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# **Joint knowledge generation in European R&D networks: Results from a latent regression - index function model**

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**Abstract.** The objective of this study is to explore the determinants of inter-organisational knowledge generation within European networks of R&D collaboration. It is argued that social capital is a key determinant for successful knowledge generation. Thus, factors that are conducive for the development of social capital like geographical proximity, collaboration duration and intensity are expected to have a positive influence on inter-organisational knowledge generation. Determinants of inter-organisational knowledge generation are investigated by casting a probit model in the form of a latent regression - index function model. Units of analysis are dyads of organisations that jointly participated in projects of the Fifth EU Framework Programme (FP5). The data used in this study derives from a survey among FP5 participants and the EUPRO database. Our findings suggest that crossing national border has a significant positive rather than negative effect on the generation of scientific knowledge [measured in terms of co-publications]. This can be attributed to the participation rules and proposal selection procedures of the Framework Programmes. Another important result is that university-university dyads have the highest probability not only to jointly generate scientific knowledge, but also to jointly generate knowledge that resulted in commercial outcome. In contrast, industry-industry dyads show a low probability for both types of knowledge generation. This result is probably due to the fact that inter-organisational knowledge generation entails disclosure of knowledge, which is actually a task of universities but problematic for industry organisations.

**JEL classification:** O38 C25 L14 D89

**Key words:** EU Framework programmes, R&D collaboration, R&D productivity, probit

## 1 Introduction

New growth theory suggests that innovation is the major engine of economic growth and competitiveness (see, for instance, Romer 1990). Since scientific and technological knowledge is regarded as the major input for innovation, the competitiveness of an economy depends on its ability to generate new knowledge. Generation of knowledge is a social process and, therefore, the performance of an economy to generate knowledge crucially depends on successful cooperation between involved actors not only on the individual, but also on the organisational level (see, for instance, Lundvall 1992). Since markets lack the necessary long-term commitment for the transfer of tacit knowledge, networks are an increasingly important mode of cooperation for inter-organisational R&D activities (DeBresson and Ammesse 1991, Powell 1990, Powell and Grodal 2005). A major R&D network in Europe is the network created by the European Framework Programmes [FPs]. The FPs are the main instrument of the EU's R&D policy and are designed to support collaborative R&D projects including actors from distinct organisational types and different countries. Recently, several studies have been published in regard to R&D partner choices (Paier and Scherngell 2011, Scherngell and Barber 2009, Autant-Bernard et al. 2007) and joint knowledge generation (Hoekman et al. 2009, Maggioni et al. 2007) in Europe and the FPs.

This study contributes to the existing literature by investigating the determinants of inter-organisational knowledge generation within the FP network. By using dyads of organisations that jointly participated in a project of the Fifth Framework Programme [FP5] as units of analysis, this study distinguishes itself from previous studies by focusing on the organisational level and not on the regional level. The data for carrying out this study is taken from a survey among FP5 participants and the EUPRO database. Determinants of inter-organisational knowledge generation are investigated by employing a probit model derived from a latent regression.

Although FP projects are supposed to generate scientific knowledge as a direct output of the project, it is stipulated by the participation rules that the results should be exploitable for commercial purposes. Thus, this study distinguishes between two types of inter-organisational knowledge generation: scientific knowledge and commercially relevant knowledge generation. Scientific knowledge generation is measured in terms of co-authored publications, while commercially relevant knowledge generation in terms of co-owned commercial outcome [irrespective of how the outcome has been materialized].

The remainder of this paper is organised as follows. Section 2 provides an overview of the goals, participation rules and proposal selection procedures of the FPs because it can be assumed that they have an influence on the pattern of inter-organisational knowledge generation. Section 3 identifies social capital and the ability to coordinate researchers from different organisations as key determinants of inter-organisational knowledge generation. Considerations are made how geographical separation and different organisational types of cooperation affect social capital and coordination problems and thereby influence inter-organisational knowledge generation. Section 4 describes the sample and the construction of variables in detail. Section 5 outlines the econometric model to be used and presents the estimation results. Section 6 concludes.

## **2 The EU Framework Programmes**

The FPs are recurrent mid-term research programmes that subsidy collaborative R&D projects linking partners from different countries and organisational types. The overall goal of the FPs is to strengthen the scientific and technological bases of European industry and to enhance its international competitiveness. Moreover, the FPs aim at fostering European market integration and regional income convergence by establishing common technological standards, increasing the mobility of researchers and promoting the dissemination of knowledge. Thus, the FPs can be seen as an important instrument for the implementation of EU policy beyond the area of science and technology (Stajano 2006, pp 289-305). Since its establishment in 1984, seven FPs have been launched. Despite shifting thematic areas and instruments, the fundamental rationale of the FPs has remained unchanged, namely to support collaborative, pan-European research that involves different actors from scientific and the private sector (Roediger-Schluga and Barber 2007). This study relies on the Fifth Framework Programme [FP5], 1999 to 2002.

There is a set of participation rules stipulated by the European Commission, which shapes the structure of collaboration within FP5. The majority of proposals were subject to the following participation rules (European Council 1998). *First*, proposals had to be handed in by self-organized consortia. *Second*, the consortia had to consist of at least two mutually independent

legal entities. *Third*, the consortia had to include legal entities from at least two different member states or one member state and one associate state<sup>1</sup>.

Proposals handed in were evaluated by a panel of independent experts on the basis of a set of criteria defined by European Council decision. The final decision about which projects were funded and which were rejected rested with the European Commission. Proposals should have met following criteria (European Commission 2001). *First*, high quality of research and high degree of innovation; *second*, added-value by carrying out the project at the European level and by combining complementary expertise of different types of organisations<sup>2</sup>; *third*, contribution to one or more EU policies, e.g. cohesion, or to the goals of the horizontal subprogrammes; *fourth*, the usefulness and range of applications, the quality of the exploitation plans and dissemination strategies for the expected results, and *finally* the quality of the partnership, i.e. adequate complementarity of the partners and a reasonable division of tasks within the consortium.

Since the FPs involve subsidies for organisations from the private sector, there is a potential for thwarting the competition policy of the EU. In order to avoid distortion of the common market, the FPs are restricted to pre-competitive research, i.e. research that is sufficiently distant to the market in order to avoid distortion of competition on product markets (Guzetti 1995, pp 77-78). Some studies came to the conclusion that organisations can materialise commercial outcome from participating in the FPs already in a short time after the termination of a FP project because they link the FP project with other in-house projects (Guy et al. 2005, Luukkonen and Hälikkää 2000, Matt and Wolff 2003). Moreover, exploitation-related goals were the major motivation of industry organisation for participating in FP5 (Guy et al. 2005). Thus, this study will not only focus on scientific knowledge as an outcome of explorative research but also on commercially relevant knowledge as an outcome of exploitative research.

### **3 Potential determinants of inter-organisational knowledge generation**

Inter-organisational knowledge generation primarily involves sharing and combining knowledge that is held by [at least two] different organisations (Moran and Ghoshal 1996). Two conditions have to be fulfilled in order that inter-organisational knowledge generation in networks can take place. *First*, the organisations must decide that they want to enter into a

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<sup>1</sup> Associated states in the context of FP5 were Bulgaria, Republic of Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta [since 2001], Poland, Romania, Slovakia, Slovenia, Iceland, Liechtenstein, Norway and Israel.

<sup>2</sup> Results of Barajas and Huergo (2010) suggest that consortia that consist of an equal presence of private and public organisations had a higher probability for being accepted.

network relation in order to share and combine knowledge. *Second*, knowledge has to be successfully shared and combined so that novel knowledge [or a novel combination of already existing pieces of knowledge] may be generated. The first condition boils down to the question about determinants of collaboration choices, which has been already investigated for the FPs (see, for instance, Autant-Bernard et al. 2007, Paier and Scherngell 2011), the investigation of the second condition is the topic of this study.

Successful sharing and combining of knowledge depends on the willingness of organisations to share knowledge and on the capacities of organisations to absorb knowledge. The willingness to share and the capacity to absorb knowledge is positively influenced by social capital. Social capital refers to resources that evolve from networks of relationships over time by repeated interactions (Nahapiet and Ghoshal 1998). Since social capital exists only between individuals, it cannot be appropriated by one individual but is collectively owned (Coleman 1988). Social capital is conducive for sharing and absorbing knowledge by providing resources like trust, shared norms, shared goals, shared language and shared mental models. Von Hippel (1987) observed in his qualitative study about US steel mini-mill producers that knowledge was shared even with competitors because it was trusted that this will be rewarded in the long run by reciprocal behaviour. A quantitative analysis about R&D consortia in Taiwan conducted by Lin et al. (2009) provides evidence that trust, shared norms and shared goals influence knowledge transfer positively.

Since transfer of tacit knowledge is costly, not all knowledge that might be necessary for inter-organisational knowledge generation is shared (Grant 1996). A great part of the necessary knowledge is combined by coordinating people, in whom tacit knowledge is embedded, to build up common capabilities for knowledge generation. Building up common capabilities for knowledge generation is difficult since this requires complex modes of cooperation. Simple modes of coordination like coordination by rules and standards or coordination by planning are not feasible because generation of knowledge involves high uncertainty and task interdependence (Kline and Rosenberg 1986, van de Ven et al. 1976). Thus employees have to be coordinated by complex modes of cooperation like mutual adjustment and group meetings (Grant 1996). Resources derived from social capital like shared goals or shared understandings facilitate complex coordination problems (Hämäläinen and Schienstock 2001).

### ***Collaboration duration and intensity***

Since social capital and common capabilities are built up by repeated interactions, it can be expected that duration of collaboration and the intensity of collaboration are crucial determinants for successful inter-organisational knowledge generation.

### ***Geographical separation***

It is widely believed that geographical separation is detrimental to inter-organisational knowledge generation for three reasons (see Boschma 2005). *First*, geographical separation complicates repeated face-to-face communication which is regarded as important for the development of social capital. *Second*, geographical separation is often negatively correlated with cultural proximity which provides potential research partners with an already existing stock of social capital in the form of shared languages and shared norms. *Third*, geographical separation also makes complex coordination more difficult since it complicates mutual adjustment and group meetings (van de Ven et al. 1976). The majority of studies confirm the negative relationship between geographical separation and the occurrence of R&D collaboration (Katz 1994, LeSage et al. 2007, Maggioni and Uberti 2009, Paier and Scherngell 2011, Scherngell and Barber 2009).

Some authors question that the proposition about the negative relationship between geographical separation and inter-organisational knowledge generation is universally valid. Bathelt et al. (2004) argue that firms are only innovative in the long run if they maintain a balance between geographically separated and geographically close R&D collaborations because geographical separated collaborations are necessary to acquire new knowledge while close collaborations are necessary to exploit new knowledge. Torre and Rallet (2005) point to the fact that organisations need not be co-localized for close R&D collaboration since people are mobile. Often, co-localisation is not necessary for the whole duration of a joint research project and short- or medium term visits are sufficient. Moreover, large organisations can afford to relocate a part of the R&D staff for the duration of joint collaboration projects. Another differentiated view was presented by Moodysson et al. (2008). They distinguish between two modes of inter-organisational knowledge generation: synthetic knowledge generation and analytical knowledge generation. While geographical separation has a negative influence on synthetic knowledge generation, it is less detrimental to analytical knowledge generation. Analytical knowledge generation is highly formalized and is mainly carried out by a process of theory-led deduction and subsequent hypothesis testing. Since the primary type of knowledge involved is know-why, primarily codified knowledge is exchanged. Often,

activities related to analytical knowledge generation are only of sequential interdependence which entails only simple coordination problems. An example for inter-organisational analytical knowledge generation is the conducting of a clinic study by a research hospital on behalf of a pharmaceutical research company.

Although geographical separation might complicate the development of social capital and common capabilities, we argue that the design of the FPs offset the negative influence of geographical separation on inter-organisational knowledge generation for several reasons. *First*, the division of labour in the FPs is highly formalized because of pre-defined work packages, ex ante agreements on meetings and milestones (Matt and Wolff 2003). Thus, it can be expected that research conducted within the FPs resembles an analytical mode of knowledge generation. *Second*, the participation rules and goals of the FPs ensure that the FPs are an explorative and an international research network (see section 2). *Third*, since the support of the mobility of researchers is one of the main instruments of the FPs, it can be expected that increased mobility of researchers substitute for a lack in co-location of organisations. *Fourth*, the legal framework provided by FPs partly substitutes for a lack of cultural proximity and social capital (Luukkonen 2001).

### ***Organisational types of cooperation***

One objective of the FPs is to stimulate collaborations between the scientific sector [in particular universities and public research organisations] and the private sector [in particular R&D laboratories of industry organisations]. Since the scientific sector and the private sector carry out complementary tasks within the innovation process, interaction between the scientific sector and the private sector is regarded as conducive for innovation and economic development (see, for instance, Mowery and Rosenberg 1993). However, collaboration between the scientific sector and the private sector is often difficult since the two sectors pursue different goals and share different cultures (Ponds et al. 2007). A major aim of scientific organisations is to generate new knowledge and share this knowledge with the scientific community by publications in order to increase reputation. Private organisations, by contrast, regard knowledge generation as a means to generate profit by reaping Schumpeterian rents and thus are highly interested in keeping knowledge secret. Moreover, they are to a lesser degree than scientific organisations interested in explorative research activities and are more interested in exploiting existing knowledge. Thus, although collaborations between scientific and private organisations are important for innovation and economic development,



R&D collaborations can be expected to have a low productivity for inter-organisational knowledge generation because of differences in goals and culture.

#### **4 Variables and data**

Two data sources are used in this study, namely, the EUPRO database and a survey among FP5 participants conducted by AIT in 2007. The EUPRO database is constructed and maintained by revising and standardizing raw data obtained from the CORDIS<sup>3</sup> project database. It contains detailed information on funded projects and project participants of the EU Framework Programmes (for the first six see Barber et al. 2008). The survey restricted its population to projects involving less than 21 participants which applies to roughly 97% of all collaborative projects in FP5. 12,892 questionnaires were sent by email, from which 8,534 were received. The survey resulted in 1,686 valid questionnaires. Since a full data set in the EUPRO database is missing for 472 cases, only 1,214 questionnaires are used in this study.

Since the objective of this study is to explore the factors that are responsible for the fact that collaboration results in successful inter-organisational knowledge generation, the units of analysis has to be a form of inter-organisational collaboration. Following previous studies collaboration is considered if two organisations participate in the same FP5 project (see, for instance, Autant-Bernard et al. 2007, Paier and Scherngell 2011). Thus, the units of analysis in this study are dyads of organisations that jointly participated in a FP5 project. The full sample consists of 7,776 dyads, which are formed by a set 3,343 distinct organisations that collaborated in 861 distinct FP5 projects.<sup>4</sup>

The area of analysis is formed by 23 countries. All EU members at the time of the FP5 [i.e. the EU15] as well as the Central East European candidate countries that joined EU in 2004 are included. Table A1 in the Annex gives an overview about the distribution of distinct organisations and participations, disaggregated by country.

#### ***Dependent variables***

Measuring knowledge generation is difficult since generated knowledge exists initially in the mind of those who generated it and is thus not directly observable (Fischer 2001). However, if the generated knowledge is scientifically or commercially valuable, one can expect that it

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<sup>3</sup> Community Research and Development Information Service, <http://cordis.europa.eu/>

<sup>4</sup> In order to increase the sample size from a few hundred dyads to 7,776 dyads, a reciprocity assumption has been made to construct the variables taken from the survey, i.e. we trusted relational data reported by one member of the dyad without a confirmation from the other partner of the dyad. The reciprocity assumption is a well-accepted assumption in regard to the analysis of social networks (Knoke and Yang 2008)

materializes in observable outcomes. This study relies on survey questions to capture outcomes of inter-organisational knowledge generation. Scientific knowledge generation is measured in terms of the occurrence of co-authored publications, and commercially relevant knowledge is measured in terms of co-owned commercial outcome. Each fifth dyad reported scientific knowledge generation; commercially relevant knowledge generation is by far less evident.

### ***Independent variables***

In section 3, we have argued that collaboration duration, collaboration intensity, geographical separation and organisational types of cooperation influence inter-organisational knowledge generation. Two variables are constructed to account for the time that is necessary for developing social capital: *project duration* and *previous collaboration*. *Project duration* is measured in terms of the duration of the FP5 project [in months] in which the members of the dyad jointly participated. *Previous collaboration* is taken as a dummy variable into account that equals one if the partners of the dyad had collaborated together in a previous FP project. Intensity of collaboration is represented by the variable *important research collaboration*, with information from the survey, and designed as a dummy variable that equals one if at least one dyad partner classified the other as an important research partner.

Two types of geographical barriers are included as independent variables: the existence of *national borders* and of *EU's external border*, designed as dummy variables. The variable *national border* equals one if the organisations forming the dyad are located in different countries. The variable *EU's external border* equals one if one organisation of the dyad is located in the EU15 and the other in a Central East European candidate country.

The sample includes four organisational types: industry organisations [including consulting firms], universities, public research organisations and government organisations. Since there are few government organisations, only dummy variables for combinations of universities, research organisations and industry organisations were created. Thus, there are six dummy variables: *university – university*, *university – research organisation*, *industry – university*, *industry – industry*, *industry – research organisation*, *research organisation – research organisation*. Dyads that include government organisations take on the role of a default dummy.

### *Control variables*

Collaboration is measured in terms of joint FP project participation. This measurement approach works well for small FP projects, but in large FP projects it is unlikely that every participant collaborated directly with every participant (Fürlinger 2010). In order to control for this shortcoming, the variable *project size*, measured in terms of number of project participants, is included as a control variable.

**Table 1: Descriptive statistics for the variables used**

	Project duration [in months]	Project size [number of project members]	EU project funding [in million €]
Minimum	4	2	0.01
First quartile	24	8	0.41
Median	36	10	0.76
Third quartile	36	13	1.03
Maximum	60	20	3.23
Mean	31.34	10.74	0.80
Standard deviation	8.49	3.58	0.48

### **Frequency of the dummy variables in the sample**

Previous collaboration (yes = 1)	22%
Important research collaboration (yes = 1)	33%
National border (yes = 1)	81%
EU's external border (yes = 1)	8%
University – university collaboration (yes = 1)	13%
University – research organisation collaboration (yes = 1)	15%
Research organisation – research organisation collaboration (yes = 1)	7%
Industry organisation – university (yes = 1)	18%
Industry – research organisation collaboration (yes = 1)	18%
Industry – industry (yes = 1)	22%
Intent to generate scientific knowledge (yes = 1)	58%
Intent to generate commercially relevant knowledge (yes = 1)	46%

Although the focus of this study is on relational characteristics, internal capacities of the organisations forming the dyad might also have an influence on knowledge generation. Since no information like budget, R&D personnel is available, proxy variables had to be used. *EU funding* devoted to the FP5 project, in which the organisations of the dyad jointly participated, serves as proxy for the monetary resources available for generating scientific or commercial relevant knowledge. The commitment of an organisation to scientific or commercially relevant knowledge generation may have also an impact on the resources available for these activities. Thus, we include two further dummy variables that take the organisations' motive for participating in FP5 into account. The first dummy variable equals one if the intent of at least one member of the dyad was to generate scientific knowledge. The second dummy

variable equals one if the intent of at least one member of the dyad was to generate commercially relevant knowledge. Both dummy variables were taken from the survey.

Table 1 summarises descriptive statistics about the variables. See also the appendix for the definition of the variables. See also the appendix for the definition of the variables and for a correlation analysis of the independent variables.

## 5 The econometric model and empirical results

Since the dependent variable  $y^*$  [inter-organisational knowledge generation] is measured by its dichotomous realisations  $y$  [observable outcomes], the appropriate econometric model is a binary response model which can be derived from a latent regression – index function model (Verbeek 2004). By assuming a linear additive relationship between inter-organisational knowledge generation and a set of explanatory variables we obtain the following latent regression:

(1)

where  $y^*$  denotes a  $n$ -by-1 vector of latent indices of knowledge generation for  $n=7,776$  dyad observations,  $X$  denotes a  $n$ -by- $K$  matrix including a constant and  $K-1$  explanatory variables,  $\beta$  denotes a  $K$ -by-1 vector of parameters to be estimated, and  $\varepsilon$  a  $n$ -by-1 random error term symmetrically distributed about the mean.  $\beta X$  is called the index function (Green 2008).

Inter-organisational knowledge generation is not directly observable but its outcomes. Thus, we define a link between inter-organisational knowledge generation  $y^*$  and the binary outcomes  $y$ .

$y$  (2)

where  $\alpha$  is a threshold that has to be surpassed in order that the generated knowledge results in an observable outcome. Since the value of the threshold has only an influence on the value of the intercept in the regression model, the threshold value is set equal zero for sake of simplicity (Greene 2008, p. 776).

Binary response models derived from a latent regression explain the probability of an event occurring dependent on the explanatory variables in the latent regression  $X$ .

(3)

where  $F(\cdot)$  denotes the cumulative distribution function of  $\varepsilon$ . Consequently, the latent variable approach leads to a binary choice model whose form depends upon the distribution that is assumed for  $\varepsilon$  (Verbeek 2004). Since we assume  $\varepsilon \sim N(0,1)$ , a probit model is specified:

$$\dots = \dots \quad (4)$$

where  $\Phi(\cdot)$  denotes the standard normal cumulative distribution function. The parameter estimates are derived by maximum-likelihood estimation (Greene 2008, pp. 777-779).

### ***Empirical results***

Table 2 presents the maximum likelihood [ML] parameter estimates for inter-organisational knowledge generation, asymptotic standard errors in parentheses. For scientific knowledge generation three different models were estimated. The basic version [model 1] includes the full sample of 7,776 dyads, while model 2 uses a sample of 2,627 dyads, which consist only of universities and research organisations, and model 3 uses a sample of 4,729 dyads involving at least one industry organisation. The model for commercially relevant knowledge generation uses the full sample of 7,776 dyads. The bottom of Table 2 provides various model fit measures. The likelihood ratio statistic that compares the estimated models with the constant-only null model indicates the significance of all models at the 0.01 significance level.

As expected, intensity and duration of collaboration increase the probability of both types of knowledge generation. Holding all other variables at their sample mean, previous collaboration increases the probability that inter-organisational scientific [commercially relevant] knowledge generation occurs by 8.3 [0.6]<sup>5</sup> percentage points. An increase of the project duration from four months [the minimum in the sample] to 60 months [the maximum in the sample] increases the probability that inter-organisational generation of scientific knowledge and commercially relevant knowledge occurs by 13 and 5.3 percentage points, respectively. Thus, relative to project duration, previous collaboration is less important for generating commercially relevant knowledge inter-organisationally than for generating scientific knowledge inter-organisationally.

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<sup>5</sup> For comparison, according to the full sample models, the probability of a dyad to generate knowledge inter-organisationally is 14.7% for scientific knowledge, 1.6% for commercially relevant knowledge.

**Table 2: ML estimates of the models for inter-organisational knowledge generation**

Variables	Scientific knowledge generation			Commercially relevant knowledge generation
	Model 1 [n=7,776]	Model 2 [n=2,627]	Model 3 [n=4,729]	[n=7,776]
Constant	-1.560*** (0.129)	-0.875*** (0.190)	-2.012*** (0.219)	-3.196*** (0.246)
<i>Collaboration duration and intensity</i>				
Previous collaboration	0.360*** (0.041)	0.324*** (0.065)	0.430*** (0.057)	0.136* (0.077)
Project duration [in months]	0.011*** (0.002)	0.006* (0.004)	0.015*** (0.003)	0.021*** (0.004)
Important research collaboration	0.924*** (0.037)	1.055*** (0.059)	0.862*** (0.051)	0.391*** (0.069)
<i>Geographical separation</i>				
National border	0.087* (0.048)	0.195** (0.092)	0.025 (0.060)	-0.059 (0.083)
EU's external border	0.176*** (0.065)	0.119 (0.092)	0.304*** (0.098)	0.130 (0.118)
<i>Organisational types of cooperation</i>				
University – university	0.573*** (0.087)	0.184** (0.081)		0.417** (0.165)
University – research organisation	0.404*** (0.086)	0.031 (0.080)		0.325** (0.162)
Research organisation – research organisation	0.382*** (0.099)			-0.101 (0.220)
Industry organisation – university	0.272*** (0.085)		0.539*** (0.172)	0.208 (0.160)
Industry organisation – research organisation	0.156* (0.086)		0.428*** (0.173)	0.097 (0.163)
Industry organisation – industry organisation	-0.007 (0.086)		0.276 (0.173)	0.152 (0.159)
<i>Control variables</i>				
Project size [number of participants]	-0.080*** (0.006)	-0.085*** (0.009)	-0.080*** (0.008)	-0.020* (0.010)
Intent to generate scientific knowledge	0.345*** (0.045)	0.274*** (0.076)	0.339*** (0.059)	0.167** (0.077)
Intent to generate commercially relevant knowledge	-0.080* (0.043)	-0.143** (0.074)	-0.047 (0.057)	0.532*** (0.079)
EU project funding [in million €]	0.187*** (0.043)	-0.013 (0.078)	0.295*** (0.053)	-0.040 (0.080)
Log-likelihood	-3084.364	-1262.162	-1640.875	-781.831
BIC	0.812	0.997	0.722	0.220
Likelihood ratio test (df=15)	1599.091***			140.351***
Likelihood ratio test (df=11)		637.894***		
Likelihood ratio test (df=12)			773.350***	

Notes: Probit transformation of the dependent variable was used. The default dummy for organisational types of cooperation in the scientific knowledge generation models 1 and 3 as well as in the commercially relevant knowledge model are dyads involving government organisations. The default dummy for organisational types of cooperation in the scientific knowledge generation model 2 are dyads of the type research organisation – research organisation. Asymptotic standard errors are given in parentheses; \*\*\* significant at the 0.01 significance level, \*\* significant at the 0.05 significance level, \* significant at the 0.1 significance level.

The classification of a dyad as an important research collaboration by at least one member of the dyad was used as a proxy for collaboration intensity. Table 2 shows that important research collaboration is by far the most important determinant for scientific knowledge generation. If a dyad is classified to indicate important collaboration the probability to generate scientific knowledge increases by 23.9 percentage points, on average. Important research collaboration has also a strong influence on commercially relevant knowledge generation. The classification of a dyad partner as an important research partner increases the probability that the dyad generates commercially relevant knowledge by 1.8 percentage points.

University–university dyads have the highest probability of generating scientific knowledge, while dyads that involve only industry organisations the lowest. Switching from a university–university dyad to a dyad that includes a research organisation and an industry organisation decreases the probability of co-publishing by 10.5 percentage points. The only two dyad types that have a significant positive impact on generation of commercially relevant knowledge are university-university dyads and dyads that consist of a university and a research organisation. Thus, dyads involving industry organisations do not have a significant influence on commercially relevant knowledge generation.

How can it be explained that industry organisational cooperations are not at the forefront of commercially relevant knowledge generation?<sup>6</sup> A likely explanation is that industry organisations do generate commercially relevant knowledge, as found by several studies (Luukkonen 2001, Guy et al. 2005, Matt and Wolff 2003), but not inter-organisationally because they fear negative knowledge spillovers of critical commercially relevant knowledge. Generating knowledge inter-organisationally entails pooling knowledge. Since a priori it is not known which knowledge will be useful to generate new knowledge, more knowledge is inevitably shared than necessary. The goal of industry organisations may be not to generate knowledge inter-organisationally in FP projects, but instead to pursue unilateral learning strategies to reduce knowledge spillovers and maximise the benefit from FP participation (Matt and Wolff 2003).

In section 2 it has been argued that crossing national border and EU's external border should not have a significant impact on inter-organisational knowledge generation since the negative

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<sup>6</sup> In the 1,214 questionnaires of the survey that are used in this study 12.5% of all universities, 15.6% of all research organisations and 14.5% of all industry organisations indicated that they generated commercially relevant knowledge [whether inter-organisationally or not]. Thus, the explanation that industry organisations do not generate commercially relevant knowledge within the FPs can be ruled out.

influence of geographical separation is offset by the participation rules of the FPs. This serves to be valid for commercially relevant knowledge generation, but not for scientific knowledge generation because both border dummies are significantly positive, but the effect is relatively small. Holding all other covariates at their sample means, crossing national border increases the probability of a dyad to generate scientific knowledge inter-organisationally only by two percentage points. Nevertheless, how can this small but significant positive influence of crossing national border be explained?

One possible explanation is that the factors described in section 3 that were expected to offset the negative influence of geographical separation on inter-organisational knowledge generation appear stronger than expected for scientific knowledge generation. Another possible explanation is that the significant and positive national border dummy can be attributed to collaborations within the scientific sector, while it is expected that industry organisations do not show an inclination to co-author publications with foreign organisations. This explanation is based on the consideration that researchers of universities and research organisations are more accustomed to work internationally and bound together by a common culture and shared mental models. As can be seen by the different significance of the coefficients of national border in models 2 and 3, this hypothesis can be confirmed. Inter-organisational generation of scientific knowledge is less sensitive to the presence of national borders within the scientific sector than between the scientific and industry sectors.

An unexpected result is that the coefficient of crossing EU's external border is insignificant in model 2 but significantly positive in model 3. In order to shed more light on this result we have run a regression for scientific knowledge generation including only dyads as observations that cross EU's external border. The empirical results of this model are presented in Table 3. It is striking that a dyad that includes an industry organisation located in a candidate country and a research organisation located in a member state has the highest impact on inter-organisational generation of scientific knowledge among all organisational types of cooperation since this kind of cooperation has only a medium impact in the full sample model. This result can probably be attributed to the desire of industry organisations in candidate countries to catch up with their counterparts in member states. A research organisation as partner can be regarded as a good choice, since they are more applied oriented than universities but less reluctant to share their knowledge than industry organisations.



**Table 3: ML estimates of the model for inter-organisational generation of scientific knowledge across EU's external border**

Variables	Coefficient estimate [standard error in parenthesis]
Constant	-1.265*** (0.456)
<i>Collaboration duration and intensity</i>	
Previous collaboration	0.294* (0.164)
Project duration [in months]	0.005 (0.010)
Important research collaboration	1.017*** (0.135)
<i>Organisational types of cooperation</i>	
Industry (C) – research organisation (EU)	0.740** (0.325)
University (C) – university (EU)	0.576** (0.290)
University (C) – industry organisation (EU)	0.546 (0.297)*
University (C) – research organisation (EU)	0.543 (0.312)*
Research organisation (C) – university (EU)	0.300 (0.304)
Research organisation (C) – research organisation (EU)	0.041 (0.313)
Research organisations (C) – industry organisation (EU)	-0.148 (0.309)
Industry organisation (C) – university (EU)	-0.102 (0.413)
Industry organisation (C) – industry organisation (EU)	-0.430 (0.345)
<i>Control variables</i>	
Project size [number of participants]	-0.078*** (0.022)
Intent to generate scientific knowledge	0.297* (0.156)
Intent to generate commercially relevant knowledge	-0.052 (0.154)
EU project funding [in million €]	0.000*** (0.000)
Log-likelihood	-262.700
BIC	0.978
Likelihood ratio test (df=16)	157.041***

Notes: Dependent variable is inter-organisational scientific knowledge generation. Probit transformation of the dependent variable was used. The model includes a sample of 650 dyads that cross EU's external border. The default dummy for organisational types of cooperation are dyads including government organisations. (C) denotes that the corresponding organisation was located in a candidate country; (EU) denotes that the corresponding organisation was located in the EU; \*\*\* significant at the 0.01 significance level, \*\* significant at the 0.05 significance level, \* significant at the 0.1 significance level.

## 6 Summary and conclusions

The objective of this study was to explore the determinants of inter-organisational knowledge generation in the network created by the FPs. It was argued that social capital is a key determinant for inter-organisational knowledge generation since social capital provides the necessary resources [e.g. trust, common language, shared mental models and shared goals] for knowledge exchange and facilitates the development of inter-organisational capabilities for knowledge generation. Thus, it was considered that factors influencing social capital are key determinants of inter-organisational knowledge generation. In section 3, four factors were identified: duration of collaboration, intensity of collaboration, geographical separation and the organisational types involved in inter-organisational knowledge generation.

A binary response model was derived from a latent regression in order to measure the impact of the above determinants on inter-organisational knowledge generation. Dyads of organisations that jointly collaborated in a FP project were used as units of analysis. Since inter-organisational knowledge generation is a latent process that is not directly measurable, observable outcomes of inter-organisational knowledge generation were used as proxies. The occurrence of a co-authored publication was used to measure scientific knowledge generation while generation of commercially relevant knowledge was measured in terms of co-owned commercial outcome.

As expected, the results show that project duration and previous collaboration have a positive and significant impact on inter-organisational generation of scientific and commercially relevant knowledge. Intensity of collaboration has the strongest positive impact on scientific knowledge generation and has also a strong and positive influence on the generation of commercially relevant knowledge.

Typically, geographical separation is expected to have a negative influence on inter-organisational knowledge generation because it curbs the development of social capital. In this study we expected that national border and EU's external border have an insignificant influence on inter-organisational knowledge generation because the negative effect of geographical separation on inter-organisational knowledge generation appears to be offset by the participation rules and proposal selection procedures of the FPs. This assumption was confirmed for commercially relevant knowledge generation but not for scientific knowledge generation.

An unexpected result is that dyads involving industry organisations are not significant in regard to generation of commercially relevant knowledge. This result can probably be explained by the fact that inter-organisational knowledge generation entails disclosure of knowledge, which is problematic for industry organisations. As expected, dyads involving universities and research organisations are at the forefront in regard to inter-organisational scientific knowledge generation.

The results of this study are in accordance with the goals of the Framework Programmes. Inter-organisational knowledge generation is not curbed by national border. On the contrary, universities and research organisations use the FPs rather for international than national scientific knowledge generation. Moreover, as intended by the European Commission, the FPs are an appropriate instrument to introduce new members into the European Research Area. Fears that the FPs contradicts the competition rules of the common market can be allayed since industry-industry collaborations in the FPs do not have a significant influence on inter-organisational commercially relevant knowledge generation.

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## Appendix

**Table A1: Distribution of organisations and participants included in the sample by country**

Country	Organisations (in %)	Participants (in %)
Germany	14.9%	17.5%
Italy	13.6%	13.4%
United Kingdom	13.2%	13.1%
Spain	11.9%	10.2%
France	11.7%	11.9%
Greece	4.4%	4.4%
Netherlands	4.2%	5.1%
Belgium	3.7%	3.4%
Sweden	3.3%	3.7%
Portugal	3.1%	2.5%
Austria	2.8%	3.0%
Denmark	2.6%	2.4%
Finland	2.1%	2.6%
Poland	1.8%	1.6%
Ireland	1.6%	1.3%
Czech Republic	1.6%	1.2%
Hungary	1.3%	1.0%
Slovenia	0.6%	0.5%
Slovakia	0.4%	0.4%
Lithuania	0.3%	0.3%
Latvia	0.3%	0.2%
Luxembourg	0.2%	0.2%
Estonia	0.2%	0.1%

**Table A2: List of variables**

Variable name	Scale of measurement	Description	Data source
<b>Dependent variables</b>			
Inter-organisational generation of scientific knowledge	Dichotomous	1 if the members of the dyad co-authored a scientific publication; 0 otherwise	Survey
Inter-organisational generation of commercially relevant knowledge	Dichotomous	1 if the members of the dyad co-own commercial outcome; 0 otherwise	Survey
<b>Geographical barriers</b>			
National border	Dichotomous	1 if the organisations forming the dyad are located in different countries	EUPRO
EU's external border	Dichotomous	1 if one organisation of the dyad is located in the EU15 and the other in a Central Eastern European candidate country; 0 otherwise	EUPRO
<b>Collaboration duration and intensity</b>			
Project duration	Ordinal	the duration of the FP5 project in which the members of the dyad jointly participated measured in terms of months	EUPRO
Previous collaboration	Dichotomous	1 if the two organisations forming the dyad have already collaborated in previous FP projects; 0 otherwise	Survey
Important research collaboration	Dichotomous	1 if at least one member of the dyad stated that the other was an important collaboration partner; 0 otherwise	Survey
<b>Combinations of organisation types</b>			
University – university	Dichotomous	1 if both organisations of the dyad are universities; 0 otherwise	EUPRO
University – research organisation	Dichotomous	1 if one organisation of the dyad is a university and the other is a research organisation; 0 otherwise	EUPRO
Industry – university	Dichotomous	1 if one organisation of the dyad is a university and the other is an industry organisation; 0 otherwise	EUPRO
Industry – industry	Dichotomous	1 if both organisations of the dyad are industry organisations; 0 otherwise	EUPRO
Industry – research organisation	Dichotomous	1 if one organisation of the dyad is an industry organisation and the other is a research organisation; 0 otherwise	EUPRO
Research organisation – research organisation	Dichotomous	1 if both organisations of the dyad are research organisations; 0 otherwise	EUPRO
<b>Control variables</b>			
Project size	Ordinal	The number of participants of the project in which both organisations of the dyad jointly participate	EUPRO
Intent to generate scientific research	Dichotomous	1 if the motivation of at least one member of the dyad to participate in FP5 was to perform scientific research; 0 otherwise	Survey
Intent to generate commercially relevant knowledge	Dichotomous	if the motivation of at least one member of the dyad to participate in FP5 was to generate commercially relevant knowledge; 0 otherwise	Survey
EU project funding	Continuous	the amount of EU funds measured in terms of Euros which are allocated to the project in which both organisations of the dyad jointly participate	EUPRO



**Table A3: Correlation matrix of variables**

	Inter-organisational generation of scientific knowledge*	Inter-organisational generation of commercially relevant knowledge*	Previous collaboration*	Project duration [in months] <sup>†</sup>	Important research collaboration*	National border*	EU's external border*	University – university*	University – research organisation*	Industry organisation – university*	Industry organisation – industry organisation*	Industry organisation – research organisation*	research organisation – research organisation*	Project size [number of participants] <sup>†</sup>	Intent to generate scientific knowledge*	Intent to generate commercially relevant knowledge*	EU project funding [in million €] <sup>‡</sup>
Inter-organisational generation of scientific knowledge*	1.00																
Inter-organisational generation of commercially relevant knowledge*	0.12	1.00															
Previous collaboration*	0.18	0.03	1.00														
Project duration [in months] <sup>†</sup>	0.18	0.21	0.03	1.00													
Important research collaboration*	0.35	0.08	0.26	0.06	1.00												
National border*	0.03	-0.01	-0.01	0.07	-0.01	1.00											
EU's external border*	0.01	0.01	-0.03	-0.02	-0.03	0.15	1.00										
University – university*	0.11	0.02	0.01	0.13	0.02	0.08	0.02	1.00									
University – research organisation*	0.08	0.02	0.04	0.21	0.04	0.07	0.06	-0.16	1.00								
Industry organisation – university*	0.00	0.01	-0.03	0.03	-0.01	-0.07	-0.04	-0.18	-0.20	1.00							
Industry organisation – industry organisation*	-0.12	-0.01	-0.05	-0.27	-0.04	-0.04	-0.07	-0.20	-0.22	-0.25	1.00						
Industry organisation – research organisation*	-0.03	-0.01	0.01	-0.03	0.01	-0.07	-0.01	-0.17	-0.19	-0.22	-0.25	1.00					
Research organisation – research organisation*	0.04	-0.02	0.03	0.16	0.02	0.06	0.05	-0.10	-0.11	-0.12	-0.14	-0.12	1.00				
Project size [number of participants] <sup>†</sup>	-0.24	-0.11	0.01	0.01	-0.13	0.03	0.05	-0.01	-0.01	-0.04	0.00	-0.02	0.03	1.00			
Intent to generate scientific knowledge*	0.19	0.01	0.08	0.27	0.09	0.02	0.00	0.12	0.11	0.01	-0.18	-0.03	0.06	-0.07	1.00		
Intent to generate commercially relevant knowledge*	-0.11	0.06	-0.11	-0.10	-0.03	-0.08	-0.02	-0.18	-0.15	0.03	0.20	0.09	-0.10	-0.12	-0.45	1.00	
EU project funding [in million €] <sup>‡</sup>	-0.05	-0.02	-0.01	0.40	-0.01	0.00	0.06	0.05	0.00	-0.07	0.00	0.00	0.01	0.20	-0.14	-0.02	1.00

Notes: \* dichotomous variables; <sup>†</sup> ordinal variables; <sup>‡</sup> continuous variable. Spearman's rank correlation coefficient was used to measure correlation between ordinal variables as well as between continuous and ordinal variables; point-biserial correlation coefficient was used to measure correlation between dichotomous and continuous variables; rank biserial correlation coefficient was used to measure correlation between dichotomous and ordinal variables; phi coefficient was used to measure correlation between dichotomous variables.