UNDERSTANDING CO-OPERATIVE R&D ACTIVITY: EVIDENCE FROM FOUR EUROPEAN COUNTRIES

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Abstract: This paper investigates co-operative research activity by firms using data from the 3rd Community Innovation Survey for four countries, France, Germany, Spain and the UK. We build on the Cassiman and Veugelers (CV) (2002) study of Belgian manufacturing firms, by incorporating information on the service sector, and considering the role of public support in affecting firms' decisions to co-operate. Our results support those in CV, in that we find a positive relationship between the likelihood of undertaking co-operative R&D and both incoming knowledge spillovers and the extent to which firms find strategic methods important in appropriating the returns to innovative activity. We find that public support is positively related to the probability of undertaking co-operative agreements particularly with regard to the likelihood of co-operation with the research base. We find some evidence, in particular for Spain, that firms carry out co-operative R&D to overcome excessive perceived risks and financial constraints.

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Executive summary

This paper investigates the extent to which European firms engage in co-operative R&D behaviour and aims to shed light on the determinants of such activity. Co-operative innovative activity is a topical policy issue, in the context of technology transfer (most prominently from universities to business) and in its interactions with competition policy. Both the OECD and the European Union support the idea of strong industry-science linkages to maximise the returns from both private and public research investments, and both recognise a role for policy.

The paper uses the framework developed in Cassiman and Veugelers (2002) that looks at the effects of information flows, both incoming and outgoing knowledge spillovers, on the likelihood of engaging in co-operative R&D, using data from the 1st Community Innovation Survey (CIS) for Belgian manufacturing firms. Here we use information from the 3rd Community Innovation Survey (CIS3) for France, Germany, Spain and the United Kingdom and extend the analysis to the service sector. Additionally we consider the relationship between receipt of public financial support and the likelihood of undertaking co-operative R&D. In all four countries policy instruments are targeted at facilitating technology transfer from universities (or wider public sector research institutions) to firms.

As in Cassiman and Veugelers (2002) we find that firms' ability to take advantage of incoming spillovers in the form of publicly available knowledge, (i.e. their absorptive capacity), and firms' ability to limit outgoing spillovers and appropriate the returns to their innovative efforts are positively associated with the likelihood that firms undertake co-operative R&D agreements. We find that receipt of public support is positively related to the probability of undertaking co-operative agreements particularly with regard to the likelihood of co-operation with the research base. Finally we find some evidence, in particular for Spain, that firms carry out co-operative R&D to overcome excessive perceived risks and financial constraints.

1 Introduction

This paper investigates the extent to which European firms engage in co-operative R&D behaviour and aims to shed light on the determinants of such activity. Co-operative innovative activity is a topical policy issue, in the context of technology transfer (most prominently from universities to business) and in its interactions with competition policy. Both the OECD and the European Union support the idea of strong industry-science linkages to maximise the returns from both private and public research investments, and both recognise a role for policy.[1] The UK government has recently conducted a major review into the extent of business-university collaboration, which suggested ways to improve government support for such activity.[2] The UK operates a number of schemes aimed at encouraging collaborative R&D activity between businesses and research institutions, and business-to-business linkages. In Germany a significant amount of public funding for innovative activity is now directed towards research consortia comprising private businesses and scientific research institutions, and policies in France and Spain also emphasise public-private sector collaboration.[3] In this context it is important to understand which types of firms tend to engage in co-operative R&D, the motivations for such activity and whether public policy is effective in increasing collaborative research.

The paper uses the framework developed in Cassiman and Veugelers (2002) (henceforth CV) that looks at the effects of information flows, both incoming and outgoing knowledge spillovers, on the likelihood of engaging in co-operative R&D, using data from the 1st Community Innovation Survey (CIS) for Belgian manufacturing firms. Here we use internationally comparable micro-data from the 3rd Community Innovation Survey (CIS3) [4] for four EU countries, France, Germany, Spain and the United Kingdom and extend the

[1] OECD (2004a,b), European Commission (2004a).

[2] HM Treasury (2003).

[3] See Abramovsky, Harrison and Simpson (2004) for a summary for the UK, Fier, Aschhoff and Löhlein (2005) for information on the direction of funding in Germany, Acosta and Modrego (2001) for further information for Spain, and MNRT(2005) for further information for France.

[4] The CIS is based on a harmonized questionnaire and methodology, agreed upon by the member states of the European Union. Its definitions and methodology are based on the so-called "Oslo Manual" OECD (1997), which recommends asking firms about their innovation behaviour during the three years before the survey is conducted. A more detailed description of the survey can be found in European Commission (2004b). See Abramovsky et al (2004) for a description of the surveys and sampling methodology in France, Germany, Spain and the U.K.

analysis to the service sector. Additionally we consider the relationship between receipt of public financial support and the likelihood of undertaking co-operative R&D.

As in CV we find that firms' ability to take advantage of incoming spillovers in the form of publicly available knowledge (their absorptive capacity), and firms' ability to limit outgoing spillovers and appropriate the returns to their innovative efforts both have a positive effect on the likelihood of firms undertaking co-operative R&D agreements. Moreover, absorptive capacity is found to be a more important factor in determining collaborative agreements with research institutions. Additionally, as might be expected given the orientation of public support for R&D we find a positive relationship between receipt of financial public support for innovative activities and the probability of co-operating with the research base, and to a lesser extent with the probability of co-operating with other firms. Finally we find some evidence, in particular for firms in Spain, that co-operative R&D is motivated by a need to overcome financial constraints, potentially reflecting differences in capital markets.

To set the scene, the following two tables show the extent to which *innovative* firms in the four EU countries we consider undertake co-operative activity. Throughout the paper we define innovative firms as those that introduced a product and/or a process innovation, or engaged in innovative activities during the period 1998-2000, including those that started but subsequently abandoned their innovation activities.[5] In table 1 we use a broad definition of co-operative activity that includes co-operation with customers and suppliers (vertical co-operation), co-operation with competitors (horizontal co-operation), and co-operation with universities or research laboratories (co-operation with the research base).[6]

The table shows that the proportion of *innovative* firms undertaking any of these three forms of co-operative innovative activity is highest in France and the U.K, followed by Germany and then Spain. Interestingly in Germany and Spain there is little difference between the manufacturing and service sectors in the proportion of innovative firms

[5] In the surveys for France, Germany and Spain it is only innovative firms that answer questions about co-operative R&D activity. Given the very broad definition of innovative firms used this should not present a selection problem. Indeed in the U.K. survey this information is available for all firms. We find that only around 4% of non-innovative firms reported that they were involved in co-operative R&D.

[6] In this paper, we are not considering co-operation with other firms in the same enterprise group, one of the reasons being that the definition of a firm and an enterprise group is not homogeneous across the four countries under consideration.

engaging in co-operative activity, whereas in the UK and to an even greater extent in France, innovative firms in the manufacturing sector are more likely to co-operate than those in the service sector. Within the manufacturing sector in all four countries on average innovative firms in high-tech manufacturing sectors are more likely to engage in co-operative activity than those in low-tech manufacturing sectors.[7]

Table 1: Percentage of innovative firms with co-operation agreements by sector, 1998-2000

Sector	France	Germany	Spain	U.K
Manufacturing	**29%**	**19%**	**13%**	**25%**
High-technology sectors	36%	28%	22%	32%
Low-technology sectors	25%	13%	10%	20%
Services	**18%**	**17%**	**15%**	**20%**
Total	**26%**	**18%**	**14%**	**23%**

Note: calculations are weighted (using national CIS3 weights) to be representative of the population of innovative firms in each country. Populations are innovative firms with 20 or more employees.

It is interesting to look at whether cross-country differences in the extent of overall collaborative activity are driven by differences in specific types of co-operative agreements. Table 2 shows the percentages of innovative firms undertaking different types of co-operative agreement. In the U.K. and France the most common type of co-operative R&D activity is with suppliers or customers. In Spain the most common form of co-operative activity is with universities or research laboratories. In Germany, co-operative activities with suppliers or customers and with universities or research laboratories are equally common. In all countries agreements with competitors are the least frequent type of R&D agreement. Despite the recent policy concern in the U.K. the proportion of innovative firms undertaking co-operative agreements with universities or research laboratories does not appear to be particularly low compared to the other countries.

Across all four countries co-operative agreements with the research base appear to be more prevalent in the manufacturing sector than in the service sector. However when looking at business-to-business co-operation (both vertical and horizontal) in some countries these types of agreement are more widespread in the service sector.

[7] See Abramovsky et. al. (2004) for further international comparisons, including whether collaborative agreements are with national or international partners, and full sector-level breakdowns.

Table 2: Percentage of innovative firms with different types of co-operative agreements, 1998-2000

Type of co-operative agreement	France	Germany	Spain	U.K
Agreements with the research base				
Manufacturing	18%	13%	12%	16%
Services	10%	9%	10%	10%
Total	**16%**	**11%**	**12%**	**14%**
Agreements with suppliers or customers				
Manufacturing	21%	13%	7%	21%
Services	14%	11%	13%	18%
Total	**19%**	**12%**	**9%**	**20%**
Agreements with competitors				
Manufacturing	7%	6%	4%	4%
Services	5%	8%	6%	6%
Total	**7%**	**7%**	**5%**	**5%**

Note: calculations are weighted (using national CIS3 weights) to be representative of the population of innovative firms in each country. Populations are innovative firms with 20 or more employees.

Finally, we examined whether, among innovative firms, co-operative firms perform differently from non-cooperative ones. First, looking at labour productivity, we found that across all four countries in the manufacturing sector innovative firms that engaged in co-operative R&D tended to have higher labour productivity than those that did not. Those that entered into co-operative agreements also reported that a higher proportion of their sales were due to innovative products introduced between 1998 and 2000. While these performance characteristics may be the direct outcome of undertaking co-operative R&D, it may also be the case that these types of firms are more likely to enter into co-operative agreements in the first place.[8] In the service sector the picture was more mixed, for example there was no clear correlation between labour productivity and co-operative activity.

The remainder of the paper is structured as follows. The next section discusses reasons why firms might engage in collaborative activity, including the effects of both incoming and outgoing information flows. Section 3 presents some cross-country descriptive statistics for the samples on which we estimate. Section 4 presents the empirical results that describe

[8] In our analysis below we include a firm level measure of R&D intensity to capture the firm's innovative capabilities and absorptive capacity.

fully the characteristics associated with different types of co-operative activity in each country. We also follow the approach used in CV and present results using instrumental variable methods to deal with potential endogeneity. Section 5 concludes.

2 Why do firms undertake collaborative R&D?

Firms may engage in collaborative R&D for a variety of reasons, for example if spreading the cost and risk associated with an R&D project leads to higher expected profits than carrying out the project individually. This argument is supported by Sakakibara (1997) who identifies cost- and skill-sharing as two basic motives for co-operation. CV chose to focus on the influence of two types of knowledge flows on the likelihood of co-operation, first the extent of *incoming spillovers*, that is beneficial external knowledge flows, and second *appropriability*, that is the ability of firms to capture the returns to their innovative activity, the converse of which can be thought of as the extent of outgoing spillovers.

The degree to which an individual firm has the internal capabilities to successfully capitalise on externally generated knowledge is often referred to as its 'absorptive capacity'. Cohen and Levinthal (1989, p.569) define absorptive capacity as a firm's ability to "identify, assimilate, and exploit knowledge from the environment." Firms that have higher absorptive capacity might also be more likely to be successful innovators, which could make them more attractive co-operation partners for other firms. However, how a firm's absorptive capability affects its own incentives to engage in co-operative R&D is ambiguous. On the one hand, firms that are better at accessing and using external knowledge can more easily benefit from the knowledge available to them for free and might thus have lower incentives to co-operate. On the other hand, if they are also better able to profit from the knowledge exchanged in a cooperative agreement than those with lower absorptive capacity, their incentives to co-operate could be higher.[9]

In general we would expect the extent to which firms are able to appropriate the returns to innovative activity to have a positive effect on how intensively they undertake R&D activity. But how might we expect it to influence their incentives to engage in collaborative R&D? On the one hand, in the face of appropriability problems firms might try and

[9] Hagedoorn (1993) argues that access to complementary knowledge and technologies is one of the most important motives for firms to engage in cooperative research.

internalise outgoing spillovers by forming explicit collaborative relationships, rather than conducting R&D on their own. On the other hand, an inability to appropriate the returns to one's own R&D efforts, even inside a collaborative arrangement, might lead to free-riding either inside[10] or outside[11] collaborative agreements and hence decrease the likelihood of such agreements occurring, by decreasing the incentives for firms to form them.

While firms may undertake collaborative R&D to overcome financial constraints or to pool risks, they may nonetheless face other constraints to co-operative activity, for example, the presence of market failures, such as coordination or information failures. These may rationalise the existence of public support programmes to encourage co-operative R&D and technology transfer between universities and firms, and firms and firms alike. Supporting cooperation and knowledge sharing among actors in the national, regional or local innovation system may also increase social welfare and enhance the innovative capacity of firms. In order to achieve a high level of knowledge sharing among actors, public funding for R&D and innovation activities is increasingly linked to co-operative R&D. Public funding may therefore facilitate co-operative R&D by firms that would otherwise not engage in such activity. If we do observe a positive correlation between co-operative R&D activity and receipt of public support, this does not necessarily imply that policies are generating additional co-operative research. It maybe that some of those firms receiving support would have engaged in some form of co-operative R&D in any case.

The motives described above are assumed to influence co-operation in general, but it is likely that the importance of different motives varies with the type of cooperation partner. This issue (especially the relationship between firms and universities) has gained increasing importance in the literature and in public policy formation in recent years[12] and will also be investigated here.

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[10] Kesteloot and Veugelers (1995), for example, found that the incentive to cheat within a cooperative agreement increases if outgoing spillovers are high, thus decreasing the incentive to cooperate in the first place.

[11] See Greenlee and Cassiman (1999).

[12] For example, see Belderbos (2004), Cassiman and Veugelers (2002) and HM Treasury (2003). The results in Miotti and Sachwald (2003) based on CIS2 data for France support the hypotheses that a firm's choice of R&D co-operation partners is affected by its need to access complementary resources. More specifically, the authors find that co-operation with competitors aims at pooling similar resources to share high R&D costs, while co-operation with universities targets complementary resources to work at the technological frontier.

The discussion above highlights that the extent to which firms benefit from incoming spillovers, the extent to which they can appropriate the returns to their innovative activity, and whether or not they face constraints in their innovation activities may themselves depend on whether or not firms engage in co-operative R&D, in addition to other firm and industry-specific factors. Following CV, our empirical framework aims to take account of this potential endogeneity. Before turning to our results, we first look in more detail at some characteristics of firms that undertake co-operative R&D.

3 Data and descriptive statistics

Using data from the CIS3 in each of the four countries Table 3 below shows the proportion of innovative firms that undertake different types of co-operative agreement for the respective samples. In contrast to CV we focus not only on manufacturing but also on the service sector. As mentioned above, the definition of innovative firms covers "firms that have either introduced a product or process innovation or have ongoing innovation activities or have abandoned innovation activities and have spent a positive amount on innovation activities between 1998-2000." The proportions shown in Table 3 below can differ from those in Tables 1 and 2 because they are based on the samples used in estimation (and not weighted up to the population). While the proportions of innovative firms undertaking co-operative activity are higher than in Tables 1 and 2, the cross-country patterns are largely similar, although in Table 3 Germany has a higher proportion of innovative firms engaging in co-operative activity than the UK.

The characteristics we focus on are measures of incoming spillovers, appropriability, constraints on innovation - a combination of cost and risk factors that hamper innovation-, firms' R&D intensity and whether or not firms received financial public support for innovative activities. We use information from the CIS3 survey to construct firm-level and industry-level variables. For comparability, we construct our variables in line with those used in CV.[13] A full set of definitions is provided in Appendix 1.

[13] We have modified the variable definitions in CV in some cases in order to construct measures that are comparable across the four countries in the current study. For example, when measuring *appropriability* we use a count of the number of protection methods used (rescaled between zero and one) rather than using information on the intensity of use (rescaled between zero and one), which was not available in all four countries. However, for the countries where the full information was available we checked that constructing the *appropriability* variable in this way does not change the overall pattern of results.

Table 3: Percentage of innovative firms undertaking different types of co-operative agreement, national samples.

	France	Germany	Spain	U.K
Innovative firms	3,590	1,183	2,747	1,145
Cooperating	1,286	408	612	324
(as % innovative firms)	*(36%)*	*(34%)*	*(22%)*	*(28%)*
Co-operating with the research base	859	317	533	200
(as % innovative firms)	*(24%)*	*(27%)*	*(19%)*	*(18%)*
Co-operating with customers or suppliers	973	268	427	265
(as % innovative firms)	*(27%)*	*(23%)*	*(15%)*	*(23%)*
Co-operating with competitors	359	146	242	67
(as % innovative firms)	*(10%)*	*(12%)*	*(9%)*	*(6%)*

Note: figures calculated from the CIS3 sample for each country. Firms with greater than 20 employees. The total number of innovative firms reported in this table is smaller than the total sample of innovative firms in each country as we only include those with non-missing values for the variables used in the subsequent analysis.

The extent of *incoming spillovers* is measured by a continuous variable bounded between 0 and 1, where a higher value implies that firms placed more value on public sources of information in carrying out their innovation activities. The measure is derived from a question that asks firms to rate the importance of different information sources for their innovation activity during the period 1998-2000. The information sources considered include professional conferences, meetings, journals or technical/trade press and fairs and exhibitions.

The measure of *appropriability* is based on information on the extent to which firms use strategic methods to protect their innovations. The question firms are asked is, *"During the period 1998-2000, did your enterprise, or enterprise group, make use of any of these methods to protect inventions or innovations developed in your enterprise"*.[14] The strategic methods we consider are, secrecy, complexity of design and lead-time advantage on competitors. This measure is again scaled between 0 and 1 and is increasing in the number of the methods used. We also construct an industry-level measure of the extent of use of different *legal protection* methods such as patents and trademarks, again an index measure between 0 and 1, which increases in the number of methods used. This captures the scope for using formal protection methods to appropriate the returns to R&D.

[14] CV base their measure on how firms rate the *effectiveness* of these methods, but unfortunately this is not how the question is phrased in CIS3, which increases concerns about endogeneity with regard to this variable.

We construct a measure that combines the extent to which firms are hampered in their innovation activities by cost and risk factors. This variable is called *constraints* and includes the extent to which availability and cost of finance and excessive perceived risks impeded firms' ability to innovate.[15] The index measure varies between 0 and 1 and is increasing in the extent to which these factors are declared to impose a constraint.

We also construct a measure of whether firms received public support for innovation activities. This is an indicator variable that takes the value 1 if the firm has received any kind of public financial support for innovation activities from local or national sources and takes the value 0 otherwise.

Finally, we consider a measure of firms' internal R&D capabilities that aims at capturing the firm's internal technological and absorptive capacities. The variable is called *R&D intensity*, which is the ratio of intramural (internal) R&D expenditure to turnover in the year 2000.[16]

Table 4 presents the sample mean values, for both firms that engage in co-operative activity and for those that do not, for each of the variables that we consider when investigating the determinants of co-operative activity. *Within* countries the mean values of all variables are significantly different across cooperative and non-cooperative firms. The only exception is that for UK there is only a weakly significant difference (at the 10% level) between the two groups in terms of the extent to which they perceive constraints (cost and risk factors) to be a barrier to innovative activity, however in the other three countries those firms that undertook co-operative R&D appeared to be significantly more constrained by these factors in their R&D activities.

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[15] CV include measures of the cost and risk factors separately. In order to construct comparable variables across countries we have had to combine this information into a single measure. The precise variable used for the French analysis (Hbur) is slightly different, due to a difference in the questionnaire in France. It takes a value of 1 if the firm was constrained in its innovation activities.

[16] In CV, firms' internal R&D capabilities were measured by a dummy variable that took the value of 1 if a firm engaged in R&D on a continuous basis. This was due to the lack of a continuous measure of R&D intensity in the Belgian data. Ideally we would like to use a measure for 1998, but this was not possible due to large numbers of missing values in the data. However it is likely that firms' R&D expenditures are very persistent. CV also used a measure of whether the firm lacked technological know-how. We omit this variable, as it is not available in the French data. However it is generally not significant when included in the regressions for the other three countries.

Across all four countries firms that undertake co-operative agreements typically place greater importance on incoming spillovers (*incoming spillovers*), place greater importance on the use of strategic methods for appropriating the returns to R&D (*appropriability*) and are typically in industries where a higher importance is placed on legal methods of protecting the returns to innovation. Firms that engage in co-operative agreements also show higher R&D intensity and are on average larger than those that do not take part in co-operative agreements. These findings are in line with those of CV. Firms that undertake co-operative R&D, are also more likely to receive public support.

Table 4: Characteristics of co-operative (C) and non-cooperative (NC) innovative firms

	France		**Germany**		**Spain**		**U.K.**	
	C	**NC**	**C**	**NC**	**C**	**NC**	**C**	**NC**
No. observations	1,286	2,304	408	775	612	2135	324	821
% of total obs.	36%	64%	34%	66%	22%	78%	28%	72%
Incoming spillovers	0.40	0.28	0.58	0.53	0.49	0.42	0.43	0.36
Appropriability	0.37	0.19	0.57	0.34	0.41	0.26	0.79	0.66
Industry level legal protection	0.25	0.24	0.28	0.22	0.18	0.17	0.46	0.42
Size (ln(employees))	5.67	4.86	5.46	4.96	2.32	2.00	5.19	4.78
Constraints (Hbur for France Dummy =1 is firm is constrained)	0.34	0.19	0.61	0.54	0.52	0.45	0.51	0.47
R&D intensity	0.05	0.02	0.06	0.02	0.08	0.02	0.03	0.01
Public Support	0.44	0.18	0.63	0.26	0.60	0.31	0.23	0.09

Notes: The sample in each country comprises innovative firms in both the manufacturing and the service sector. C = cooperating firms, NC = non-cooperating firms.

We also looked at whether there were significant differences in the mean values of these variables *across* countries within the two categories of firms – e.g. comparing cooperative firms in France with those in Germany. We found that in the vast majority of cases there are significant differences across countries. For example, firms in Germany that undertake co-operative agreements place more importance on *incoming spillovers* than those in Spain, the UK and France. Innovative firms in the UK, both those that engage in co-operative

agreements and those that do not, place more importance on strategic methods of protection (*appropriability*), and formal methods of protection than their counterparts in Germany, France and Spain. Among co-operative innovative firms R&D intensity is highest in Spain and lowest in the UK. The proportion of co-operative innovative firms that receive public support for innovation is highest in Germany and Spain at around 60% and significantly lower in the UK at just over 20%.[17]

4 Empirical results

As a first step in examining the relationship between these factors and the likelihood of co-operation we estimate a probit model for each country, where the dependent variable takes on a value of one if the firm is engaged in a co-operative agreement. Table 5 shows the results of this exercise. The figures shown are the marginal effects of each of the explanatory variables on the probability of undertaking a co-operative agreement. For each country we also include an industry-level measure of the extent of co-operative activity, to control for unobserved industry characteristics associated with this decision.

In all four countries, conditional on other factors, firms that use strategic protection methods (appropriability) were more likely to be engaged in co-operative R&D, which is in line with the findings in CV. Firms are more likely to be engaged in co-operative agreements the higher their R&D intensities, although this variable is not significant in the UK. Also, in all countries we find a positive association between the likelihood that firms have received financial public and the probability of being engaged in a co-operative agreement. In the UK and France we find that firms that are engaged in co-operative agreements place a higher importance on incoming knowledge spillovers. Turning to the measures of the extent to which constraints such as cost and risk factors are perceived as an obstacle to R&D activity, we find that in particular in Spain and France firms engaged in co-operative research are more likely to see these factors as obstacles. Finally there is also evidence for Germany and in particular for Spain that larger (although not necessarily the largest) firms are most likely to engage in co-operative R&D.

[17] Indeed innovative firms in France, Germany and Spain that were not involved in co-operative R&D were also more likely to receive public support than those in the UK.

Table 5: Characteristics of firms that undertake co-operative agreements

Dependent variable = 1 if firm has a cooperative agreement				
	France	**Germany**	**Spain**	**U.K.**
Incoming spillovers	0.242*** (0.032)	0.009 (0.056)	0.031 (0.026)	0.174*** (0.062)
Appropriability	0.195*** (0.025)	0.242*** (0.040)	0.079*** (0.018)	0.078** (0.038)
Industry level legal protection	0.101 (0.178)	-0.195 (0.215)	-0.040 (0.131)	-0.133 (0.147)
R&D intensity	0.186** (0.087)	0.638* (0.344)	0.180** (0.089)	0.371 (0.251)
Size (ln no. employees)	0.004 (0.044)	0.126** (0.050)	0.342*** (0.083)	0.022 (0.740)
Size squared	0.007* (0.004)	-0.005 (0.004)	-0.038** (0.017)	0.002 (0.007)
Constraints (Hbur for France)	0.090*** (0.021)	0.101* (0.055)	0.104*** (0.026)	0.053 (0.055)
Public Support	0.227*** (0.020)	0.313*** (0.031)	0.151*** (0.017)	0.231*** (0.046)
Industry level of cooperation	0.699*** (0.071)	0.744*** (0.160)	0.733*** (0.071)	0.943*** (0.178)
LL	-1910.54	-599.16	-1171.87	-611.57
No. Observations	3,590	1,183	2,747	1,145

*** significant at 1% level, ** significant at 5% level, * significant at 10% level. The numbers reported are the marginal effect of the independent variable on the probability of cooperation.

As mentioned above there are reasons to believe that the variables appropriability, incoming spillovers, R&D intensity and constraints are endogenous, and we therefore return to this issue below. However, although these results only represent associations between the different characteristics and the likelihood of undertaking co-operative R&D they do shed light on the characteristics of firms that are active in co-operative agreements.

Co-operation with different partners

Table 6 reports results for the three different types of co-operative agreement, (with the research base, with customers and suppliers and with competitors), separately. In terms of incoming spillovers and appropriability the pattern is very similar across the different types of co-operation agreement to that in Table 5. Although we do not find a significant relationship between R&D intensity and the likelihood of co-operation for the UK in Table 5, we do find a strong positive relationship when considering agreements with the research base, which is not mirrored in the other three countries.

Looking across the different types of agreements we find that for Spain and to a lesser extent for France, in all cases it is those firms that report being constrained in their R&D activity, for example due to financial constraints, that are more likely to be engaged in co-operative R&D. For Spain we also find a significant relationship between firm size and the likelihood of undertaking co-operative R&D.

Receipt of public support is positively correlated with the probability of co-operating with all three types of partners in Germany and France and Spain, but in the UK we find no relationship with the probability of co-operating with competitors. In all countries the marginal effects are highest with regard to co-operating with the research base. This finding is consistent with the aims of policy in this area in terms of encouraging co-operation between firms and universities and facilitating technology transfer from the public sector, and reflects the focus of the policies in operation in all four countries.

In France, the Ministry of Research puts a lot of emphasis on developing R&D cooperation between the public and private sectors. There are two main forms of support: the RRIT (R&D and Technology Innovation Networks), which aim to improve partnerships between public sector R&D and firms – there were 15 at the end of 2004; and the CNRTs (National Centres of Technological Research), which support collaboration between public R&D labs and labs in large manufacturing firms - 18 centres have been created since 2000.[18] Since 1980 Germany has seen a significant rise in the proportion of publicly funded R&D projects that involve collaborative networks (from around 30% of spending in 1980-89 to nearly 90% by 2004), which has been driven by a substantial increase in publicly funded projects that involve collaboration between business and scientific research institutions.[19]

In Spain, the National R&D plan was adopted in 1988. One of the instruments of technological policy included in this plan is known as the Industrial Research Concerted Projects. The objective of this national initiative is to finance pre-competitive research projects developed by industrial firms, which must include the participation of universities, public research centers or research and technology organizations (RTOs).[20] Finally, in the UK during the period 1998 to 2000, the LINK and Faraday Partnerships schemes provided

[18] See MNRT (2005) for further details.

[19] See Fier et al (2005) for further details.

[20] See Acosta and Modrego (2001) for further details.

grant funding for research consortia including university partners, for research into pre-market areas and technology transfer.

In the next section we present instrumental variables estimates, following the approach suggested in CV in an attempt to control for potential endogeneity of the incoming spillovers, appropriability and R&D intensity variables and we also attempt to control for potential endogeneity in the constraints variable.

Table 6: Characteristics of firms that undertake different types of co-operative agreement

	Dependent variable = 1 if firm has a cooperative agreement with the research base				**Dependent variable = 1 if firm has a cooperative agreement with suppliers or customers**				**Dependent variable = 1 if firm has a cooperative agreement with competitors**			
	France	**Germany**	**Spain**	**U.K.**	**France**	**Germany**	**Spain**	**U.K.**	**France**	**Germany**	**Spain**	**U.K.**
Incoming spillovers	0.216*** *(0.026)*	0.074 *(0.048)*	0.046* (0.024)	0.127*** (0.048)	0.205*** *(0.028)*	0.042 *(0.046)*	0.033 (0.021)	0.150*** (0.058)	0.070*** *(0.016)*	0.010 *(0.033)*	0.019 (0.014)	0.104*** (0.26)
Appropriability	0.139*** *(0.020)*	0.156*** *(0.037)*	0.079*** (0.016)	0.070** (0.031)	0.178*** *(0.021)*	0.155*** *(0.035)*	0.074*** (0.014)	0.055* (0.035)	0.062*** *(0.012)*	0.067** *(0.025)*	0.029*** (0.009)	0.003 (0.017)
Industry level legal protection	0.014 *(0.147)*	0.142*** *(0.049)*	0.023 (0.122)	-0.163 (0.110)	-0.019 *(0.156)*	0.157*** *(0.046)*	-0.083 (0.105)	-0.061 (0.125)	-0.017 *(0.094)*	-0.005 *(0.033)*	0.011 (0.076)	-0.033 (0.052)
R&D intensity	0.029 *(0.067)*	-0.012 *(0.123)*	0.134* (0.071)	0.485*** (0.184)	0.121* *(0.072)*	0.210 *(0.136)*	0.162** (0.068)	-0.072 (0.221)	0.062* *(0.037)*	-0.061 *(0.056)*	0.030 (0.019)	0.123* (0.072)
Size (ln no. employees)	0.047 *(0.035)*	0.072* *(0.042)*	0.328*** (0.074)	0.072 (0.056)	0.037 *(0.036)*	0.050 *(0.039)*	0.255*** (0.064)	0.005 (0.066)	-0.018 *(0.018)*	-0.009 *(0.027)*	0.108*** (0.040)	-0.019 (0.028)
Size squared	0.002 *(0.003)*	-0.002 *(0.003)*	-0.039*** (0.015)	-0.003 (0.005)	0.002 *(0.003)*	-0.001 *(0.003)*	-0.028** (0.013)	0.002 (0.006)	0.003* *(0.002)*	0.002 *(0.002)*	-0.009 (0.008)	0.003 (0.002)
Constraints (Hbur for France)	0.075*** *(0.017)*	0.086* *(0.049)*	0.095*** (0.023)	0.068 (0.043)	0.076*** *(0.018)*	0.053 *(0.044)*	0.087*** (0.021)	0.030 (0.051)	0.047*** *(0.012)*	0.044 *(0.033)*	0.075*** (0.015)	-0.005 (0.025)
Public Support	0.222*** *(0.018)*	0.350*** *(0.029)*	0.144*** (0.015)	0.228*** (0.043)	0.126*** *(0.018)*	0.122*** *(0.027)*	0.084*** (0.013)	0.155*** (0.043)	0.046*** *(0.012)*	0.111*** *(0.021)*	0.040*** (0.009)	0.027 (0.021)
Industry level of specific type of cooperation	0.711*** *(0.058)*	0.614*** *(0.093)*	0.650*** (0.065)	0.777*** (0.117)	0.569*** *(0.089)*	0.577*** *(0.123)*	0.558*** (0.072)	0.930*** (0.175)	0.482*** *(0.080)*	0.560*** *(0.106)*	0.475*** (0.059)	0.340** (0.080)
LL	-1480.8	-481.24	-1064.52	-431.45	-1795.41	-526.84	-965.53	-572.52	-1022.1	-382.21	-677.60	-215.52
No. observations	3,590	1,183	2,747	1,145	3,590	1,183	2,747	1,145	3,590	1,183	2,747	1,145

*** significant at 1% level, ** significant at 5% level, * significant at 10% level. The numbers reported are the marginal effect of the independent variable on the probability of cooperation.

4.1 Instrumental variables results

We follow the CV approach for the four countries and also consider the potential endogeneity of the *constraints* variable.[21] CV use a two-step approach. First the potentially endogenous explanatory variables are regressed on a set of (assumed) exogenous variables. The predicted values of the potentially endogenous variables are obtained from the first step regression and are used in place of the endogenous variables in the second step regression. We instrument the same three variables as in CV – *incoming spillovers, appropriability* and *R&D intensity*- and we also consider the *constraints* variable as endogenous, following the discussion in section 2 (i.e. it may be that co-operative agreements alleviate constraints that were present ex-ante).

We use the same set of assumed exogenous variables as CV as instruments. The instrument set includes industry-level measures of the potentially endogenous variables, i.e. incoming spillovers, appropriability, R&D intensity and constraints and the extent of co-operative activity. These are intended to capture the effect of unobserved industry-specific attributes related to the specific endogenous variables at the 2-digit level. In addition, we include a firm-level measure of export intensity (exports as a proportion of total sales). This is designed to capture the intensity of competition which firms face, thought to be highly correlated with appropriability conditions – higher competition being associated with lower appropriability, and the greater reliance on strategic protection methods. We also include a firm-level measure of the extent to which the firm's R&D activity is orientated towards basic research. This is derived from questions on the extent to which a firm sources information for its research activities from the research sector (see Appendix 1). We might expect this variable to be positively correlated with a firm's innovative capabilities (R&D intensity) and their absorptive capacity and the extent to which they can capitalise on incoming spillovers more generally. The results of the first step regressions are given in table A1 in Appendix 2.[22,23]

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[21] See López (2004) and Schmidt (2005), which consider this issue in the context of Spain and Germany.

[22] These instruments are based on those used in CV. We consider them to be the most relevant and most likely to be exogenous from the variables available in the CIS. It is difficult to find a set of truly exogenous and powerful instruments within the CIS. Also, as CV noted in their paper, the IV approach used could introduce multicollinearity between the predicted values of the endogenous variables, reducing the significance of the estimated coefficients.

Table 7 and table A2 in Appendix 2 show the results of the second step regressions for the national samples. Comparing the second step results in table 7 for general co-operation to the results from the simple probit estimation in table 5, it can be seen that the marginal effects of the incoming spillovers and the appropriability variables increase substantially in the IV specifications –though appropriability is insignificant for the UK. The increase in the marginal effects could be due endogeneity, or potentially due to measurement error. For example, the fact that the marginal effect on the incoming spillovers variable increases after instrumenting suggests that firms that ex-ante place more importance on the use of publicly available information are more likely to benefit from co-operative agreements, but once such firms are in co-operative agreements they may substitute the use of publicly available information with information generated within the partnership and hence place less importance on other external spillovers.

Our findings for the effects of incoming spillovers and appropriability show very few departures from the original findings in CV for Belgium. However we find some evidence, contrary to the findings in CV, that co-operation less likely in industries where legal methods of protecting innovations are more effective. Taking this together with the findings on appropriability for France, Germany and Spain, it may be that co-operative activity is a method of internalising outgoing knowledge flows in industries where formal, legal protection methods are weak and for firms for whom more strategic methods of appropriating returns are more important.

A further point is that after instrumenting we find no statistically significant relationship between the perception of cost and risk constraints and co-operative R&D, apart from in Spain. The marginal effect on this variable actually increases in the case of Spain, and we might have expected the marginal effects to be biased downwards in table 5 had co-operative R&D activity been undertaken to alleviate cost and risk constraints. It is also only in the case of Spain where we find that firm size is positively related to the probability of undertaking co-operative R&D.

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[23] It should be noted that the original explanatory endogenous variables exhibit firm level variation as well as industry level variation. In the first step regressions it can be seen that in some cases a substantial amount of the predictive power for each variable's fitted value comes from the industry level variables. This means that the fitted values provide more industry variation than firm level variation.

After instrumenting, the marginal effects on the R&D intensity variable decrease compared to table 5. We do not find that higher intramural R&D intensity increases the likelihood of engaging in co-operative R&D amongst innovative firms. Indeed, if anything the results for France suggest the opposite. It may be that ex-ante firms choosing to collaborate perceive co-operative R&D as a substitute for carrying out R&D activity purely in house – those firms with strong internal capabilities may have less need to engage in collaborative R&D. We explore what is driving this finding when we differentiate between different types of R&D agreement and between R&D agreements in the manufacturing and service sectors in the next sections. Finally, in all cases we continue to find a positive relationship between having received public financial support and the likelihood of co-operating.

Table 7: Understanding co-operative activity: 2nd-step results

Dependent variable = 1 if firm has a cooperative agreement				
	France	**Germany**	**Spain**	**U.K.**
Incoming spillovers **(I)**	0.854*** (0.107)	1.214*** (0.244)	0.575*** (0.106)	0.633*** (0.196)
Appropriability **(I)**	0.358** (0.168)	0.456*** (0.191)	0.438*** (0.134)	0.252 (0.180)
Industry level legal protection	-0.092 (0.195)	-0.759*** (0.285)	-0.744*** (0.184)	-0.248 (0.186)
R&D intensity **(I)**	-0.410** (0.205)	-0.788 (0.482)	-0.067 (0.149)	-0.585 (0.663)
Size (no. Employees)	-0.001 (0.045)	0.046 (0.059)	0.331*** (0.093)	-0.040 (0.076)
Size squared	0.006 (0.004)	-0.001 (0.005)	-0.039** (0.018)	0.006 (0.007)
Constraints **(I)** (Hbur for France)	0.115 (0.163)	-0.410 (0.350)	0.357** (0.163)	-0.066 (0.330)
Public support	0.149*** (0.023)	0.340*** (0.038)	0.071*** (0.017)	0.228*** (0.047)
Industry level of cooperation	0.674*** (0.085)	1.044*** (0.223)	0.782*** (0.091)	0.972*** (0.199)
LL	-1900.34	-592.22	-1087.92	-606.2
No. observations	3,590	1,183	2,747	1,145

*** significant at 1% level, ** significant at 5% level, * significant at 10% level. The numbers reported are the marginal effect of the independent variable on the probability of cooperation. **(I)** indicates instrumented.

Table A2 in Appendix 2 shows the results for co-operation with different types of partners. The findings in CV suggested that incoming spillovers were an important factor in determining co-operation with research institutions, but not vertical co-operation with suppliers or customers, and while appropriability was an important factor in determining vertical co-operation, it was not for co-operation with research institutes. Our findings are

not entirely consistent with this. Turning to co-operative agreements with the research base, we find that as in CV the extent to which firms value incoming spillovers has a positive effect on the probability of undertaking collaborative research with universities and that it is greater than the effect on the probability of co-operating with other type of partners. However, unlike the findings in CV, we do find some evidence that strategic protection has a positive influence and that the importance of legal protection measures has a negative influence. In France and Germany we find that firms with lower *intramural* R&D intensity are actually more likely to engage in co-operative R&D with the research base, perhaps accessing expertise that they do not have in-house at a lower cost.

Looking at co-operation with customers and suppliers and with competitors, contrary to the findings in CV, we do find that incoming spillovers have a positive and significant effect on the probability of co-operation with other firms, though as might be expected the marginal effects are smaller than for co-operation with the research base. This could indicate that absorptive capacity, in terms of being able to benefit from external information flows, is a more important determinant of whether a firm enters into a collaborative agreement with the research base compared to a potentially more 'near market' or developmental agreement with another company.

Differences between manufacturing and services

Finally, we looked at the manufacturing and the service sectors separately to see if any of the relationships above differed across the two sectors and whether there were any interesting differences across countries within the two sectors. We detail the main points of interest below.

First, our finding in table 7 that in Germany and Spain co-operation is less frequent in industries where legal protection methods are used more intensively is largely driven by the manufacturing sector. This finding is common across all the four countries, and suggests that whereas co-operative R&D may act as a substitute to patenting innovations in the manufacturing sector, it may not be used as a substitute to formal protection methods such as trademarks and copyright in the service sector.

There are also some interesting differences within sectors across the four countries. First, there is some evidence that strategic protection methods are less important in determining co-operative R&D in the service sector than in manufacturing in France, Germany and the

UK, but are important in both sectors in Spain. Second, in the UK and to a lesser extent in France, the significant positive correlation between public support and the probability of co-operation is only present for firms in the manufacturing sector and not for firms in the service sector. For the UK, this again fits in with the orientation of policy at this time towards collaboration with the research base on basic research and new technologies which are more likely to be of direct relevance to manufacturing firms. Third, the negative (although in some cases insignificant) relationship in table 7 between R&D intensity and the likelihood of co-operation appears to be largely driven by the service sector in all countries except for France, implying that co-operative R&D and intramural R&D intensity might be substitutes to a greater extent in the service sector than in manufacturing in Spain, Germany and the UK.

Finally, in Spain the positive and significant correlation between the importance of constraints (as hampering factors for innovation) and co-operation in table 7 is largely driven by the manufacturing sector. We find that this effect disappears for services. Moreover, firm size only has a significant effect in the manufacturing sector.

5 Conclusions

Our findings support those in Cassiman and Veugelers (2002), in that we find a positive relationship between the extent to which firms are able to benefit from external information flows and the likelihood of undertaking a co-operative agreement. We also find that firms that find strategic methods important in appropriating the returns to innovative activity are more likely to undertake co-operative agreements – suggesting that these are an effective way of internalising outgoing spillovers and securing the rewards to R&D, particularly in the manufacturing sector.

Our findings for Spain differ to some extent from those for Germany and the UK. In Spain we find that, particularly in the manufacturing sector, larger firms are more likely to undertake co-operative R&D, and that conditional on size we find evidence that firms are undertaking co-operative R&D in order to overcome financial constraints and excessive perceived economic risks (we also find some evidence of this for France). Taken together these findings may be driven by differences in capital markets and in the availability and cost of external private finance for innovative activity, between Spain and the other three countries. For example, in 2001 venture capital investment in Spain was, approximately,

one third of the investment in Germany or in the UK. Moreover, Loan Guarantee Programs are not well developed in Spain.[24]

Finally we find that public support is positively related to the probability of undertaking co-operative agreements particularly with regard to co-operation with the research institutions. This is very much in line with the orientation of public R&D funding towards this type of activity and the promoting technology transfer. However, from these results it is not possible to make definitive statements about the additionality of such public support schemes. It maybe that at least some of those firms receiving support would have engaged in some form of co-operative R&D (albeit perhaps on a smaller scale) in any case. The extent to which such schemes do overcome market failures and enable additional and economically efficient co-operative R&D to take place is an important research question given the direction of public policy in this area.

[24] Cotec (2004) and European Commission (2003).

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Appendix 1: Variable definitions

Absolute Basicness of R&D: Sum of the scores of importance of the following information sources for innovation process (number between 0 (not used) and 3 or 4 (high)): Universities; government or private non-profit research institutes. Rescaled between 0 (not used) and 1 (high)

Appropriability: Sum of indicator variables that take the value 1 if the firm uses the following methods for protecting inventions or innovations (0 (not used) and 1 (used)): Secrecy; Complexity of design; Lead-time advantage on competitors. Rescaled between 0 (not used) and 1 (used all methods)

Cooperation: Indicator variable that takes the value 1 if the firm cooperates with suppliers, customers, competitors, commercial laboratories/R&D enterprises, universities, or government or private non-profit research institutes.

Cooperation with Competitors: Indicator variable that takes the value 1 if the firm cooperates with competitors.

Cooperation with Research Base: Indicator variable that takes the value 1 if the firm cooperates with commercial laboratories/R&D enterprises, universities, or government or private non-profit research institutes.

Cooperation with Suppliers or Customers: Indicator variable that takes the value 1 if the firm cooperates with suppliers or customers.

Constraints: Importance of the following obstacles to innovation process (number between 3 or 4 (high) and 0 (not relevant)): Innovation costs too high; Lack of availability of finance; Excessive perceived economic risks. Rescaled between 0 (not relevant) and 1 (high). The questions used to construct the variable *constraint* are not available in the French survey. Hence, for the French case we use an alternative variable that also captures whether firms are constrained in their innovative activities. This is an indicator variable that takes the value 1 if the firm considers that innovation activity was burdened/encumbered with serious problems.

Export intensity: Exports divided by turnover in 2000.

Incoming Spillovers: Sum of the scores of importance of the following information sources for innovation process (number between 0 (not used) and 3 (high)): Professional conferences, meetings and journals; Fairs and exhibitions. Rescaled between 0 (not used) and 1 (high)

Industry Level of Legal Protection: Mean of Legal Protection at the industry level. Legal Protection is the sum of indicator variables that take the value 1 if the firm uses the following methods for protecting inventions or innovations (0 (not used) and 1 (used)): Patents; Registration of design patterns; Trademarks; Copyright. Rescaled between 0 (not used) and 1 (used all methods) (milegprot2)

Industry level of variable: Mean of the variable at the 2-digit NACE level.

Public support: Variable that takes the value 1 if the firm has received any kind of public financial support for innovation activities from local or national sources.

R&D intensity: Ratio of intramural/internal R&D expenditure in 2000 over turnover in 2000.

Size: Log of number of employees.

Appendix 2: Additional tables

Table A1: Results of first step OLS regression: Incoming spillovers and Appropriability

	Dependent variable = Incoming spillovers				Dependent variable = Appropriability			
	France	**Germany**	**Spain**	**U.K.**	**France**	**Germany**	**Spain**	**U.K.**
Size (no.employees)	0.019 (0.018)	0.016 (0.023)	-0.144*** (0.052)	0.088*** (0.032)	-0.019 (0.022)	0.004 (0.037)	0.037 (0.085)	0.095* (0.053)
Size squared	-0.002 (0.002)	-0.001 (0.002)	0.024** (0.010)	-0.007** (0.003)	0.005** (0.002)	0.004 (0.003)	0.002 (0.018)	-0.006 (0.004)
Industry level legal protection	0.053 (0.096)	0.144 (0.159)	0.109 (0.182)	-0.044 (0.104)	0.047 (0.110)	-0.443* (0.232)	0.110 (0.259)	-0.105 (0.197)
Public Support	0.028*** (0.010)	-0.019 (0.017)	0.033*** (0.011)	-0.016 (0.017)	0.077*** (0.014)	0.019 (0.022)	0.013 (0.016)	-0.025 (0.032)
Absolute Basicness of R&D	0.479*** (0.020)	0.298*** (0.030)	0.387*** (0.021)	0.508*** (0.034)	0.224*** (0.027)	0.182*** (0.041)	0.189*** (0.030)	0.328*** (0.062)
Export intensity	-0.035** (0.017)	0.008 (0.034)	-0.027 (0.022)	-0.016 (0.022)	0.100*** (0.024)	0.258*** (0.049)	0.150*** (0.032)	0.078** (0.039)
Industry level of cooperation	-0.154*** (0.051)	-0.227** (0.103)	-0.111 (0.069)	-0.106 (0.087)	-0.324*** (0.066)	-0.188 (0.138)	-0.107 (0.089)	-0.105 (0.163)
Industry level incoming spillovers	0.843*** (0.147)	1.004*** (0.171)	0.867*** (0.118)	0.663*** (0.210)	0.015 (0.178)	-0.045 (0.239)	0.011 (0.153)	-0.286 (0.398)
Industry level appropriability	0.034 (0.094)	-0.147 (0.122)	-0.094 (0.144)	-0.059 (0.092)	1.109*** (0.109)	1.203*** (0.164)	0.774*** (0.193)	0.969*** (0.189)
Industry level R&D intensity	-0.347*** (0.127)	0.135 (0.222)	-0.143 (0.109)	-0.078 (0.300)	-0.050 (0.174)	0.366 (0.301)	0.042 (0.149)	0.143 (0.458)
Industry level constraints	-0.054 (0.074)	-0.035 (0.147)	-0.146 (0.110)	-0.091 (0.133)	-0.008 (0.096)	-0.094 (0.177)	0.039 (0.140)	-0.048 (0.249)
Constant	-0.023 (0.062)	0.027 (0.112)	0.255*** (0.089)	-0.064 (0.125)	-0.054 (0.077)	-0.050 (0.151)	-0.121 (0.123)	-0.132 (0.210)
R^2	0.20	0.13	0.16	0.21	0.13	0.21	0.08	0.15
No. observations	3,590	1,183	2,747	1,145	3,590	1,183	2,747	1,145

** significant at 1%, ** significant at 5% level, * significant at 10% level.

Table A1 continued: Results of first step OLS regression: R&D intensity and Constraints

	Dependent variable: R&D intensity				Dependent variable: Constraints			
	France	**Germany**	**Spain**	**U.K.**	**France**	**Germany**	**Spain**	**U.K.**
Size (no.employees)	0.002 (0.006)	-0.007 (0.010)	-0.026* (0.014)	0.006 (0.012)	-0.005 (0.030)	-0.054** (0.023)	-0.231*** (0.063)	-0.022 (0.034)
Size squared	0.00004 (0.0005)	0.001 (0.001)	0.003 (0.002)	-0.001 (0.001)	0.003 (0.003)	0.004** (0.002)	0.036*** (0.013)	0.002 (0.003)
Industry level legal protection	0.009 (0.038)	-0.013 (0.027)	0.023 (0.039)	-0.023 (0.026)	0.037 (0.144)	0.133 (0.172)	0.037 (0.192)	0.082 (0.118)
Public Support	0.011*** (0.004)	0.024*** (0.006)	0.017*** (0.004)	0.002 (0.007)	0.059*** (0.018)	0.038** (0.018)	0.025** (0.012)	0.030 (0.021)
Absolute Basicness of R&D	0.016** (0.008)	0.023** (0.009)	0.035* (0.021)	0.013* (0.007)	0.196*** (0.034)	0.122*** (0.032)	0.196*** (0.022)	0.192*** (0.041)
Export intensity	0.005 (0.005)	-0.005 (0.012)	-0.001 (0.010)	0.029*** (0.010)	0.077** (0.030)	-0.071** (0.035)	-0.008 (0.023)	-0.014 (0.027)
Industry level of cooperation	-0.022 (0.016)	-0.015 (0.018)	-0.002 (0.032)	-0.023 (0.018)	-0.249*** (0.084)	-0.017 (0.108)	-0.015 (0.076)	-0.057 (0.107)
Industry level incoming spillovers	-0.004 (0.051)	-0.018 (0.033)	-0.019 (0.020)	0.002 (0.048)	-0.006 (0.234)	0.061 (0.170)	-0.108 (0.130)	-0.142 (0.240)
Industry level appropriability	0.008 (0.037)	0.005 (0.027)	-0.027 (0.025)	0.003 (0.017)	0.083 (0.131)	-0.041 (0.124)	-0.053 (0.153)	-0.081 (0.110)
Industry level R&D intensity	0.993*** (0.139)	1.001*** (0.280)	0.970*** (0.099)	1.019*** (0.231)	-0.053 (0.197)	-0.325 (0.240)	-0.115 (0.122)	0.123 (0.341)
Industry level constraints	-0.004 (0.019)	-0.026 (0.027)	-0.028 (0.058)	-0.003 (0.040)	0.987*** (0.121)	0.840*** (0.138)	0.873*** (0.116)	0.863 (0.147)
Constant	-0.011 (0.020)	0.042 (0.027)	0.049* (0.026)	-0.004 (0.039)	-0.057 (0.100)	0.202* (0.114)	0.381*** (0.094)	0.192 (0.135)
R^2	0.31	0.23	0.30	0.21	0.07	0.08	0.06	0.05
No. observations	3,590	1,183	2,747	1,145	3,590	1,183	2,747	1,145

** significant at 1%, ** significant at 5% level, * significant at 10% level.

Table A2: Understanding different types of co-operative activity: 2nd-step results

	Dependent variable = 1 if firm has a cooperative agreement with the research base				Dependent variable = 1 if firm has a cooperative agreement with suppliers or customers				Dependent variable = 1 if firm has a cooperative agreement with competitors			
	France	**Germany**	**Spain**	**U.K.**	**France**	**Germany**	**Spain**	**U.K.**	**France**	**Germany**	**Spain**	**U.K.**
Incoming spillovers **(I)**	0.888*** (0.086)	1.354*** (0.231)	0.492*** (0.094)	0.647*** (0.152)	0.495*** (0.091)	0.517** (0.204)	0.294*** (0.083)	0.419** (0.175)	0.271*** (0.052)	0.299** (0.139)	0.159*** (0.052)	0.172** (0.080)
Appropriability **(I)**	0.122 (0.140)	0.577*** (0.143)	0.468*** (0.113)	0.330** (0.142)	0.378** (0.144)	0.320*** (0.120)	0.301*** (0.103)	0.222 (0.161)	0.003 (0.090)	0.097 (0.089)	0.149** (0.067)	0.092 (0.078)
Industry level legal protection	-0.252 (0.160)	-0.636*** (0.263)	-0.617*** (0.161)	-0.270** (0.130)	-0.123 (0.170)	-0.379* (0.196)	-0.478*** (0.147)	-0.172 (0.163)	-0.055 (0.100)	-0.304** (0.124)	-0.200** (0.101)	-0.085 (0.073)
R&D intensity **(I)**	-0.341** (0.164)	-0.869** (0.383)	-0.061 (0.115)	-0.267 (0.460)	-0.265 (0.174)	-0.551* (0.321)	-0.085 (0.128)	-0.829 (0.554)	-0.095 (0.095)	-0.270 (0.215)	-0.039 (0.059)	-0.442 (0.431)
Size (ln no. employees)	0.033 (0.034)	0.029 (0.051)	0.315*** (0.081)	-0.000 (0.052)	0.039 (0.035)	0.020 (0.048)	0.227*** (0.072)	-0.032 (0.066)	-0.022 (0.017)	-0.004 (0.031)	0.098** (0.046)	-0.035 (0.031)
Size squared	0.002 (0.003)	-0.001 (0.004)	-0.040** (0.016)	0.001 (0.005)	0.0009 (0.003)	0.001 (0.004)	-0.026* (0.014)	0.004 (0.006)	0.003** (0.002)	0.002 (0.002)	-0.008 (0.008)	0.004 (0.003)
Constraints **(I)** (Hbur for France)	0.304** (0.138)	-0.299 (0.340)	0.485*** (0.152)	-0.009 (0.240)	0.047 (0.138)	-0.286 (0.286)	0.218* (0.129)	-0.049 (0.305)	0.068 (0.085)	0.093 (0.211)	0.164* (0.091)	-0.055 (0.146)
Public Support	0.125*** (0.021)	0.363*** (0.038)	0.059*** (0.015)	0.214*** (0.044)	0.075*** (0.021)	0.153*** (0.034)	0.043*** (0.014)	0.149*** (0.044)	0.032** (0.013)	0.106*** (0.026)	0.015 (0.009)	0.021 (0.022)
Industry level of specific type of cooperation	0.627*** (0.067)	0.743*** (0.194)	0.641*** (0.078)	0.597*** (0.122)	0.557*** (0.104)	0.992*** (0.210)	0.672*** (0.105)	-0.996*** (0.196)	0.534*** (0.047)	0.707*** (0.151)	0.493*** (0.076)	0.550*** (0.175)
LL	-1400.25	-436.10	-945.11	-408.28	-1825.06	-546.41	-940.52	-568.86	-1029.92	-379.17	-658.83	-218.84
No. observations	3,590	1,183	2,747	1,145	3,590	1,183	2,747	1,145	3,590	1,183	2,747	1,145

*** significant at 1% level, ** significant at 5% level, * significant at 10% level. The numbers reported are the marginal effect of the independent variable on the probability of cooperation. **(I)** indicates instrumented.