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DOES R&D-COOPERATION BEHAVIOR DIFFER BETWEEN REGIONS?

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Cooperation in the field of research and development (R&D) constitutes a main ingredient in recent attempts to explain regional economic development. It plays a prominent role, for example, in the concept of "innovative milieus" (Aydalot and Keeble 1988; Crevoisier and Maillat 1991) as well as in the literature on innovation "networks" (cf. Camagni 1991; Grabher 1993) and on "industrial districts" (cf. Pyke *et al.* 1990; Porter 1998). Furthermore, R&D cooperation is assumed to be an important vehicle for knowledge spillovers that constitute a fundamental element in recent approaches to growth theory (cf. Krugman 1991; Romer 1994) and in the concept of (national or regional) innovation systems (cf. Lundvall 1992a; Nelson 1993; Cooke *et al.* 1997; Edquist 1997). However, beyond some more or less "anecdotal" evidence, little is known in how far differences between regions with regard to R&D cooperation really exist and whether such differences in cooperative behavior could provide an explanation for divergent economic performance.

This paper attempts to throw some light on the role of R&D cooperation by analyzing magnitude and significance of differences in R&D-cooperative behavior of manufacturing establishments in 11 European regions. After a brief review of the main hypothesis concerning possible effects of R&D cooperation on innovation activity, some information on the spatial framework of the analysis and the indicators for R&D cooperation is given. The results of the empirical analyses of R&D-cooperative behavior are then discussed. The final section summarizes the main findings and draws some conclusions.

POSSIBLE EFFECTS OF R&D COOPERATION ON INNOVATION ACTIVITY

An important difference between R&D and a "normal" production process is that the final result of innovation activity is often more or less unknown, so that it cannot be completely specified beforehand. For this reason, a division of innovative labor between firms inevitably includes incomplete contracts that leave room for opportunistic behavior, i.e. self-serving interpretation of the terms of the contract to the disadvantage of other contract parties. Therefore, engaging in such incompletely specified, long-term agreements ("relational contracting") may require a considerable degree of trust.[1] For this reason, many relationships in the division of innovative labor between organizations may be characterized as a cooperation in a relatively wide

1 See MacNeil (1978) for a detailed characterization of the different types of agreement.

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definition of the term.[2] According to such a broad definition, every relationship between actors that involves more than just a spot-market exchange but which is not subject to complete hierarchical control may be considered a cooperation.

The literature on the relationship between cooperation behavior and innovation activities suggests that cooperation should be conducive to innovation processes for at least two reasons (cf. Fritsch and Lukas 1999: 158f.). First, as has already been explained, to benefit from the advantages of labor division in the field of innovation activities, some sort of cooperation according to the wide definition of the term given above is unavoidable. Assuming that labor division results in efficiency gains one may expect that intensive R&D cooperation will lead to relatively high productivity of innovation processes. Second, as far as cooperative relationships are characterized by a relatively "open" exchange of information, such information flows may have a stimulating effect on innovation activities.[3] Many authors suggest that not only formal cooperative relationships like joint ventures or contract research serve as conduits for knowledge flows, but that informal relationships like "information trading" (reciprocal exchanges of information between personnel of competing firms) play a significant role (e.g. von Hippel 1987; Saxenian 1994).

Although the importance of R&D cooperation for a division of innovative labor has been widely recognized, many questions remain unanswered. For example, very little is known about what effect spatial proximity has on the establishment and maintenance of cooperative relationships (see for example Audretsch and Stephan 1996). To what extent does the supply of cooperation partners in a region affect the likelihood of establishing such a relationship? We also know only little about the significance of interregional differences in the propensity of enterprises to cooperate. If such differences exist, is there a relationship between cooperation behavior and the quality of the regional innovation system?

The spatial framework

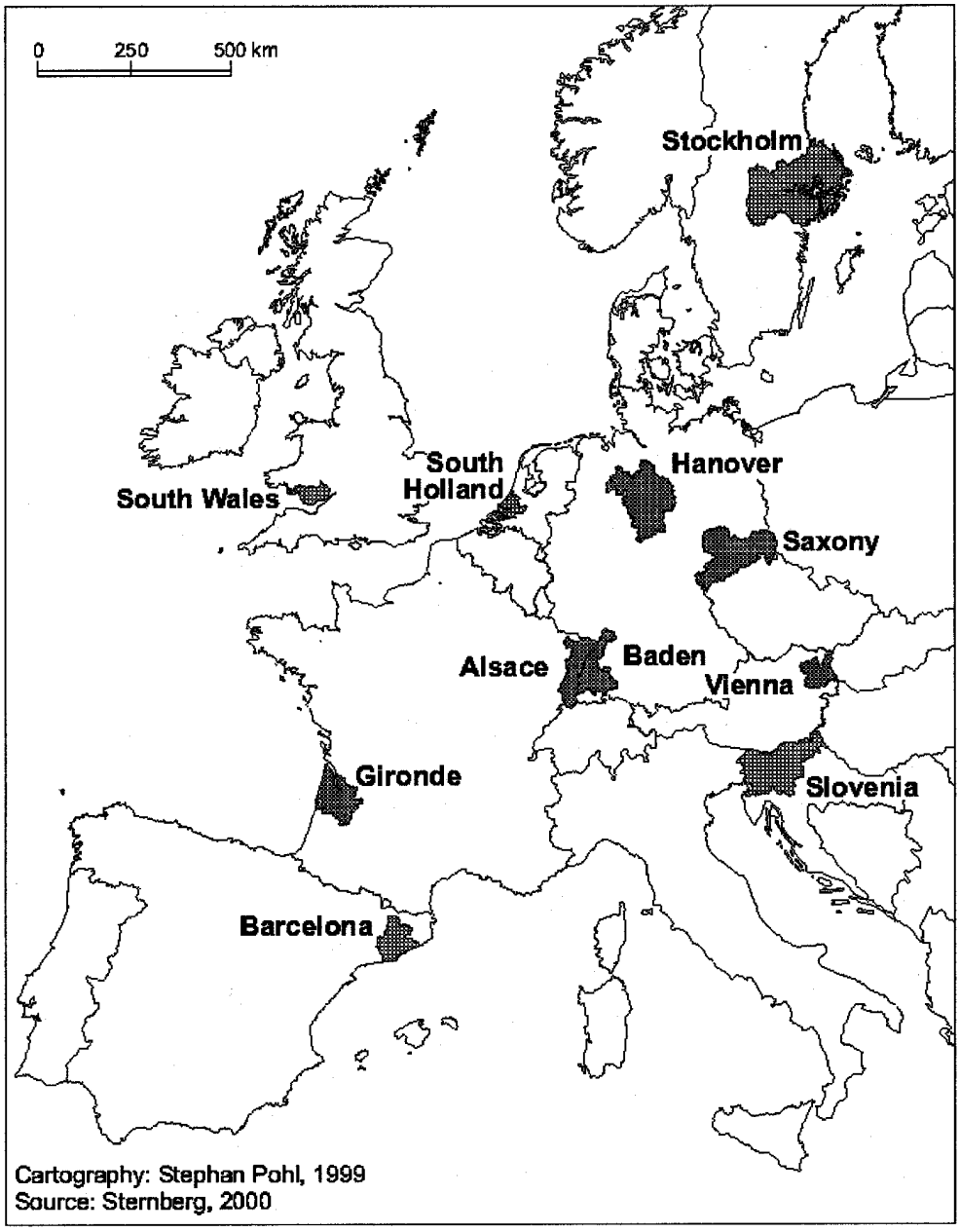
The empirical analyses reported here are based on data gathered by a postal inquiry of manufacturing enterprises in 11 European regions (Figure 1). This inquiry was carried out in two phases between 1995 and 1998, and resulted in approximately 4,300 usable questionnaires which constitute the data-set. The questions concentrated on innovation related issues, but 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 11 regions in which the inquiry was carried out, 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 regimes until 1990-91 and are faced with the need to more or less completely reorganize their

2 It is quite remarkable that many studies of cooperation between organizations leave the exact definition of a cooperative relationship more or less open. The above definition is in accordance with the way the term is used in most of the literature on cooperation.

3 See for example Powell (1990), Axelsson (1992), and Lundvall (1992b).

Figure 1: CASE STUDY AREAS.



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). In the other West German region of Hanover, there is 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 variety with regard to economic development and local conditions of the regions in our sample, we may expect to find some differences with regard to innovation activities, particularly concerning R&D cooperation in the data.[4]

The four regions in our sample that are dominated by large cities of international importance (Barcelona, Rotterdam, Stockholm, and Vienna) may be classified as "centers" according to a center-periphery paradigm, that is rather popular in the literature dealing with the impact of location on innovation activities (for a brief overview see Fritsch 2000: 410f.). 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 that ranks relatively high 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 in the spatial hierarchy. If spatial proximity is of importance for establishing and maintaining R&D cooperation, one can expect that the propensity to cooperate is also relatively high in the center regions due to the rich supply of cooperation partners.

Indicators for cooperation

Information on R&D cooperation with the different types of partners was gathered through a number of questions. One sort of question tried to assess whether or not in the preceding 3 years the respective enterprise had maintained a cooperative relationship with a certain type of partner that was focused on innovation activities. This particular question was asked about each of the five types of partners:

- customers
- manufacturing suppliers
- suppliers of business services[5]
- "other", non-vertically related firms
- publicly funded research institutions.

The research institutions were comprised of the universities[6] and publicly funded non-university research institutions. The "other" firms are non-vertically related businesses, particularly including competitors. There are clear indications that most

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

5 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 had been left out in analyses that were focused on these regions.

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

of the relationships to "other" firms were horizontal in nature. Cooperation 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 cooperative. For each partner type, we know the number of cooperative relationships within different regional categories ("within the region", "rest of the country", "abroad").[7] However, we have no information about further characteristics of cooperation partners such as their size, their structure or if there is any common ownership or legal merging of cooperating units.

Suppliers of business-oriented services have been most frequently named as a partner for R&D cooperation. Of all manufacturing enterprises 67.3 percent maintained cooperative relationship with this type of partner. Also, more than half of the respondents, 58.2 percent, 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 percent while R&D cooperation with public research institutions (30.0 percent of all enterprises) and with "other" firms (25.9 percent) was less common.

Interregional Differences with Regard to Cooperation Behavior

There exist remarkable differences between the case study areas with regard to R&D-cooperation behavior. Looking at the share of enterprises that maintain at least one cooperative relationship to a certain kind of partner (Figure 2), we find above average values particularly in Baden, Hanover, Saxony, and Slovenia. Conversely, these shares are relatively low in Stockholm and Vienna. There is no somewhat clear tendency towards higher shares of cooperating enterprises in the four "centers" in our sample (Barcelona, Rotterdam, Stockholm, and Vienna). On the contrary, the share of establishment with cooperative relationships tends to be higher in the less urbanized regions. The lowest shares of cooperating establishments are found in Vienna, Stockholm, South Wales, and Alsace. For establishments in Hanover, Saxony, and Slovenia this share is relatively high. In Baden, the proportion of enterprises with R&D cooperation is above the average but has by far not the highest value. 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 another kind of partner tends to be also relatively high (low). This indicates that cooperativeness is not limited to a certain type of partner (e.g. customers), but represents a more general attitude, quite likely involving various kinds of actors.

Calculating the fraction of cooperative relationships with partners in the same case study area reveals pronounced differences between regions, as well as between partner types (Figure 3). A relatively high share of local ties can be found for

7 We also have some information on the intensity of the collaboration and some other related issues. Unfortunately, there were some severe differences between the case study regions concerning the questions used to gather information on cooperative relationships so that parts of the information are not comparable for all 11 regions. 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.

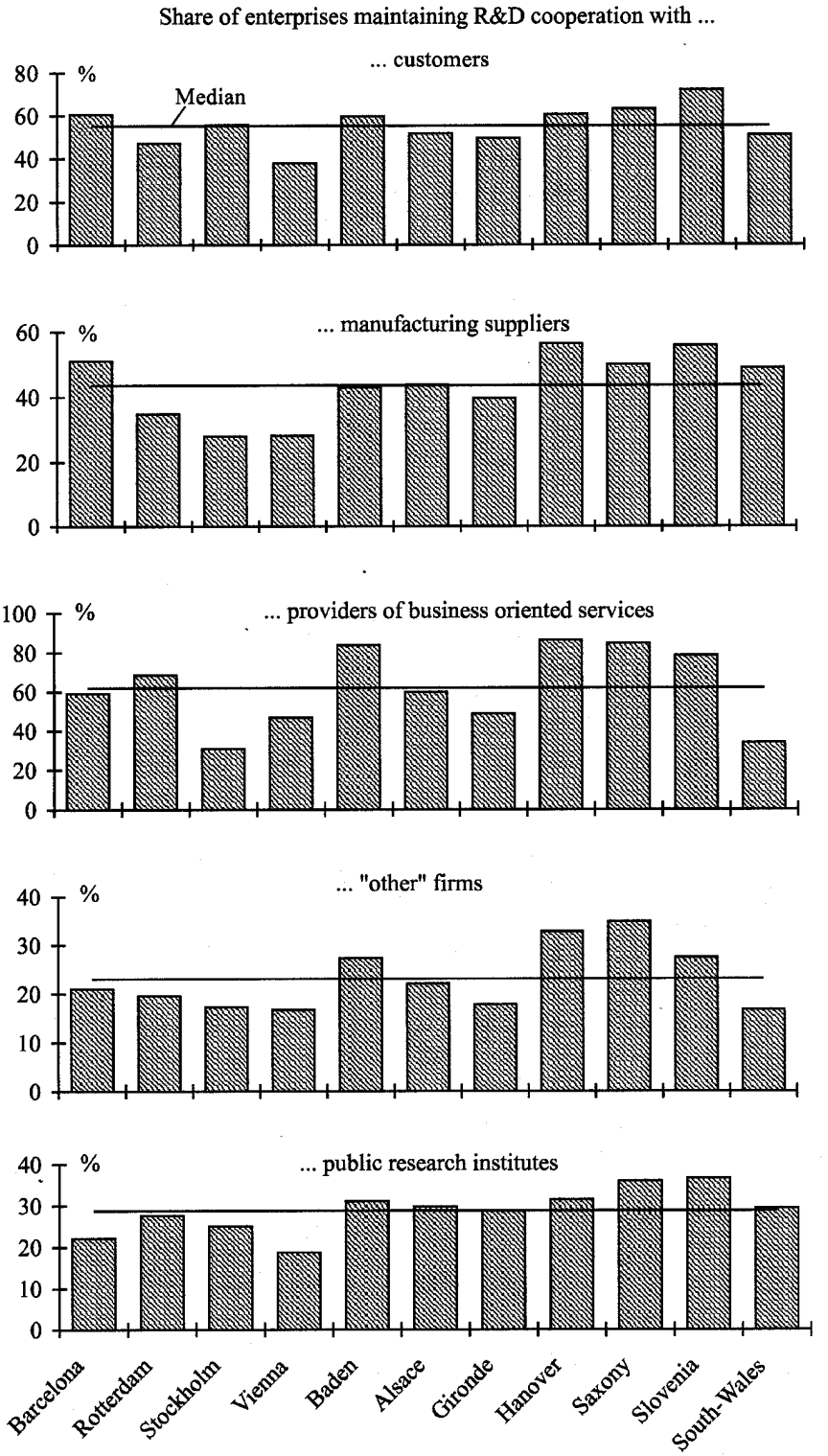
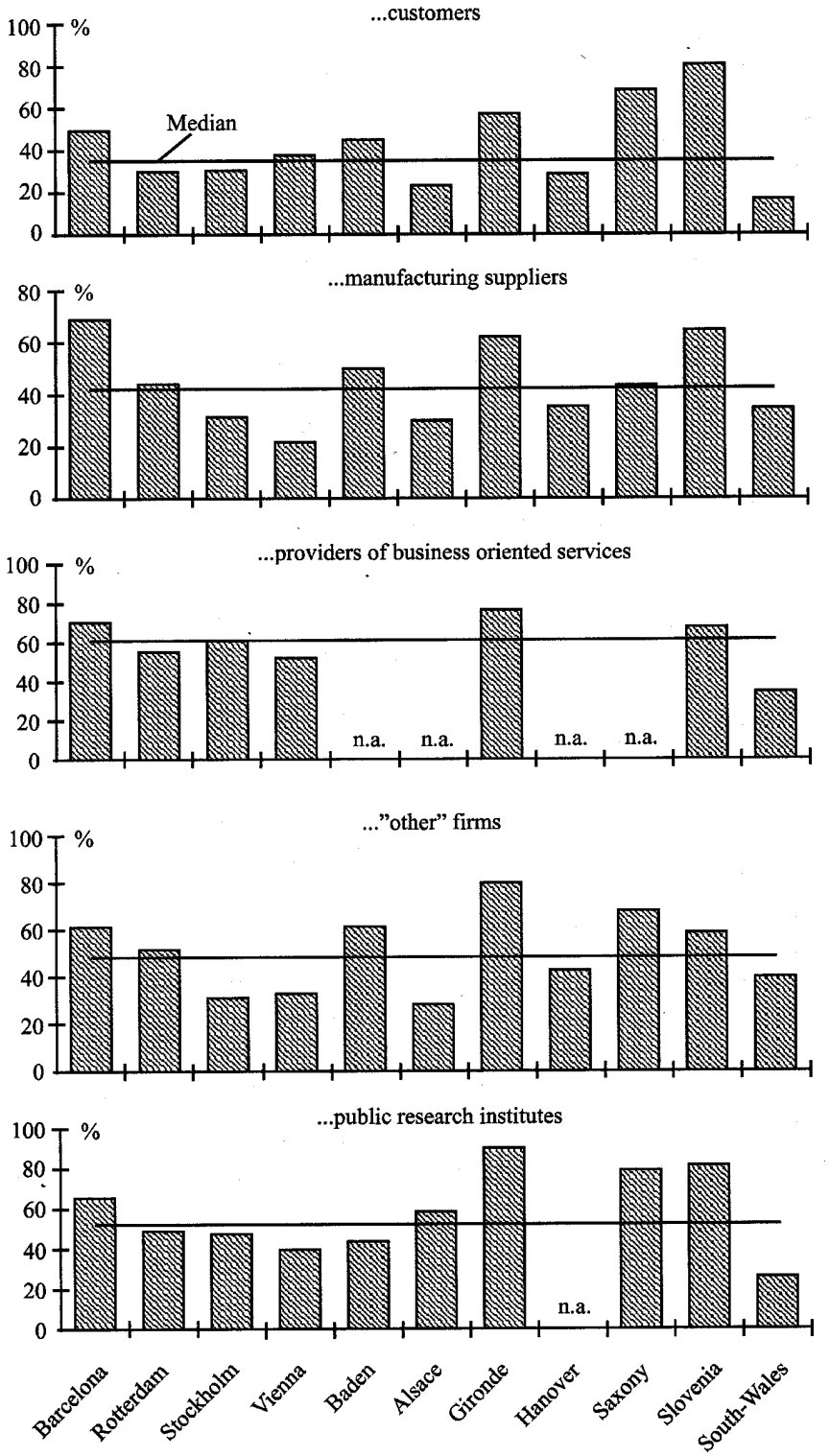


Figure 3: Share of cooperative relationships with actors located in the same region.



relationships with suppliers of business-oriented services, public research institutes, and "other" firms. This may be understood as an indication for relatively high importance of spatial proximity in establishing and maintaining cooperative relationships with these types of partners. If this interpretation is correct, then spatial proximity is of only relatively minor importance for cooperative relationships with customers and manufacturing suppliers because for these types of actors, the proportion of local partners is relatively low. One may, therefore, suspect that the presence of competitors, service providers, and research institutions in the region plays a more significant role as a locational factor for R&D activities than having customers and manufacturing suppliers located near by. Comparisons of the shares of cooperative relationships with partners in the same region between the case study areas may be problematic because of varying geographical size and economic potentials. Nevertheless, it is quite interesting that the proportion of local partners is not higher in the four urbanized regions of the sample that can be assumed to be characterized by a rich supply of opportunities to cooperate. Obviously, a high number of potential partners for cooperation in a region does not automatically lead to a correspondingly high degree of local networking.

Identifying differences between regions with regard to the share of enterprises that maintain a certain kind of cooperative relationship is not sufficient for concluding that there exist regional differences in the propensity of firms to have cooperative relationships. The reason is simply that the relatively high share of establishments with such cooperative relationships in a region could be the result of a correspondingly high share of establishments that possess characteristics of businesses that are likely to engage in R&D cooperation (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 cooperate it is, therefore, desirable to control for the effects of the characteristics of cooperating establishments by applying multivariate analyses. Hence, models for the propensity to maintain a least one cooperative 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 a certain region and 0 if not located in that region. The establishments in Baden were taken as 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 cooperate (depending on the sign of the respective coefficient) than establishments in the control group. 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.

Multivariate analysis

To analyse the impact of exogenous variables on the propensity to cooperate as well as on the number of cooperative relationships, a two-stage count-data hurdle model is applied here.[8] This model has two parts. The first part consists of a logit model,

8 See Winkelmann and Zimmermann (1995) for a detailed description of this kind of model.

which aims to explain whether the respective enterprise has at least one cooperative 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 cooperative relationship with a certain type of partner and analyses those factors that determine the number of such contacts. A major advantage of the logit-negbin hurdle model which is applied here over an ordinary count-data model is that it deals with the problem of "too many" zero values in the data compared with an ordinary Poisson distribution. This type of model is, therefore, in good accordance with the basic assumptions of the estimation procedure. The model also allows for differences with regard to the determinants of the decision to cooperate at all with a certain kind of partner and the factors that explain the number of such cooperative relationships. Assuming that the number of cooperative relationships results from a Poisson-like process, Poisson-regression analysis may be used as estimation method. However, negative-binomial (negbin) regression was applied here because it is based on somewhat more general assumptions than Poisson regression.[9]

The main characteristics of the establishments that proved to have a significant impact on cooperation behavior and that were controlled for in the empirical analysis are establishment size (measured as natural logarithm of the number of employees) and the share of R&D employees. The propensity to have at least one cooperative relationship as well as the number of cooperation partners tends to be relatively high for large enterprises and for enterprises with a high share of R&D employees. The influence of these two variables was more or less the same with regard to cooperative relationships for all the different partner types (see Fritsch and Lukas 2001 for details). This corresponds to the observation that a positive attitude towards R&D cooperation tends to be a phenomenon that is not restricted to one type of partner (cf. Figure 2). Twelve industry dummies were included into the models to control for industry-specific effects.[10] The estimated coefficients for the regional dummy variables indicate if the establishments in the respective region demonstrate 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.

As an example, Table 1 shows the results of logit-negbin analyses of the whole model for cooperative relationships to public research institutes. 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 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: 931-939).

10 A further variable that tends to be positively related with cooperation behavior is the existence of a "gatekeeper", who is screening the environment relevant for the innovation activity. Establishments that maintain R&D cooperation are also often characterized by a relatively high level of aspiration in their R&D activity. Furthermore, some types of cooperation seem to effect in a relatively low share of value added to turnover in the cooperating firms indicating the outsourcing of certain tasks that would otherwise have to be fulfilled within the enterprise itself. For details see Fritsch (2001a) and Fritsch and Lukas (2001). These variables were omitted here for two reasons. First, some of them were only available for a subsample of establishments. Second, a relatively high aspiration level in innovation activity, a low share of value added to turnover as well as the existence of a gatekeeper may not represent a cause, but a result of R&D cooperation and should, therefore, not be used as control variables.

TABLE 1: THE PROPENSITY TO COOPERATE WITH PUBLIC RESEARCH INSTITUTES—LOGIT-NEGBIN HURDLE MODELS[a]

	Yes/no (logit)	No. of relations (negbin)
Number of employees (ln)	0.735** (20.13)	0.226** (7.42)
R&D intensity (share of R&D employees)	0.043** (11.87)	0.023** (8.48)
Industry dummies:		
Food, beverages, and tobacco	−0.533** (2.58)	0.032 (0.17)
Textiles, clothing, leather	−0.414* (1.95)	0.016 (0.09)
Wood (excl. furniture)	−0.731** (2.77)	0.145 (0.59)
Paper, printing, publishing	−0.741** (3.61)	−0.105 (0.56)
Furniture, jewelry, musical instruments, toys	−1.156** (4.64)	−0.254 (1.06)
Mineral oil, chemicals	−0.303 (1.42)	0.400* (2.44)
Rubber and plastics	−0.494* (2.20)	−0.057 (0.26)
Stone, ceramics, and glass	−0.420 (1.88)	0.112 (0.56)
Metal products, recycling	−0.357* (2.13)	−0.103 (0.74)
Mechanical engineering	−0.053 (0.31)	0.292* (2.22)
Vehicles	−0.585** (2.65)	−0.271 (1.42)
Data processing, electrical, and electronic equipment	−0.342 (1.82)	−0.221 (1.38)
Regional dummies:		
Barcelona	−0.389* (2.04)	0.245 (1.443)
Rotterdam	−0.311 (0.21)	0.158 (0.88)
Stockholm	−0.205 (1.14)	0.322 (0.96)
Vienna	−0.839** (3.47)	−0.133 (1.58)
Alsace	0.041 (0.21)	−0.005 (0.03)
Gironde	0.411 (1.48)	−0.578 (0.147)
Hanover	−0.443* (2.51)	n.a.
Saxony	0.461** (3.24)	−0.146 (1.38)
Slovenia	−0.034 (0.20)	−0.126 (0.87)
South Wales	−0.083 (0.43)	0.372* (1.98)
Model summary:		
Alpha	—	0.396**
Chi-square for covariates	687.77	205.90
Significance of chi-square	0.00	0.00
Pseudo $R^2_{adj.}$	0.150	0.072
Number of cases	3,690	648

[a]Estimated logit-negbin coefficients. Asymptotic, absolute *t*-values in parentheses.
*Statistically significant at the 5 percent level.
**Statistically significant at the 1 percent level.

Like in nearly all estimations, the size of the respective enterprise (number of employees) and R&D intensity (the share of R&D employees) prove to be highly significant with a positive sign at both stages of the model. The strong association between size and R&D cooperation corresponds well with the results of other studies (e.g. Fusfeld and Haklisch 1985; König *et al.* 1994). This size effect may have a rather simple explanation. If the probability of R&D cooperation is related to the amount of value added, then the propensity for a certain enterprise to have at least one cooperative relationship rises with its size. The positive impact of the share of R&D employees indicates that the need for cooperation increases with R&D intensity in the respective enterprise. That many of the industry dummies have a negative sign suggests 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 cooperation with public research institutions.

Table 2 shows the results for the regional dummy variables in the models with all the different partner types. Information concerning Barcelona, Rotterdam, Stockholm, and Vienna, the four regions that are dominated by large cities (the "centers"), is grouped in the upper part of the table to make identification of the special characteristics of these regions easier. There is a remarkably high number of significant differences in cooperation behavior between the regions. Obviously, regions differ considerably in this respect. A relatively high share of those dummy variables that prove to be statistically significant show a negative sign. This confirms the supposition that enterprises located in Baden (the reference group in the estimates) are characterized by a relatively positive attitude towards cooperation (see Sabel *et al.* 1989; Semlinger 1993; Heidenreich and Krauss 1998). The two regions in our sample that were formerly under socialist regimes, Saxony and Slovenia, are striking exemptions from this pattern. Many of the coefficients of the dummy variables for these two regions assume highly significant positive values in the first part of the model (yes/no). One could have expected negative signs here for two reasons. First, these regions do not represent "centers" characterized by a rich supply of cooperation partners. And second, the transformation to a market driven system that took place in these regions since the early 1990s led to a destruction of many of the "old" networks there, and many such relationships, often based on personal contacts, had to be established anew (cf. Albach 1994, for a detailed analysis). However, the dummy variables for these regions often show a negative sign in the second part of the model concerning the number of cooperative relationships. This may serve as an indication of the problems and costs that are involved in establishing network relationships.

Another remarkable result of the analyses summarized in Table 2 is that most of the coefficients for location in those regions in our sample that are dominated by large cities (Barcelona, Rotterdam, Stockholm, and Vienna), we find negative signs. This suggests that being located in a region that provides a rich supply of intra-regional contact opportunities alone is not particularly stimulating for R&D cooperation.

Concluding Remarks

The empirical analyses conducted here revealed a number of pronounced differences between regions with regard to the propensity to maintain a cooperative relationship. Obviously, regions differ with regard to cooperation behavior independent of size structure, R&D intensity, and industry structure of the enterprises located there. The reasons for these differences remain, however, largely unclear.

One main result of the empirical analysis is that a positive attitude towards cooperation tends to be a general phenomenon that is not limited to a certain type of partner. Establishments that have a cooperative relationship with a certain partner type are also quite likely to cooperate with other kinds of actors. Remarkably, the propensity to maintain a cooperative relationship with a certain type of partner tends to be relatively high in the two regions of our sample that have experienced a transformation from a socialist system to a market economy in the last years (Saxony

TABLE 2: REGIONAL DIFFERENCES OF COOPERATION BEHAVIOR: RESULTS FOR REGIONAL DUMMY VARIABLES

	Cooperative relationship with:									
	Customers		Manufacturing suppliers		Service firms		"Other" firms		Research institutes	
Region	Yes/no	Number	Yes/no	Number	Yes/no	Number	Yes/no	Number	Yes/no	Number
Barcelona	−0.09	*0.67***	0.28	−0.16	*−1.23***	*−0.44**	*−0.47**	*−0.81***	*−0.39**	0.25
Rotterdam	*−0.60***	*−0.52**	*−0.47**	*−0.62***	*−0.53**	Contr.	*−0.64***	−0.36	−0.31	0.16
Stockholm	−0.05	*−1.04***	*−0.58***	*−1.47***	*−2.51***	*−1.09***	*−0.54***	*−0.66***	−0.20	0.13
Vienna	*−0.83***	0.17	*−0.73***	−0.44	*−1.81***	*−0.57***	*−0.72***	−0.16	*−0.84***	0.32
Alsace	−0.19	*0.71***	0.09	−0.01	*−1.27***	n.a.	−0.2	−0.26	0.04	−0.01
Gironde	−0.11	*−2.32***	−0.01	*−1.64***	*−1.53***	−0.72	−0.43	−0.48	0.412	−0.58
Hanover	−0.12	−0.3	*0.37**	*−0.37**	0.05	n.a.	0.15	0.04	*−0.44**	n.a.
Saxony	*0.25**	*−0.44***	*0.32***	*−0.33**	0.2	n.a.	*0.45***	−0.11	*0.46***	−0.15
Slovenia	*0.44***	−0.12	*0.32**	−0.16	*−0.5***	0.14	*−0.13**	−0.2	−0.03	−0.13
South Wales	*−0.43**	−0.21	0.23	−0.23	*−2.36***	*−0.58**	*−0.57***	−0.00	−0.08	*0.37**

*Statistically significant at the 5 percent 1 level.
**Statistically significant at the 1 percent level.
n.a. = no data available; 2 Contr. = region is the control group in the respective estimate.

and Slovenia). This finding was rather unexpected because the transformation process has led to the destruction of many old established networks so that many cooperative relationships of establishments in these regions had to be built up anew. Another noteworthy result is that no relatively high propensity for R&D cooperation could be found for establishments located in highly urbanized regions ("centers") with a rich supply of potential cooperation partners.

A starting point of the analysis was the recognition that differences in the propensity to cooperate constitute a prerequisite for explaining diverging performance of regional innovation systems with factors like innovation networks and intensity in the division of labor. However, empirical analyses of the relationship between cooperation behavior and the quality of the innovation system in the respective region provide no support for the suggestion that cooperation or a relatively pronounced cooperative attitude in a region is conducive to innovation activity (see Fritsch and Franke 2000; Fritsch 2001b). Our sample of regions contains impressive counter-examples for such a hypothesis, i.e. regions that are characterized by a relatively low/high propensity to cooperate on R&D and high/low efficiency of innovation activities (e.g. Vienna and Slovenia). Obviously, a simple "cooperation is good for innovation" hypothesis is too crude to meet the complexity of reality. Hence, the effects of the different forms of innovative labor division on R&D activities should be explored in more detail.

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