



Co-operation in Regional Innovation Systems

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(Received May 1999; in revised form June 2000)

FRITSCH M. (2001) Co-operation in regional innovation systems, *Reg. Studies* 35, 297–307. The paper deals with co-operative relationships of manufacturing firms in three German regions. By applying a hurdle-count data model, differences between regions as well as between smaller and larger firms are analysed. The differences between regions regarding the propensity of firms to co-operate are mainly due to peculiarities of the small business sector. Spatial proximity is obviously of particular importance for horizontal co-operation and for relationships to publicly funded research institutions. The link between the co-operative behaviour of firms and the performance of the regional innovation system remains, however, unclear.

Co-operation Division of innovative labour Innovation Regional innovation systems

FRITSCH M. (2001) Le partenariat dans les systèmes d'innovation régionaux, *Reg. Studies* 35, 297–307. Cet article traite du partenariat des entreprises industrielles situées dans trois régions en Allemagne. On analyse les différences inter-régionales ainsi que les différences entre les petites entreprises et les grandes entreprises. Pour ce qui est de la propensité des entreprises à coopérer, les différences interrégionales s'expliquent largement par des particularités de la petite entreprise. Il va sans dire que la proximité géographique est d'une importance indéniable pour la coopération horizontale et pour les rapports avec les centres de recherche publics. Toujours est-il que le lien entre le partenariat des entreprises et la performance des systèmes d'innovation régionaux reste ambigu.

Partenariat Division du travail innovateur
Innovation Systèmes d'innovation régionaux

FRITSCH M. (2001) Kooperation in regionalen Innovationssystemen, *Reg. Studies* 35, 297–307. In dem Aufsatz wird das Kooperationsverhalten von Industriebetrieben in drei deutschen Regionen anhand eines Hürden-Zählmodells analysiert. Dabei werden sowohl interregionale Unterschiede als auch Unterschiede zwischen kleinen und größeren Betrieben herausgearbeitet. Es zeigt sich, dass Unterschiede hinsichtlich der Kooperationsneigung zwischen den Regionen vor allem auf entsprechenden Besonderheiten der Kleinbetriebe beruhen. Räumliche Nähe ist offenbar insbesondere für die horizontale Kooperationsbeziehungen sowie für die Zusammenarbeit mit öffentlichen Forschungseinrichtungen von Bedeutung. Der Zusammenhang zwischen Kooperationsneigung und der Leistungsfähigkeit des entsprechenden regionalen Innovationssystems bleibt unklar.

Kooperation Arbeitsteilige Innovationsprozesse
Innovation Regionale Innovationssysteme

INTRODUCTION

The concept of an innovation system was introduced only little more than a decade ago. It is based on the recognition that innovation activities are normally embedded in a division of labour with a plurality of organizations involved. Because of the importance of this division of innovative labour, an analysis of innovation processes should not be limited to a single actor, but account for the respective innovation system.¹ Up to now, the respective research was concentrated on national or sector oriented systems of innovation leaving the regional dimension largely neglected. Regional systems of innovation would be a relevant category of analysis if innovation processes were shaped by region-specific factors (see COOKE *et al.*, 1997; COOKE, 1998).

This paper analyses R&D co-operation of manufacturing establishments in three German regions. One of the guiding questions of this investigation is how great the differences of R&D co-operation behaviour between regions are and if such differences could explain divergent performance of the firms located in the three regions. The next section gives a brief overview of hypotheses concerning the relationship between innovation, co-operation and spatial proximity for a division of innovative labour. In the empirical part, first some information on the underlying data and on the range of different kinds of co-operative relationships in the sample is given. Regional differences in co-operative behaviour are then analysed on the basis of a multivariate model with a special focus on the importance of spatial proximity for co-operative relationships. Finally, some conclusions from this study are drawn.

HYPOTHESES AND EMPIRICAL EVIDENCE

It is frequently argued in the literature that many relationships between actors in a division of innovative labour have to be 'co-operative' in nature (see FRITSCH and LUKAS, 1999). One reason for this necessity is that innovation activities in their very nature comprise the generation of knowledge and that a division of innovative labour implies the transfer of such knowledge. Because information, for a number of reasons (see GEROSKI, 1995), cannot be traded on markets in the same manner as a 'normal' good, the respective exchange relationships are more than pure 'spot-market' relations and may be characterized as 'co-operative' in a wide definition of the term. Accordingly, co-operative relationships can be an important means for transferring information in a division of innovative labour ('innovation needs or causes co-operation').

A number of authors argue for a reverse direction of this relationship, i.e. that co-operation stimulates innovation. The core of this argument contains the assertion that the quality of information transferred in co-operative relationships tends to be relatively high and that this quality, as well as the openness and complexity of information transfer in co-operative relationships, may stimulate collective learning and innovation activities ('co-operation stimulates innovation').

The importance of co-operation between the relevant actors within the region for innovation processes and their relations with external institutions is particularly pronounced in the literature on 'innovative networks' or 'milieux' (for an overview see STERNBERG, 2000). A common assumption in this context states that a high degree of intraregional co-operation leads to a high efficiency of the regional innovation system (STORPER, 1992; SAXENIAN, 1994). There are at least two reasons why co-operative relationships may be conducive to innovation activities. First, a high level of co-operation may indicate a correspondingly high degree of innovative labour division and specialization. Second, co-operative relationships may be regarded as a channel of knowledge spillovers. Empirical research has shown that such 'spillover' effects are concentrated in spatial proximity to the respective source (JAFTE, 1989; ACS *et al.*, 1992; JAFTE *et al.*, 1993; ANSELIN *et al.*, 1997). An explanation for this finding could be that close location is conducive for establishing and maintaining co-operative relationships due to the necessity of frequent face-to-face contacts (NOHRIA and ECCLES, 1992).

In summarizing the theory and the respective empirical evidence, it appears that our understanding of the importance of co-operation and spatial proximity for the division of innovative labour and the efficiency or quality of regional innovation systems is still rather vague. Little is known, for example, about the role of certain types of actors (e.g. academic institutions) or

types of relationships for regional innovations systems. In particular, it is unclear how far interregional differences in co-operative behaviour exist and if there is a causal relationship between the propensity to co-operate on R&D and the output of innovation activities. What is the role of co-operative relationships in regional innovation systems?

DATA

The spatial framework

The analysis is based on data gathered by postal questionnaires from manufacturing enterprises in three German regions. The survey was part of a larger project aiming at identifying the causes for regional differences in innovation performance and growth.² The questions focused mainly on diverse aspects of innovation behaviour. The regions under inspection here are (see Fig. 1):

- Baden, the western part of the State of Baden-Württemberg, a prosperous region characterized by a well above-average performance with regard to innovation. According to conventional wisdom, transfer institutions and co-operative relationships are well developed in this region (SEMLINGER, 1993; COOKE, 1996; HEIDENREICH and KRAUSS, 1998). The share of small establishments is considerably above the national average.
- The region Hanover-Brunswick-Göttingen in the State of Lower Saxony. The region has a high

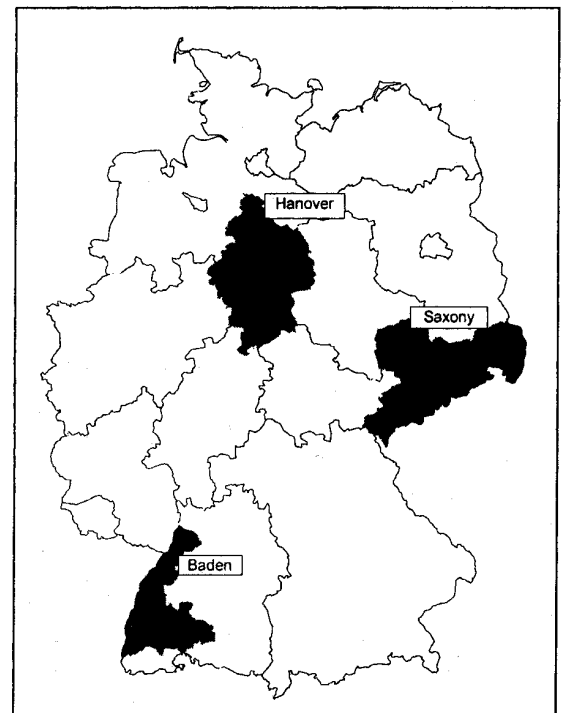


Fig. 1. Case study areas

share of employment in large scale industries (e.g. automobiles, steel) and the proportion of employment in new innovative industries is comparatively low. Despite various policy attempts to improve innovation performance in this region, the innovation system is said to have considerable deficiencies (SCHASSE, 1995).

- Saxony, one of the new German states until 1990 under a socialist regime. The region has a long tradition in manufacturing, particularly in the mechanical engineering industry. Due to the breakdown of the manufacturing sector after the fall of the 'Iron Curtain' it is dominated by small establishments. About 50% of the manufacturing establishments in our sample located in this region have less than 35 employees. Large establishments are rather rare.

Because the focus of the inquiry was on innovation one could expect a relatively low representation of non-innovative enterprises in the data.³ A non-response analysis for the survey taken in Saxony revealed that there is no such bias with respect to the share of innovative enterprises. However, the innovative enterprises in the sample tended to have a slightly higher share of R&D personnel than the entire population of enterprises. With regard to innovation, the establishments in Baden performed the best, Hanover followed and Saxony lagged somewhat behind (see FRITSCH *et al.*, 1999; and FRITSCH, 2000, for a detailed analysis).

Indicators for co-operation

The questionnaire tried to assess the presence of co-operative relationships with different types of partners separately. These types of co-operative partners were:

- customers
- manufacturing suppliers⁴
- 'other' firms
- publicly funded research institutions.

The research institutions comprised the universities, the *Fachhochschulen* (universities with a particular focus on applied studies in engineering, business and other subject areas) and publicly funded non-university research institutions.⁵ The 'other' firms are non-vertically related businesses, particularly including competitors. There are clear indications that most of the relationships to 'other' firms are horizontal in nature. The 'other' firms do not comprise suppliers of business oriented services (e.g. consulting firms).

Information on co-operative relationships with the different types of partners was gathered through a number of questions. In the first question respondents were asked if, in the last three years, the respective enterprise maintained co-operative relationships with customers, manufacturing suppliers, publicly funded

research institutes or with 'other' firms. Co-operation with suppliers or customers was defined as a relationship which went beyond normal business interaction. With regard to 'other' firms and publicly funded research institutes, all kinds of relationships were assumed to be co-operative. In a subsequent question four categories of co-operative relationships were given that constitute more concrete definitions. Respondents were asked to attach weights to these types of co-operative relationships on a three-grade scale ranging from 'unimportant' (no such kind of co-operation) to 'very important'. For co-operative relationships with customers and manufacturing suppliers these categories were 'casual contact for information purposes', 'organized exchange of information and experiences', 'involvement in planning and operation of projects' and 'pilot use of an innovation'. For the assessment of co-operative relationships with 'other' firms, the final two categories were substituted by 'joint use of equipment or laboratories' and 'joint R&D projects'. With regard to co-operation with publicly funded research institutions, the categories for the type of relationship were 'use of equipment or laboratories', 'research contracts', 'joint R&D projects' and 'collaboration with regard to thesis' (see Table 1). The questionnaire also provided information on the number of co-operative relationships with the different types of partner in certain regional categories ('within the same region' (case study area), 'outside the region', 'abroad').⁶

According to this method of questioning, it cannot be completely excluded that respondents have reported co-operative relationships that had nothing to do with innovation activities. However, to decide how far a certain relationship is in some way concerned with innovation activities may be quite hard or impossible, even for managers of the respective firms. For this reason, the first question was not limited to those co-operative relationships that, in the eyes of the respondents, were associated with innovation. However, there is some information about the type of relationship available based on the second question. In analysing the characteristics of enterprises that were engaged in a certain form of co-operative relationship with a certain kind of partner (see FRITSCH and LUKAS, 1998) no significant differences between the various forms of co-operative relationship could be found. Obviously, the characteristics of enterprises that co-operate are about the same for the different kinds of relationship and are largely independent from how close the co-operation is linked to innovation activities.

OVERVIEW ON CO-OPERATIVE RELATIONSHIPS IN THE SAMPLE

A little more than 60% of the enterprises in our sample maintained co-operative relationships with their customers; nearly 49% had co-operative relationships with their manufacturing suppliers; 33% with public research

Table 1. Share of enterprises with a certain kind of co-operative relationship (%)

Type of relationship	Share of enterprises with the respective type of relationship
<i>Customers</i>	61.6
Casual contact for information purposes	52.6
Organized exchange of information and experiences	40.0
Involvement in planning and operation of projects	44.0
Pilot use of an innovation	32.2
<i>Suppliers</i>	49.5
Casual contact for information purposes	40.8
Organized exchange of information and experiences	31.2
Involvement in planning and operation of projects	36.1
Pilot use of an innovation	21.4
<i>'Other' firms</i>	32.5
Casual contact for information purposes	25.6
Organized exchange of information and experiences	19.3
Joint use of equipment or laboratories	12.8
Joint R&D projects	14.6
<i>Publicly funded research institutions</i>	33.8
Use of equipment or laboratories	16.5
Research contracts	14.9
Joint R&D projects	22.2
Thesis collaboration	18.8

institutions; and approximately 31% with 'other' enterprises (Table 1). Looking at the different kinds of co-operative relationships with suppliers, customers and 'other' firms, casual contacts for information purposes had the highest share. For co-operation with vertically related firms, the involvement in planning and the operation of innovation projects constituted the second most important type of co-operation, followed by the organized exchange of information and experiences. About 30% of enterprises which maintained co-operative relationships with their customers stated that these customers acted as pilot users of their new products. Looking at the different kinds of relationship with suppliers, 21.4% of the enterprises served as pilot users for their suppliers' innovation. In the relationships with 'other' firms, an organized exchange of information and experiences (19.3%) was the second most important form of co-operation followed by joint R&D projects (14.6%) and joint use of equipment or laboratories (12.8%). In relationships with publicly funded research institutions, joint R&D projects (22.2%) and thesis collaboration (18.8%) played the most prominent roles followed by use of equipment or laboratories (16.5%) and contracted research (14.9%).

Regarding those enterprises that maintained at least one relationship with a certain kind of partner, the most numerous co-operative relationships were with

customers (median: 11) and the lowest number with publicly funded research institutions (median: 2). The median number of co-operative relationships with suppliers, as well as with 'other firms', was nine.

INTERREGIONAL COMPARISONS

Identifying differences between regions with regard to the share of enterprises that maintain a certain kind of co-operative relationship is not sufficient for concluding that regional differences exist in the propensity of firms to have co-operative relationships. The reason is simply that a relatively high share of establishments with such co-operative relationships in a region could be the result of a correspondingly high share of establishments that possess characteristics of businesses that are likely to have R&D co-operation (e.g. firms that are relatively large or have a relatively high share of R&D employees). In order to identify interregional differences in the propensity to co-operate, it is therefore desirable to control for the effects of the characteristics of co-operating establishments by applying multivariate analyses. For this reason, models for the propensity to maintain at least one co-operative relationship, as well as for the number of such relationships, are estimated with the relevant characteristics of the establishments as independent variables, including dummy variables for the respective region. These dummy variables assume the value 1 if the establishment is located in Baden or in the Hanover region, and 0 for establishments in Saxony which represent the control group. A statistically significant coefficient for a regional dummy variable indicates that the establishments in the respective region show a higher or lower propensity to co-operate (depending on the sign of the respective coefficient) than establishments in Saxony. 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.

To analyse the impact of exogenous variables on the propensity to co-operate, as well as on the number of co-operative relationships, a two-stage count-data hurdle model is applied here.⁷ This model has two parts. The first part consists of a logit model, which aims to explain whether the respective enterprise has at least one co-operative relationship with a certain type of partner or not. The second part is restricted to those enterprises that have overcome this hurdle of having at least one co-operative relationship with a certain type of partner and analyses those factors that determine the number of such contacts. Assuming that the number of co-operative relationships results from a Poisson-like process, Poisson-regression analysis may be used as the estimation method. However, a negative-binomial (negbin) model was applied here because it is based on somewhat more general assumptions than the Poisson regression model.⁸

The logit-negbin model which is applied here has a major advantage over an ordinary count data model. It deals with the fact that there are too many zero values in our data compared to an ordinary Poisson distribution and, therefore, is in better accordance with the basic assumptions of the estimation procedure. The model also allows for differences with regard to the determinants of the decision to co-operate at all with a certain kind of partner and the factors that explain the number of such co-operative relationships.

Table 2 shows the results of logit-negbin analyses aimed at identifying the characteristics of those firms that maintain co-operative relationships with a certain type of actor. The estimates of the first step of the model (logit analysis) are given in the first column and the results of the second step of analysis, the negbin regression, are reported in the second column.⁹ In nearly all estimations, the size of the respective enterprise (number of employees) was statistically significant with a positive sign at both stages of the model. The negbin regression for the number of co-operative relationships with customers constitutes an exception in this respect, but even here the coefficient for size proved to be statistically significant at the 10% level. This indicates that not only the propensity to have at least one co-operative relationship, but also the number of co-operative relationships increases with the size of the respective unit. Such strong association between size and R&D co-operation corresponds well with the results of other studies (e.g. FUSFELD and HAKLISCH, 1985; KÖNIG *et al.*, 1994). This size effect may be simply explained by the assumption that a certain probability for R&D co-operation per unit of value added exists such that the propensity of a certain enterprise to have at least one co-operative relationship rises with its size. The parameter estimates for the first stage of the model indicate that this size effect is particularly pronounced with regard to co-operative relationships with public research institutes. Another marked positive relationship with the propensity for maintaining at least one co-operative relationship can be found for R&D intensity, measured as the share of R&D employees. With regard to the number of co-operative relationships, such a statistically significant impact of R&D intensity could only be found for co-operation with public research institutes.

The coefficients for the share of value-added to turnover¹⁰ may be seen as an indication of how much co-operation is related to outsourcing of certain tasks. A negative sign for this variable would signify that the co-operation goes together with a substitution of previously internal tasks. A positive sign would imply a complementary relationship. The significance of a negative sign for the coefficient of the share of value added in the logit-model for co-operative relationships with suppliers suggest that the contribution of suppliers in R&D co-operation tends to involve substitutions, i.e. replacing parts of the internal innovation activities.

The positive sign in the estimation for the number of co-operative relationships with 'other' firms suggests that this type of co-operation is, in most cases, complementary in nature. This also seems to hold for relationships with public research institutions. However, in the negbin-regression for the number of relationships to this type of partner we find a statistically significant negative sign for the share of value added. The highest number of statistically significant industry dummies is found in the logit-model for the existence of at least one co-operative relationship with publicly funded research institutions. The negative signs for these industry dummies suggest that innovation activities of the enterprises in the control group, suppliers of medical-technical instruments, tended to be rather science based, leading to a relatively high propensity to maintain R&D co-operation with public research institutions.

Quite surprisingly, the regional dummy variables for location in Hanover and Baden assumed statistically significant negative values in the first stage of our model (logit analysis). This indicates that the propensity to co-operate in the western German regions was lower than in Saxony. However, in the second stage of the model (negbin regression) a number of coefficients for the regional dummy variables show statistically significant positive values. Obviously, the western German enterprises tended to maintain co-operative relationships with a larger number of partners once they had overcome the hurdle to co-operate at all. In order to gain more insights into the patterns of co-operative behaviour, the analyses were conducted separately for co-operative relationships with partners within and outside the region as well as for smaller (less than 200 employees) and for larger (200 and more employees) establishments. The results for the regional dummy variable in the two stages of our model are summarized in Table 3 (first stage, logit analysis) and Table 4 (second stage, negbin regression).

The estimations limited to establishments of a certain size or to co-operative relationships with partners located inside or outside the respective region lead to results that are quite similar to the non-differentiated analyses. However, there are also a number of interesting peculiarities. Establishments in the Hanover region, for example, were significantly less likely to co-operate with customers outside the region than the establishments in Saxony (Table 3). However, if firms in Hanover have established at least one such relationship, the number of partners tends to be greater (Table 4).

Establishments in Baden show a relatively low propensity to co-operate with their manufacturing suppliers. But again, if they have overcome the hurdle of maintaining at least one such relationship, the number of co-operative partners is higher. The establishments in Baden, as well as those in Hanover, are also characterized by a significantly lower propensity to co-operate with 'other' firms within the region. Also, in the

Table 2. The propensity to co-operate with different types of actors: logit-negbin hurdle models

	Co-operation with				Co-operation with			
	Customers		Suppliers		'Other' firms		Public research institutions	
	Yes/no (logit)	No. of relations (negbin)	Yes/no (logit)	No. of relations (negbin)	Yes/no (logit)	No. of relations (negbin)	Yes/no (logit)	No. of relations (negbin)
Number of employees (ln)	0.324** (6.24)	0.106 (1.72)	0.406** (8.08)	0.227** (4.26)	0.190** (3.87)	0.178** (3.85)	0.843** (13.56)	0.143** (2.96)
R&D-intensity (share of R&D employees)	2.317** (3.96)	-0.004 (0.97)	1.751** (3.55)	0.007 (1.45)	1.845** (3.82)	0.002 (0.59)	5.173** (8.57)	0.015** (3.38)
Share of value added to turnover (%)	0.003 (1.06)	0.003 (0.67)	-0.10** (3.17)	-0.006 (1.52)	0.003 (1.01)	0.009** (2.92)	0.007* (2.18)	-0.008* (2.46)
Dummy for location in Hanover	-0.258 (1.17)	0.107 (0.61)	0.070 (0.61)	0.104 (0.68)	-0.246 (0.67)	0.041 (0.31)	-1.070** (6.18)	—
Dummy for location in Baden	-0.265 (1.90)	0.428** (2.63)	-0.312* (2.27)	0.485** (3.16)	-0.603** (4.00)	-0.093 (0.72)	-0.513** (3.18)	0.251* (2.11)
<i>Industry dummies</i>								
Food, beverages and tobacco	-0.871** (2.80)	0.432 (1.18)	0.316 (1.04)	0.123 (0.37)	-0.285 (0.88)	0.303 (1.03)	-0.540 (1.58)	-0.125 (0.45)
Textiles, clothing, leather	-0.248 (0.82)	0.096 (0.318)	-0.091 (0.31)	0.520 (1.67)	-0.382 (1.22)	-0.268 (0.90)	-0.495 (1.55)	-0.331 (1.32)
Wood (excluding furniture)	-0.548 (1.60)	-0.904* (2.42)	-0.228 (0.67)	0.288 (0.70)	-0.250 (0.67)	0.196 (0.52)	-1.000* (2.31)	-0.218 (0.57)
Paper, printing, publishing	-0.492 (1.65)	0.223 (0.67)	-0.071 (0.24)	0.045 (0.14)	0.340 (1.15)	0.368 (1.43)	-1.025** (3.00)	-0.714* (2.29)
Furniture, jewellery, musical instruments, toys	-0.490 (1.49)	0.283 (0.78)	-0.216 (0.67)	1.018** (2.84)	-0.382 (1.08)	0.440 (1.39)	-0.956* (2.54)	-0.223 (0.72)
Mineral oil, chemicals	0.066 (0.19)	0.879** (2.59)	-0.172 (0.52)	0.757* (2.08)	0.093 (0.27)	1.348** (4.50)	-0.343 (0.93)	0.423 (1.53)
Rubber and plastics	-0.201 (0.64)	-0.078 (0.25)	0.112 (0.37)	-0.013 (0.04)	-0.155 (0.48)	-0.024 (0.08)	-0.637 (1.83)	0.033 (0.10)
Stone, ceramics and glass	-0.133 (0.43)	-0.099 (0.30)	0.021 (0.07)	-0.276 (0.90)	-0.028 (0.09)	0.123 (0.45)	-0.478 (1.44)	-0.089 (0.31)
Metal products, recycling	-0.290 (1.13)	-0.463 (1.84)	-0.193 (0.78)	0.236 (0.87)	0.118 (0.46)	0.598** (2.72)	-0.726** (2.62)	-0.161 (0.78)
Mechanical engineering	0.083 (0.31)	-0.322 (1.31)	0.094 (0.38)	0.434 (1.70)	0.094 (0.03)	0.339 (1.61)	0.029 (0.11)	0.382* (2.18)
Vehicles	0.291 (0.73)	-1.047** (3.04)	-0.051 (0.144)	0.232 (0.66)	-0.145 (0.39)	-0.416 (1.12)	-0.278 (0.70)	-0.143 (0.51)
Data processing, electrical and electronic equipment	0.409 (1.30)	-0.457 (1.64)	0.142 (0.49)	0.682* (2.47)	0.081 (0.28)	0.547* (2.26)	-0.574 (1.83)	-0.215 (0.97)
<i>Model summary</i>								
Alpha	—	1.795	—	1.439	—	0.684	—	0.402
χ^2 for covariates	109.58	66.49	121.95	68.45	59.74	63.08	359.53	68.11
Significance of χ^2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pseudo R^{2adj}	0.053	0.014	0.057	0.018	0.03	0.032	0.181	0.05
Number of cases	1,546	538	1,540	472	1,539	331	1,537	328

Notes: Estimated logit/negbin coefficients. Asymptotic, absolute *t*-values in parentheses.

*Statistically significant at the 5% level.

**Statistically significant at the 1% level.

Hanover region, the number of co-operative relationships with 'other' firms within the region tended to be smaller than in Saxony. Obviously, local horizontal networks are far more developed in Saxony than in the two western German regions. This result is particularly remarkable with regard to Baden, because this region is said to be characterized by a relatively high level of intraregional co-operation and networking (see SEM-

LINGER, 1993; COOKE, 1996; HEIDENREICH and KRAUSS, 1998). The only confirmation for this hypothesis that can be found in the data is the significantly larger number of co-operating manufacturing suppliers from within the region for those establishments that maintain at least one such relationship. Note that the number of co-operative relationship with partners outside the region tends to be significantly larger in

Table 3. Logit analyses of the propensity to co-operate with different types of partners within and without the response region: results for regional dummy variables

Co-operative relationship with	Dummy variable for a location in:					
	All enterprises	Baden		All enterprises	Hanover	
		Enterprises with <200 employees	Enterprises with ≥200 employees		Enterprises with <200 employees	Enterprises with ≥200 employees
<i>Customers</i>						
All	n.s.	-*	+*	n.s.	-*	n.s.
Within the region	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Outside the region	n.s.	n.s.	n.s.	-*	-*	n.s.
<i>Suppliers</i>						
All	-*	-**	n.s.	n.s.	n.s.	n.s.
Within the region	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Outside the region	n.s.	n.s.	n.s.	n.s.	+*	n.s.
<i>'Other' firms</i>						
All	-**	-**	n.s.	n.s.	n.s.	n.s.
Within the region	-**	-*	n.s.	-*	n.s.	n.s.
Outside the region	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
<i>Public research institutes</i>						
All	-**	-**	n.s.	-**	-**	-**
Within the region	-**	-*	n.s.		not tested	
Outside the region	+*	n.s.	+*		not tested	

Notes: * Statistically significant at the 5% level.
 ** Statistically significant at the 1% level.
 n.s. Not statistically significant.
 + Denotes positive estimated coefficient.
 - Denotes negative estimated coefficient.

Table 4. Negbin regression analyses of the number of co-operatative relationships with different types of partners within and outside the respective region: results for the regional dummy variables

Co-operative relationships with	Dummy variable for a location in:					
	All enterprises	Baden		All enterprises	Hanover	
		Enterprises with <200 employees	Enterprises with ≥200 employees		Enterprises with <200 employees	Enterprises with ≥200 employees
<i>Customers</i>						
All	+**	+*	n.s.	n.s.	n.s.	n.s.
Within the region	n.s.	n.s.	n.s.	-**	-**	n.s.
Outside the region	+**	+**	n.s.	+**	n.s.	n.s.
<i>Suppliers</i>						
All	+**	+**	n.s.	n.s.	n.s.	+*
Within the region	+**	+**	n.s.	n.s.	n.s.	n.s.
Outside the region	n.s.	n.s.	n.s.	+*	n.s.	+*
<i>'Other' firms</i>						
All	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Within the region	n.s.	n.s.	n.s.	-*	-**	n.s.
Outside the region	n.s.	n.s.	n.s.	+**	+**	n.s.
<i>Public research institutes</i>						
All	+*	+**	n.s.		not tested	
Within the region	-**	-**	n.s.		not tested	
Outside the region	+**	+**	n.s.		not tested	

Notes: See notes to Table 3.

the western German regions indicating a higher degree of integration into interregional networks than in Saxony. In the case of Baden, this higher degree of integration may particularly involve relationships to Württemberg, the other part of the State of Baden-Württemberg.

With regard to relationships with public research institutions, the estimates show a lower propensity to co-operate for the establishments in Baden, as well as for the establishments in Hanover. Due to some differences in the respective questionnaires, the regional distribution of co-operating public research institutions cannot be analysed for the Hanover region. The respective estimates indicate that the propensity to co-operate with public research institutions outside the region is significantly higher in Baden when compared to Saxony. Obviously, the lower likelihood of establishments in Baden to co-operate with research institutions holds only for relationships with partners inside the region. This implies that, with regard to industry-university co-operation, firms in Baden rely to a much lesser degree on the regional innovation system than do manufacturing companies in Saxony. One possible reason for this result could be respective differences on the supply side, that is to say, Saxony is relatively well equipped with a large infrastructure of technical universities¹¹ and universities of applied sciences (*Fachhochschulen*). This suggests that firms in Saxony have less of a need to look for appropriate partners outside the region.

Running the analyses for smaller and for larger establishments separately reveals that the majority of interregional differences in the propensity to co-operate (Table 3) as well as the number of co-operative relationships (Table 4) are due to corresponding differences among the small establishments. For the larger establishments, only few statistically significant coefficients of the regional dummy variables could be found. This means that region-specific factors mainly shape co-operative behaviour of the smaller establishments, and to a much lesser degree of the larger firms.

The higher propensity to co-operate among the establishments in Saxony is quite surprising, considering the deep restructuring of the economy of the former East Germany (GDR) and of its innovation system after the opening of the border (FRITSCH and MALLOK, 1998; FRITSCH and WERKER, 1999). In the course of these events, many of the research institutes in the former East Germany were shut down, drastically reorganized or newly established. The same holds for manufacturing enterprises. Generally, this transformation process led to a destruction of many of the old networks (see ALBACH, 1994). A large part of such relationships, often based on personal contacts, had to be established anew in the former GDR. In contrast to this situation, the region of Baden possesses a highly developed infrastructure of transfer institutions and is said to be characterized by a dense system of co-

operative relationships between actors (SEMLINGER, 1993; COOKE, 1996; HEIDENREICH and KRAUSS, 1998). The fact that there are long established and well-developed innovation systems in Baden and Hanover obviously results in a significantly higher number of co-operative relationships, however, not necessarily in a higher propensity to co-operate. In these regions, an enterprise that wants to co-operate tends to have a larger number of pre-existing or relatively easily developed relationships at its disposal.

THE IMPORTANCE OF SPATIAL PROXIMITY FOR CO-OPERATIVE RELATIONSHIPS

Calculating the share of co-operative relationships with partners within the respective region reveals pronounced differences between regions, as well as between partner types (Fig. 2). These figures suggest that spatial proximity is of only relatively minor importance for co-operative relationships with customers (only slightly more than 30% of co-operative partners in the same region). The results for the regional structure of co-operative relationships to manufacturing suppliers are in a similar range. The share of co-operative relationships with partners located in the same region is much higher in the case of 'other' firms and public research institutions. For both types of partner, the share of co-operative relationships to actors within the same region is relatively high in Saxony, e.g. in more than 60% of all co-operative relationships

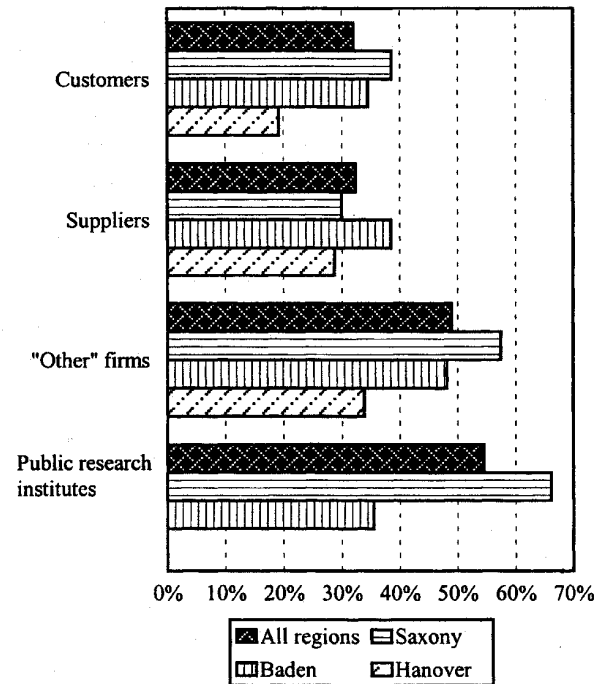


Fig. 2. Share of co-operative relationships with actors located in the same region

between Saxon establishments and public research institutions, these research institutions are located in Saxony.

The high importance of spatial proximity for co-operative relationships also becomes clear in our survey of the public research institution, where the institutions have been asked for the regional distribution of the manufacturing enterprises with which they maintain co-operative contact. Analysis of these data clearly shows that, from the perspective of the public research institutions, the majority of their manufacturing co-operative partners are located in the same region (see FRITSCH and SCHWIRTEN, 1999).

CONCLUSIONS

The analysis of co-operative relationships in three German regions reported here has led to a number of very interesting findings. Obviously, geographic distance is unfavourable for establishing or maintaining a co-operative relationship. As a consequence, the co-operation partners tend to be concentrated in spatial proximity to a firm's own location. Being located close to the co-operative partner seems to be particularly important for relationships with public research institutions and with non-vertically related firms. The relatively high degree of concentration of co-operative relationships for non-vertically related firms in the same region indicates the relatively high importance of localization economies for a division of innovative labour. This corresponds to the results of a number of other analyses (FELDMAN, 1994; AUDRETSCH and FELDMAN, 1996) which show that innovation activities in a certain technological field tend to be highly concentrated in space. In co-operative relationships with suppliers and with customers, spatial proximity seems to be much less important. A further important result of the analysis is that statistically significant differences between regions in the propensity to co-operate are mainly caused by differences among the smaller enterprises with less than 200 employees. Co-operative behaviour of the larger firms seems to be much less affected by location factors.

On the basis of the empirical results presented here, it may be concluded that innovation systems have a pronounced regional dimension. Obviously, regions are characterized by specific innovation systems that should be analysed in more detail in order to identify those factors that lead to a high degree of innovation and to economic success in some regions, while others fall behind. Looking at the relationship between the propensity to co-operate and the workability of the regional innovation system, our results are somewhat surprising. The highest propensity to co-operate on R&D was found in Saxony, while the data suggest that establishments in Baden are leading with regard to innovation. In this respect, the enterprises in Saxony fall behind their West German competitors (FRITSCH *et al.*, 1999). If, as is frequently stated in the literature,

a high level of local co-operation is conducive to innovation activities, Saxon establishments should perform better. However, if the *number* of co-operative relationships is used as an indicator for the level of co-operation, the simple 'co-operation is good for innovation' hypothesis is confirmed by our data. Obviously, reality is complex and demands careful and differentiated analysis.

We still know very little about the reasons for the differences in co-operation behaviour found in this analysis and what they mean for innovation and growth in the respective region. Obviously, the role played by regional networks should not be over-estimated. On the one hand, networking inside the region should have a positive effect on regional development, because it is a form of exploiting the potential for agglomeration economies. On the other hand, we can assume that the effects of regional co-operation depend on the concrete needs and the availability of co-operative partners that match these demands. Clearly, maximizing the number of co-operative relationships or the share of co-operative partners within a region cannot be recommended as a strategy (GRABHER and STARK, 1997). Local networks should have significant connections to the 'outer world' in order to be able to absorb externally generated knowledge for the innovation activities within the region. Concentrating more or less purely on local ties could work as a disadvantage.

Acknowledgements – This paper is based on a joint project with four teams involved in the design of the questionnaires and the collection of the data, all supported by the German Science Foundation (Deutsche Forschungsgemeinschaft). For an outline of this project see STERNBERG, 2000.

NOTES

1. The term 'innovation system' includes all institutions and actors that contribute to the development and the diffusion of inventions or new technologies (see, for example, FREEMAN, 1987; LUNDVALL, 1992; NELSON, 1993; METCALFE, 1995). Relevant actors in this respect are R&D departments in private sector firms as well as universities, public research facilities and politicians. The innovation system is not just the sum of these elements. Of crucial importance for the workability of an innovations system is the interaction of the different elements.
2. The survey was conducted between September and December 1995.
3. The questionnaire had been sent out to all enterprises with 10 or more employees. The response rate amounted to 17.8% in Baden, 20.6% in Hanover and 27.7% in Saxony.
4. Information on R&D co-operation with service firms was raised by a different kind of question in a different way and is not included here.
5. For example, institutes of the Max-Planck and the Fraunhofer Society.

6. The information on the number of relationships comprises all kinds of co-operation with a certain type of partner and is not available at the level of single categories of relationship.
7. See JOHNSON and KOTZ, 1969; MULLAHY, 1986; as well as WINKELMANN and ZIMMERMANN, 1995, for a detailed description of these kinds of model.
8. Negative binomial regression allows for a greater variance of observations than is assumed for a Poisson process. For a more detailed description of these estimation methods see GREEN, 1997, 931–39.
9. Estimating models for different modes of co-operation with a certain type of partner leads to results that are quite similar to those attained with models relating to all kinds of relationship with this partner (see the Appendix of FRITSCH and LUKAS, 1998). In these estimations the value of the pseudo R^2 tends to be relatively high for intensive forms of co-operation (e.g. joint R&D projects) and relatively low for relationships that constitute only rather loose links and are therefore informal in character (e.g. casual contact for information purposes).
10. Calculated as 'sales minus expenses for raw materials and obtained goods/sales'.
11. In Saxony there are three technical universities (in Chemnitz, Dresden and in Freiberg) compared to only one technical university in Baden (Karlsruhe).

REFERENCES

- ACS Z. J., AUDRETSCH D. B. and FELDMAN M. P. (1992) The real effects of academic research: comment, *Am. Econ. Rev.* **82**, 363–67.
- ALBACH H. (1994) *The Transformation of Firms and Markets: A Network Approach to Economic Transformation Processes in East Germany*. Almqvist & Wiksell, Stockholm.
- ANSELIN L., VARGA A. and ACS Z. J. (1997) Local geographic spillovers between university research and high technology innovation, *J. Urban Econ.* **42**, 422–48.
- AUDRETSCH D. B. and FELDMAN M. P. (1996) R&D spillovers and the geography of innovation and production, *Am. Econ. Rev.* **86**, 630–40.
- COOKE P. (1996) The new wave of regional innovation networks: analysis, characteristics and strategy, *Small Bus. Econ.* **8**, 159–71.
- COOKE P. (1998) Introduction: origins of the concept, in BRACZYK H.-J., COOKE P. and HEIDENREICH M. (Eds) *Regional Innovation Systems – The Role of Governances in a Globalized World*. UCL Press, London.
- COOKE P., GOMEZ U. and ETXEBARRIA G. (1997) Regional innovation systems: institutional and organisational dimensions, *Research Policy* **26**, 475–91.
- FELDMAN M. P. (1994) *The Geography of Innovation*. Kluwer, Boston.
- FREEMAN C. (1987) *Technology Policy and Economic Performance: Lessons from Japan*. Frances Pinter, London.
- FRITSCH M. (2000) Interregional differences in R&D activities – an empirical investigation, *Europ. Plann. Studies* **8**, 409–27.
- FRITSCH M. and LUKAS R. (1998) Who cooperates on R&D?, Freiberg Working Paper 98/12, Technical University Bergakademie Freiberg.
- FRITSCH M. and LUKAS R. (1999) Innovation, co-operation, and the region, in AUDRETSCH D. B. and THURIK R. (Eds) *Innovation, Industry Evolution and Employment*. Cambridge University Press, Cambridge.
- FRITSCH M. and MALLOK J. (1998) Surviving the transition: the process of adaptation of small and medium-sized firms in East Germany, in HORST BREZINSKI H., FRANCK E. and FRITSCH M. (Eds) *The Microeconomics of Transformation and Growth*. Edward Elgar, Cheltenham.
- FRITSCH M. and SCHWIRTEN C. (1999) Enterprise–university co-operation and the role of public research institutions in regional innovation systems, *Industry & Innovation* **6**, 69–83.
- FRITSCH M. and WERKER C. (1999) Systems of innovation in transition, in FRITSCH M. and BREZINSKI H. (Eds) *Innovation and Industrial Recovery in Eastern Europe*. Edward Elgar, Cheltenham.
- FRITSCH M., FRANKE G. and SCHWIRTEN C. (1999) Innovation in manufacturing – an East West-German comparison, in FRITSCH M. and BREZINSKI H. (Eds) *Innovation and Industrial Recovery in Eastern Europe*. Edward Elgar, Cheltenham.
- FUSFELD H. and HAKLISH C. I. (1985) Cooperative R&D for competitors, *Harv. Bus. Rev.* **63**, 60–76.
- GEROSKI P. (1995) Markets for technology: knowledge, innovation and appropriability, in STONEMAN P. (Ed) *Handbook of the Economics of Innovation and Technological Change*. Blackwell, Oxford.
- GRABHER G. and STARK D. (1997) Organizing diversity: evolutionary theory, network analysis and postsocialism, *Reg. Studies* **31**, 533–44.
- GREEN W. H. (1997) *Econometric Analysis*, 3rd edition. Prentice Hall, New York.
- HEIDENREICH M. and KRAUSS G. (1998) The Baden-Württemberg production and innovation regime: past successes and new challenges, in BRACZYK H.-J., COOKE P. and HEIDENREICH M. (Eds) *Regional Innovation Systems – The Role of Governances in a Globalized World*. UCL Press, London.
- JAFFE A. B. (1989) Real effects of academic research, *Am. Econ. Rev.* **79**, 957–70.
- JAFFE A. B., TRAJTENBERG M. and HENDERSON R. (1993) Geographic localization of knowledge spillovers as evidenced by patent citations, *Quart. J. Econ.* **108**, 576–98.
- JOHNSON N. L. and KOTZ S. (1969) *Distributions in Statistics: Discrete Distributions*. John Wiley, New York.
- KLEINKNECHT A. and REIJNEN J. O. N. (1992) Why do firms cooperate on R&D? An empirical study, *Research Policy* **21**, 347–60.
- KÖNIG H., LICHT G. and STAAT M. (1994) F&E-Kooperationen und Innovationsaktivität (R&D co-operation and

- innovation activity), in GAHLEN B., HESSE H. and RAMSER H.-J. (Eds) *Europäische Integrationsprobleme aus wirtschaftswissenschaftlicher Sicht*. Siebeck, Tübingen.
- LUNDVALL B.-A. (1992) User-producer relationships, national systems of innovation and internationalisation, in LUNDVALL B.-A. (Ed) *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. Frances Pinter, London.
- METCALFE J. S. (1995) The economic foundations of technology policy: equilibrium and evolutionary perspectives, in STONEMAN P. (Ed) *Handbook of the Economics of Innovation and Technological Change*. Blackwell, Oxford.
- MULLAHY J. (1986) Specification and testing in some modified count data models, *J. Econometrics* **33**, 341-65.
- NELSON R. R. (Ed) (1993) *National Innovation Systems - A Comparative Analysis*. Oxford University Press, New York.
- NOHRIA N. and ECCLES R. (1992) Face-to-face: making network organizations work, in NOHRIA N. and ECCLES R. (Eds) *Networks and Organizations; Structure, Form, and Action*. Harvard Business School Press, Boston, MA.
- SAXENIAN A. (1994) *Regional Advantage*. Harvard University Press, Cambridge, MA.
- SCHASSE U. (1995) Produkt- und Prozeßinnovationen in Niedersachsen (Product and process innovation in Lower Saxony), in SCHASSE U. and WAGNER J. (Eds) *Erfolgreich produzieren in Niedersachsen*. Niedersächsisches Institut für Wirtschaftsforschung (NIW-Vortragsreihe, Bd. 10), Hanover.
- SEMLINGER K. (1993) Economic development and industrial policy in Baden-Württemberg: small firms in a benevolent environment, *Europ. Plann. Studies* **1**, 435-63.
- STERNBERG R. (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, *Europ. Plann. Studies* **8**, 389-407.
- STORPER M. (1992) The limits of globalization: technology districts and international trade, *Econ. Geogr.* **28**, 60-93.
- WINKELMANN, R. and ZIMMERMANN K. F. (1995) Recent developments in count data modelling: theory and application, *J. Econ. Surveys* **9**, 1-24.