25.0	20	27.0	3.8
Vienna	78.9	46.5	56.5	21.4	15	28.0	16.8
Alsace	61.9	53.6	58.6	25.0	20	18.0	4.5
Baden	71.8	65.6	66.6	25.0	30	31.6	8.0
Gironde	65.0	45.0	49.0	21.4	20	15.1	2.6
Hanover	78.2	66.1	75.3	20.0	20	37.7	6.9
Saxony	79.2	66.6	76.5	50.0	40	19.9	3.8
Slovenia	76.4	59.6	70.2	100	25	10.4	2.8
South-Wales	82.0	56.8	74.5	30.0	20	26.3	2.0

Notes: + Median, innovative enterprises only.

[5] A product was classified as 'new' if it was new in the enterprise's product program. This relatively broad definition of a new product clearly did not rule out imitation.

The relatively low share of enterprises in Saxony and Slovenia that had registered at least one invention for patenting in the preceding three years (Table 2) is probably a result of the special situation in these regions, which were both formerly under a communist regime. Due to general technological backwardness, innovation activities in these regions were dominated by the necessity to catch-up, which merely requires the adoption and imitation of already existing products and processes. Such catch-up imitations are clearly excluded from patenting because only something that is completely new is patentable. The highest proportion of enterprises with registered patents was found in the two West German regions, Baden and Hanover, followed by the three large agglomerations of Barcelona, Vienna and Stockholm. We find the lowest average number of patents per enterprise in Saxony and in South-Wales (Table 2). By far the highest value for this indicator was attained in Vienna. Baden and Barcelona also appear to be rather innovative according to this measure.

All in all, we see a number of strong differences between the regions with respect to innovation input and innovation output. These differences clearly suggest that location is important and that regions do matter for R&D. Remarkably, no indication of a center-periphery pattern in innovation activity has been found. Because many innovation-related indicators tend to be strongly influenced by such factors as business size, industry characteristics and other issues (e.g., affiliation with a multi-plant firm), differences in the values of innovation indicators for the regions may be caused in large part by differences in establishment size or industry structure. It could, therefore, be desirable to control for such influences by means of a multivariate analysis.[6] The results of such a multivariate analysis measuring the efficiency of regional innovation activities are presented in the next section.

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[6] However, as far as those influences that are controlled for in the analysis (e.g., the size structure and the industry structure in a region) can be interpreted as resulting from location factors, the effects of size or industry are also (indirectly) generated by regional characteristics. Therefore, it may be dubious to try to identify the impact of location by controlling for size and

5. Measuring the efficiency of regional innovation activities

Relating innovative output to a measure of R&D input such as the number of employees or the number of R&D employees, leads to measures that may be interpreted as indicators of the productivity of innovation activity. In as much as the R&D productivity of an establishment is determined by factors in the external environment, these productivity measures may also be regarded as an indication of the quality, particularly the efficiency and workability of the national, regional or industry-specific innovation system. The figures for the average number of new products and patents per employee or per R&D employee in Table 3 diverge widely. With regard to the number of new products, the four leading regions are Rotterdam, Gironde, Baden and Saxony, with Stockholm, Vienna and Hanover ranked at the bottom. As in the previous parts of this analysis, with regard to the productivity measures reported in Table 3, no clear center-periphery pattern is evident which would indicate relatively favorable conditions for innovation activities in the urban areas.

Table 3: Indicators for the productivity of the innovation process

	Number of new products per employee+	Number of new products per R&D employee+	Number of patents per employee++	Number of patents per R&D employee++
Barcelona	0.36	5.80	0.048	0.28
Rotterdam	1.17	19.91	0.023	0.40
Stockholm	0.21	2.33	0.018	0.31
Vienna	0.21	1.84	0.039	0.26
Alsace	0.35	6.47	0.011	0.19
Baden	0.64	8.8	0.034	0.41
Gironde	0.61	12.46	0.026	0.64
Hanover	0.12	2.8	0.017	0.35
Saxony	0.55	9.3	0.029	0.39
Slovenia	0.32	9.88	0.005	0.12
South-Wales	0.36	7.71	0.009	0.71

Notes: + Mean, innovative enterprises only; ++ mean, enterprises with patents only.

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industry structure because such a strategy neglects the indirect effects of location on the economic structure of a region.

A rather sophisticated assessment of R&D productivity can be made by estimating the output elasticity of innovative input in the framework of a knowledge production function for the different regions. Output elasticity can serve as an overall measure of the quality of a regional innovation system. The main advantage of this approach is that the inclusion of certain control variables provides a simple way of accounting for industry structure and other region-specific factors (see Fritsch, 2002a for a detailed exposition). The basic assumption underlying the concept of the knowledge production function is that the output of the innovation process represents a result of R&D capital or investment. Taking the Cobb-Douglas production function as a framework, the basic relationship is

(1) $R\&D\ output = a\ R\&D\ input^{b}$,

with the term *a* representing a constant factor and *b* giving the elasticity by which R&D output varies in relation to the input to the R&D process. If the elasticity value equals one, a 100 percent increase in R&D expenditure would lead to a doubling of innovative output. An elasticity value lower than one indicates that innovative output does not rise in proportion to R&D input. The elasticity should increase as the quality of inputs to the R&D process improves and the spillovers stemming from the R&D activities of other actors in the region become more pronounced. The output elasticity is dimensionless, and therefore is not affected by price level differences in the regions or by exchange rates in the case of an international comparison if the input and/or output to the innovation process is measured in monetary terms.

The key input factor to this process, knowledge, tends to be cumulative in character, so that innovation is based on a stock of knowledge capital. In practice, this knowledge stock can be measured only incompletely. The best that we might know is the R&D effort, i.e. the investment into the knowledge stock within a certain time period that may not cover all the relevant flows. In many data sets available for an empirical analysis of innovation activities, we cannot be entirely sure if R&D investment is properly defined and if it relates to that part of the knowledge stock which was relevant for the innovation output being measured. In particular, information about an R&D investment which was made long ago is hard to obtain. However, under the assumption that innovation effort is fairly constant over time, an incompletely measured R&D input may serve as a good proxy for knowledge capital.

In the estimates presented here (Table 4), the indicator used for R&D output was the number of inventions registered for patenting during the preceding three years. To avoid problems of having 'too many' zero-values in the model[7], estimates were made only for those enterprises that had registered at least one invention for patenting during the preceding three years. A patent is granted for a significant invention that is new on a world-wide scale. For this reason, including only establishments with patent applications in the sample implies that the estimations are based solely on information from enterprises which are performing near the technological frontier. This approach has the great advantage that the output of the innovation process is somewhat standardized, and that innovation processes of about the same level of novelty are compared. Because R&D expenditure includes inputs to the R&D process that are purchased from other establishments, it is a more comprehensive measure than the number of R&D personnel. Six dummies-variables are used to control for the influence of the different industries which the establishments belong to. Interregional differences were investigated by including two types of regional dummy-variables.[8] Dichotomous variables having the value 1 if the respective establishment was located in a certain region and the value 0 otherwise, indicated differences with regard to the constant term of the knowledge production function.[9] The coefficients for an interaction of these

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[7] A distribution of observations that is characterized by a relatively large number of cases at one end violates basic assumptions underlying most standard estimation procedures.

[8] As an alternative approach, the model was estimated for each of the regions separately (see Fritsch, 2000, 2002a). Because both approaches to estimating regional innovation output elasticities with regard to R&D input lead to quite similar results (cf. Fritsch, 2002a), only the estimates derived from a knowledge production function for all regions are reported here

[9] The interpretation of estimates for the constant term of the knowledge production function is somewhat problematic. If the number of innovations is used as indicator for the success of R&D activities, the constant term denotes how many innovations have been generated without a

dummies with an establishment's R&D input (R&D expenditure or R&D employment, respectively) reflect differences of the slope of the knowledge production function pointing to diverging output elasticity or productivity of innovation processes. Baden is taken as the reference region for testing statistical significance of differences found.

Table 4: Regional dummy variables for the output elasticity of R&D input estimated in the framework of a knowledge production functions – results of negative binomial regressions with output measured as number of patents

	Output elasticity with respect to R&D expenditure	Output elasticity with respect to R&D employment
Barcelona	-0.10	-0.20*
	(1.11)	(2.20)
Rotterdam	-0.07	0.05
	(0.55)	(0.36)
Stockholm	0.01	0.14
	(0.18)	(1.54)
Vienna	0.20*	0.48**
	(2.10)	(4.11)
Alsace	-0.07	-0.12
	(0.50)	(0.95)
Gironde	-0.61**	-0.56**
	(5.77)	(3.53)
Hanover	-0.12	-0.13
	(1.41)	(1.68)
Saxony	-0.07	-0.01
	(0.74)	(0.09)
Slovenia	-0.43**	-0.40**
	(3.37)	(2.84)
South-Wales	-0.14	0.02
	(1.15)	(0.10)
Pseudo R^2	0.134	0.127
N. of cases	705	707

**: Statistically significant at the one-percent level. *: Statistically significant at the five-percent level. Asymptotic *t*-values of the coefficient in parentheses.

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corresponding R&D input during the period in which R&D input was measured. Assuming that the generation of an innovation necessitates some R&D input, there are two possible explanations for the existence of a positive constant term. One possible explanation is that the respective innovation has resulted completely from knowledge spillovers from other sources, without any R&D effort on the part of the firm that is supposed to have generated it. In this case, the constant term of the knowledge production function represents those innovations that fall like manna from heaven on a certain firm. Another possible explanation concerns the measurement of the input to the innovation process. A positive constant term of the knowledge production function may indicate that the innovation was not based on current R&D investment, but on the existing stock of 'old' knowledge, which could not be measured. In this case, the constant term of the knowledge production function represents an error in specifying the input variable.

Looking at the estimated dummy-coefficients for divergent regional output elasticities of R&D input, we find a lot of negative signs indicating a lower efficiency of innovation activities than in Baden. This confirms many judgments found in the literature that emphasize relatively good quality of the innovation system in this region (e.g., Cooke, 1996; Heidenreich and Krauss, 1998; Sabel, Herrigel, Deeg and Kazis, 1989). The highest output elasticity is found for Vienna (cf. Table 4). While the elasticities for Rotterdam and for Stockholm were not significantly different from the value for Baden (the reference region), the coefficient for Barcelona estimated on the basis of R&D employment as input measure indicates a significantly lower productivity than in Baden. By far, the lowest values for the output elasticity of R&D input are found for Gironde and Slovenia.[10] For many of the other regions, the dummies measuring differences of R&D output elasticities have a negative sign, indicating a lower productivity in R&D activities when compared to Baden. These differences are not statistically significant, but if a region like Barcelona, Gironde, or Slovenia is taken as reference, considerably more significant regional effects are found. The estimates of the regional dummies based on R&D expenditure differ to some extent from the estimates using R&D employment as indicator for R&D input, yet, these differences are within reasonable limits.

On the whole, the results correspond to a center-periphery paradigm. This suggests that being located in a large agglomeration tends is more conducive to R&D activities than being located in less densely populated or more peripheral regions. However, there were also relatively high values of output elasticity in some less urbanized areas (e.g., Saxony, South-Wales) indicating that R&D activity may also be conducted productively in these locations. Other measures for innovation activities point in the same general direction, but the regional pattern is less clear (cf. Fritsch, 2000). At least there are nothing in the data that

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10 However, estimates for these regions are based on relatively few observations, so it might be argued that they do not reflect the conditions in the respective regions correctly. The number of usable observations for Gironde was 13 (model with R&D expenditure as input variable) and

indicates that peripheral areas or regions with low population density have a clear advantage over the centers with regard to R&D.

6. Can cooperation behavior explain differences in R&D efficiency?

The dataset, which provides rich information on R&D cooperation with different types of partners, was gathered by a number of questions. One sort of question tried to assess whether or not the given enterprise had maintained cooperative relationships with a focus on innovation activities with a certain type of partner in the preceding three years. This particular question was asked for five types of partners separately: customers, manufacturing suppliers, suppliers of business services[11], "other" firms, and publicly-funded research institutions. The research institutions comprised universities[12] and publicly-funded non-university research institutions. The "other" firms are non-vertically related businesses, particularly including competitors. There are clear indications that most of the relationships to "other" firms were horizontal in nature. Cooperation with suppliers or customers was defined as a relationship beyond "normal" business interaction. With regard to "other" firms and publicly-funded research institutes, all kinds of relationships were assumed to be cooperative. For each partner type, we know the number of cooperative relationships within different regional categories ("within the region", "rest of the country", "abroad").[13]

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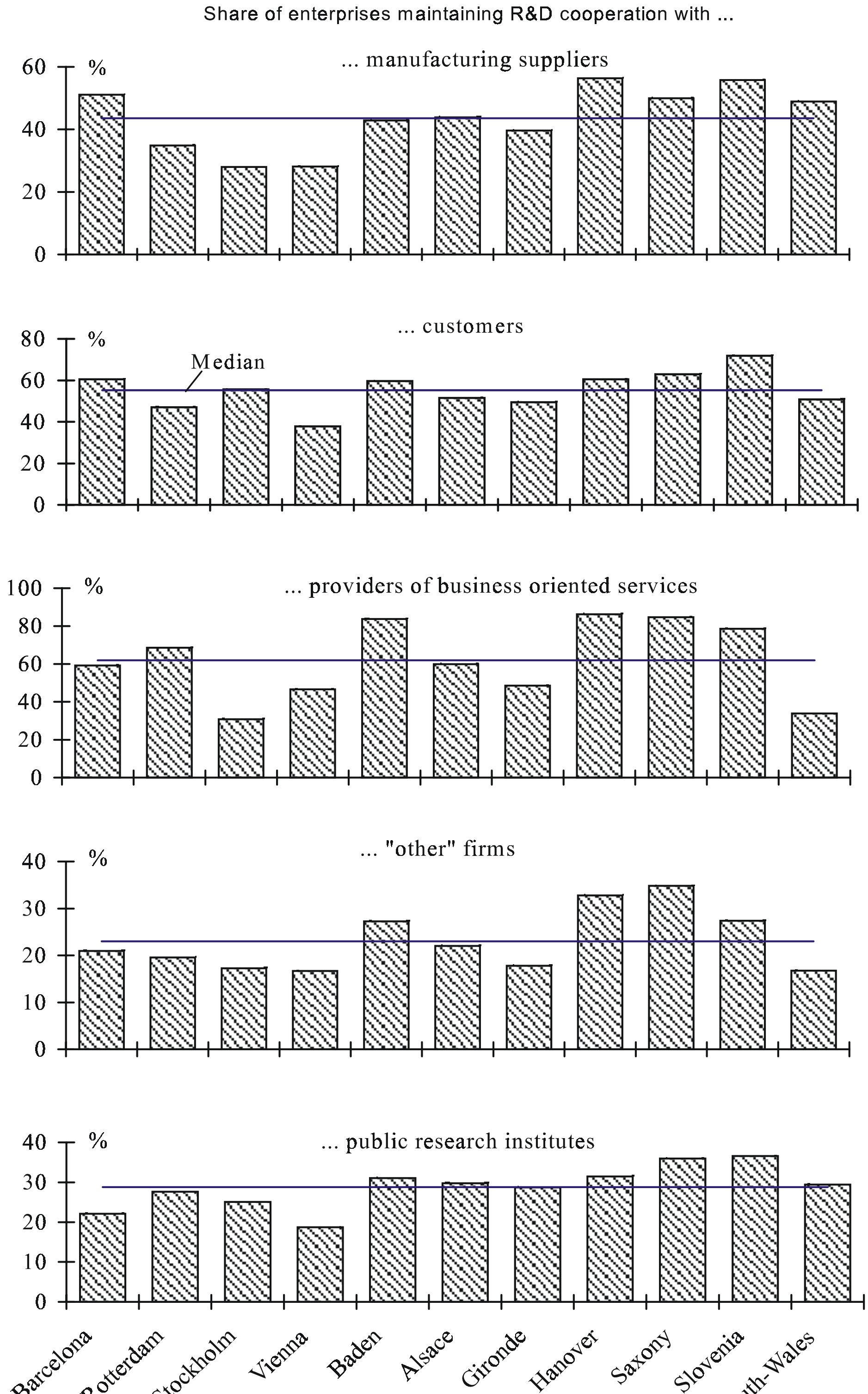
11 enterprises (model with R&D employment as input variable). The estimates for Slovenia were based on 31 and 35 cases, respectively.

11 The main fields were software development, tax and legal examination, auditing, business consultancy, market research, advertising, engineering and planning services, check and test services, architecture, etc. For some of the regions, Alsace, Baden, Hanover and Saxony, information about cooperative relationships with suppliers of business-oriented services was not raised in the same way as the information on cooperation with other partner types. Therefore, relationships with suppliers of business services has been left out in analyses focusing on these regions (Fritsch and Lukas, 2001; Fritsch, 2001).

12 In Germany, this included the *Fachhochschulen* (universities with a particular focus on applied studies in engineering, business and other subject areas).

13 For an overview of the different kinds of cooperative relationship with the different partner types see Fritsch and Lukas (2001).

Figure 2: The propensity to cooperate in the case study areas



Suppliers of business-oriented services have been most frequently named as a partner for R&D cooperation. Roughly two thirds (67.3%) of all manufacturing enterprises maintained cooperative relationship with this type of partner. More than half of the respondents, 58.2%, claimed to have R&D cooperation with their customers. The share of establishments with at least one cooperative relationship with their manufacturing suppliers amounted to 45.4%, while R&D cooperation with public research institutions (30.0% of all enterprises) and with "other" firms (25.9%) was less common. There are remarkable differences between the case study areas with regard to R&D cooperation behavior. Looking at the share of enterprises that maintained at least one cooperative relationship to a certain kind of partner (Figure 2), we find above average values particularly in Baden, Hanover, Saxony, and in Slovenia. Conversely, these shares are relatively low in Stockholm and in Vienna. Noticeably, when a relatively high (low) share of establishments with cooperative relationships to a certain type of partner can be found in a region, the propensity to have R&D cooperation with other kinds of partner tends to be also relatively high (low). This indicates that cooperative behavior is less about a relationship with a certain type of partner (e.g., customers), but is more a general attitude, quite likely involving various kinds of actors.

Identifying some variance between regions with regard to the share of enterprises that maintained cooperative relationships with a certain type of partner is not sufficient, however, for concluding that there are different propensities to cooperate. The reason is that a relatively high share of establishments with such cooperative relationships in a region could simply be the result of a correspondingly high proportion of establishments that possess characteristics of businesses that are likely to maintain R&D cooperation (e.g., establishments that are relatively large or have many R&D employees). In order to identify interregional differences in the propensity to cooperate, one has to control for the effects of the characteristics of cooperating establishments. Therefore, multivariate models for the propensity to maintain at least one cooperative relationship, as well as for the number of such relationships, were estimated. These models included the relevant characteristics of the establishments (in particular size and share of R&D employees) as explanatory variables and also dummy variables for location in a certain region. A relatively high value for the regional dummy variable indicates that the establishments in that region show a higher or lower propensity to cooperate (depending on the sign of the respective coefficient) than the control group, the establishments in Baden. This method of analysis ensures that the regional differences identified are not caused by interregional variance with respect to the establishment characteristics controlled for in the multivariate approach. The analyses resulted in quite a high number of statistically significant differences in cooperation behavior between the regions (for details see Fritsch and Lukas, 2001 and Fritsch, 2001a,b, 2002b).

Figures 3 and 4 show the values of those dummy variables reflecting the propensity to have cooperative relationship with customers and with "other" firms. These results are fairly representative examples for the other indicators of regional cooperation behavior. Remarkably, we find a relatively low propensity for cooperation coefficients for those regions in our sample that are dominated by large cities (Barcelona, Rotterdam, Stockholm and Vienna). This suggests that being located in a region that provides a rich supply of intra-regional contact opportunities is itself not particularly stimulating for R&D cooperation.[14] Calculating rank correlation coefficients for the different combinations of indicators of regional cooperation behavior and the efficiency of R&D activities leads to negative signs in the majority of cases (see Fritsch, 2001b). This clearly indicates that there is no strong overall positive relationship between cooperation behavior and the efficiency of innovation activities in the data. Some positive signs of the correlation coefficients can be found for indicators of regional cooperative behavior that are based on

14 Running these regressions for cooperative relationships with partners in the different spatial categories ("within the region", "rest of the country", "abroad") does not lead to different results. The main reason for this finding is that cooperation with a partner located in the same region is obviously the first step in building a network. Accordingly, establishments that maintain R&D cooperation with partners outside their region nearly always also have cooperation partners within the region. Hence, there is a positive relationship between the number of cooperative relationships and the spatial extent of the network.

Figure 3: Combinations of values of regional dummy variables for cooperation with manufacturing suppliers and output elasticity with regard to R&D employment

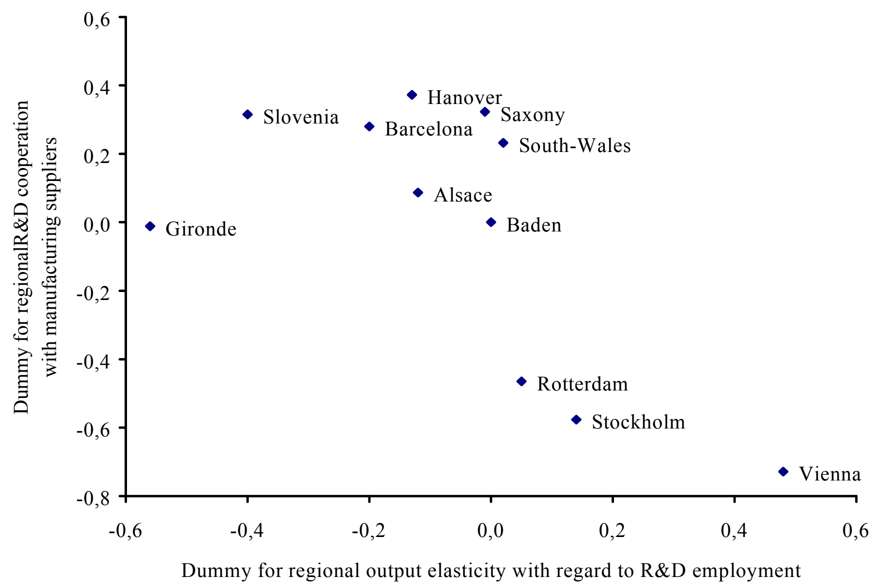
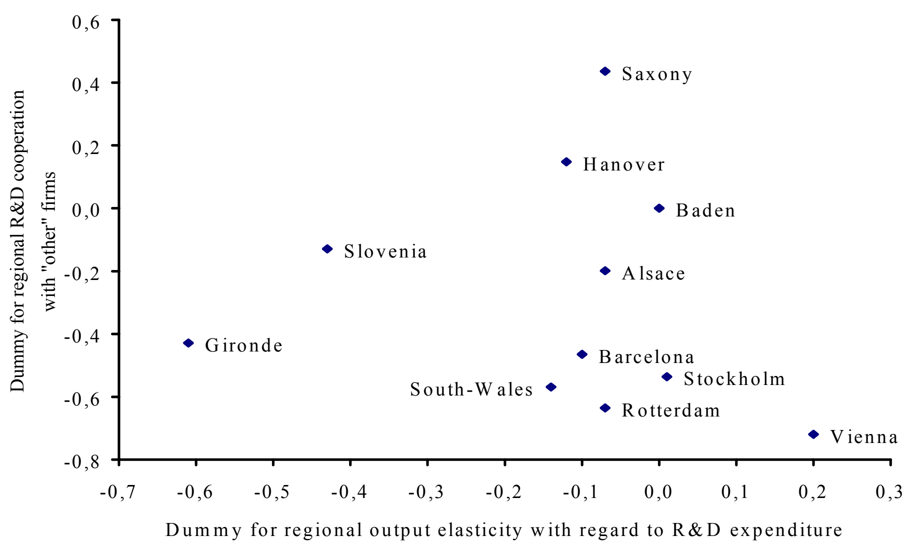


Figure 4: Combination of values of regional dummy variables for cooperation with "other" firms and output elasticity with regard to R&D expenditure



estimates for the number of cooperative relationships. This holds particularly for the number of cooperative relationships to public research institutes.

In order to illustrate the relationship between regional R&D cooperation behavior and the efficiency of innovation activities, Figures 3 and 4 show the combinations of two dummy variables for the propensity to cooperate on R&D and indicators for the regional output elasticity of R&D expenditure (Table 4). Obviously, the relationship between cooperation behavior and R&D efficiency is rather diffuse. Those four regions in the sample that are dominated by large urban areas appear to represent remarkable special cases. They are characterized by a relatively efficient innovation system while at the same time, firms in these regions have a low propensity to cooperate. However, excluding these somewhat ‘outlying’ regions from the analysis does not does not result in a much clearer pattern that would confirm the hypothesis that there is a positive relationship between R&D cooperation and innovation activities. If such a relationship exists it is obviously not adequately measured by the indicators used here or it is perhaps dominated by other influences.

7. Concluding remarks

The empirical analyses reported here revealed pronounced differences in innovation activities between regions. Assessing the quality of regional innovation systems with a multivariate approach that estimates the efficiency of private-sector R&D activities, these differences partially confirm the center-periphery hypothesis proposed in the literature. Analyzing R&D-cooperation behavior also shows a number of significant differences between the case-study regions. However, these differences do not explain the diverging efficiency of R&D activities. In particular, no support was found for the suggestion that cooperation or a relatively pronounced cooperative attitude in a region is conducive to innovation activities. Obviously, regions matter for both the efficiency of innovation activities as well as R&D cooperation behavior. The reasons for the interregional differences found, however, remain unclear and deserve further investigation.

References

Acs, Zoltan J., David B. Audretsch and Maryann P. Feldman (1992), The Real Effects of Academic Research: Comment, *American Economic Review*, 82, 363-367.

Almeida, Paul and Bruce Kogut (1997), The Exploration of Technological Diversity and the Geographic Localization of Innovation, *Small Business Economics*, 9, 21-31.

Anselin, Luc, Attila Varga and Zoltan J. Acs (1997), Local geographic spillovers between university research and high technology innovation, *Journal of Urban Economics*, 42, 422-448.

Audretsch, David B. and Maryann P. Feldman (1996), R&D Spillovers and the Geography of Innovation and Production, *American Economic Review*, 86, 630-640.

Aydalot, Philippe und David Keeble (1988) (eds.), *High Technology and Innovative Environments: The European Experience*. London: Routledge.

Baptista, Rui and Peter Swann (1998), Do firms in clusters innovate more? *Research Policy*, 27, 525-540.

Baptista, Rui and Peter Swann (1999), A comparison of clustering dynamics in the US and UK computer industries, *Journal of Evolutionary Economics*, 9, 373-399.

Camagni, Roberto (ed.) (1991), *Innovation Networks: Spatial Perspectives*, London: Belhaven.

Cooke, Phillip (1996), The new wave of regional innovation networks: Analysis, characteristics and strategy, *Small Business Economics*, 8, 159-171.

Cooke, Phillip (1998), Global clustering and regional innovation – Systemic integration in Wales, in Hans-Joachim Braczyk, Phillip Cooke and Martin Heidenreich (eds), *Regional Innovation Systems - The role of governances in a globalised world*, 245-272, London: UCL Press.

Crevoisier, Oliver and Dennis Maillat (1991), Milieu, Industrial Organization and Territorial Production System – Towards a New Theory of Spatial Development, in: Roberto Camagni (ed.) (1991), 13-34.

Feldman, Maryann P. (1994), *The Geography of Innovation*, Boston: Kluwer.

Fritsch, Michael and Claudia Werker (1999), Systems of Innovation in Transition, in: Michael Fritsch and Horst Brezinski (eds.), *Innovation and Technological Change in Eastern Europe – Pathways to Industrial Recovery*, Cheltenham: Edward Elgar Publishers, 5-22.

Fritsch, Michael (2000), Interregional differences in R&D activities – an empirical investigation, *European Planning Studies*, 8, 409-427.

Fritsch, Michael and Grit Franke (2000), *Innovation, Regional Knowledge Spillovers and R&D*, Working Paper 2000/25, Faculty of Economics and Business Administration, Technical University Bergakademie Freiberg.

Fritsch, Michael (2001a), Cooperation in regional innovation systems, *Regional Studies*, 35, 297-307.

Fritsch, Michael (2001b), *R&D-Cooperation and the Efficiency of Regional Innovation Activities*, Working Paper 2001/4, Faculty of Economics and Business Administration, Technical University Bergakademie Freiberg.

Fritsch, Michael and Rolf Lukas (2001), Who cooperates on R&D? *Research Policy*, 30, 297-312.

Fritsch, Michael (2002a), Measuring the Quality of Regional Innovation Systems – A Knowledge Production Function Approach, *International Regional Science Review*, 25, 86-101.

Fritsch, Michael (2002b), Does Cooperation Behavior Differ between Regions? forthcoming in *Industry and Innovation*, 9.

Grabher, Gernot (1993) (ed.), *The embedded firm – On the socioeconomics of industrial networks*, London: Routledge.

Heidenreich, Martin and Gerhard Krauss (1998), The Baden-Württemberg production and innovation regime: past successes and new challenges, in: Hans-Joachim Braczyk, Phillip Cooke and Martin Heidenreich (eds.), *Regional Innovation Systems - The role of governance structures in a globalized world*, London: UCL Press, 214-244.

Jaffe, Adam B., Manuel Trajtenberg and Rebecca Henderson (1993), Geographic localization of knowledge spillovers as evidenced by patent citations, *Quarterly Journal of Economics*, 108, 576-598.

Kleinknecht, Alfred and Tom P. Poot (1992), Do Regions Matter for R&D? *Regional Studies*, 26, 221-232.

Porter, Michael (1998), Clusters and the new economics of competition, *Harvard Business Review*, November-December, 77-90.

Pyke, Frank, GiacomoBecattini and Werner Sengenberger (eds.) (1990), *Industrial districts and inter-firm cooperation in Italy*. Geneva: International Institute for Labor Studies.

Sabel, Charles F., Gary B. Herrigel, R. Deeg and R. Kazis (1989), Regional prosperities compared: Massachusetts and Baden Württemberg in the 1980's, *Economy and Society*, 18, 374-405.

Saxenian, Annalee (1994), *Regional Advantage*, Cambridge (MA): Harvard University Press.

Sternberg, Rolf (2000), Innovation Networks and Regional Development – Evidence from the European Regional Innovation Survey (ERIS): Theoretical Concepts, Methodological Approach, Empirical Basis and Introduction to the Theme Issue, *European Planning Studies*, 8, 389-407.