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THE REGIONAL DIMENSION OF UNIVERSITY-INDUSTRY INTERACTION*

Joaquín M. Azagra-Caro*

INGENIO (CSIC-UPV)

Universidad Politécnica de Valencia, Camino de Vera s/n, 46071 Valencia, Spain

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Abstract

Policymakers and university managers tend to express their willingness to maximise university-industry interaction inside the region. Implicitly they assume that the incentives and possibilities of all firms and faculty to interact inside the region are homogenous. However, there is no a priori reason to justify that interaction will not take place outside the region. The objective of this research is to analyse what type of firm managers and faculty members interact more often inside and outside the region. We use a sample of 700 firm managers and 380 faculty members from the Valencian Community, a Spanish region, coming from two surveys. Our dependent variables are proxies for the propensity to interact and the frequency of interaction inside and outside the region. Because of their qualitative nature, we run discrete choice econometric models to find their determinants. We include institutional and input variables and personal characteristics as regressors. Firm managers need a high academic degree to engage into R&D cooperation with universities, but then the frequency of cooperation with universities inside the region depends on their firm's revenue. On the other hand, the frequency of R&D cooperation with universities outside the region depends on being part of a group. Faculty members who usually participate in contracts (male, senior, managerial faculty) do not do it more frequently with firms inside the region. In contrast, some faculty members who do not stand out for participation in contracts (those who have done research abroad for longer periods) do it so frequently with firms inside the region as with firms outside the region. We discuss first, the key role that human capital plays at firms for interaction to take place inside the region. Second, to what extent our results are idiosyncratic of a region with low absorptive capacity like the Valencian Community. We conclude that policymakers and university managers should design conscious strategies to find equilibrium between university-industry interaction inside and outside the region.

Keywords: university-industry interaction

JEL-codes: O31-Innovation and Invention: Processes and Incentives, C25-Discrete Regression and Qualitative Choice Models

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* Tel: +34 963 877 048; fax: +34 963 877 091; e-mail address: jazagra@ingenio.upv.es.

1. Introduction

It is commonplace for scientific policymakers and university managers to mention the convenience of promoting university-industry interaction (UII) to increase technological innovation. Not so frequent is for them to clarify if they refer to interaction inside or outside the region. Implicitly they are assuming that incentives and possibilities of all firm managers and faculty members to interact inside the region are homogenous. Nevertheless, there is no a priori reason to justify that interaction will not take place outside the region.

The target of this study is to analyse what type of firm managers and faculty members interact more often inside and outside the region. In order to reach it, it is useful to decompose the question in three new ones: What type of firm managers interacts more with universities? What type of faculty members interacts more with firms? Does the answer to the previous questions vary according to whether the actors are inside or outside the same region? To find some answers, the rest of the paper follows the usual structure. Section 2 revises the literature and derives testable hypotheses. Section 3 explains the methodology and data used to test them. Section 4 shows the results. Section 5 includes the conclusions.

2. The decision to interact and the frequency of interaction inside and outside the region

This section explores the existing literature on the determinants of UII according to our target questions. Sub-section 2.1 focuses on firm managers and sub-section 2.2 on faculty members. Sub-section 2.3 treats them jointly in order to argue whether they will tend to interact more frequently inside or outside the region.

2.1. Interaction with university by type of firm manager

Since the empirical part of this paper will follow an econometric methodology, the literature review has focused on other econometric studies, when they are enough to justify the hypothesis. It has widened the scope of possibilities in other case. Sub-section 2.1.1 raises hypotheses on the relation between firm manager's institutional and input factors and their decision to interact with universities. Sub-section 2.1.2 follows accordingly, about their personal characteristics.

2.1.1. *Firm manager's institutional and input factors*

By institutional factors, we do not understand “organizations” but “things that print character” (Edquist, 1997) or, more concretely, the type of firm in which the firm manager works. Several statistical and econometric works exist on the relation between the characteristics of the firm and the degree of interaction with university. We focus on firm size, technological level, belonging to a group and geographic location¹.

Beise and Stahl (1999) find a positive, significant effect of firm size, measured through the number of employees, on the generation of innovations that could not have been developed without public research by universities. Caloghirou et al. (2000) do not find evidence that the number of employees of firms that have participated in Research Joint Ventures (RJV) of the European Union Framework Programmes (EU-FP) influences the degree of participation in R&D cooperative agreements with universities, but their sales revenue do. Acosta and Modrego (2001) do not find a significant effect of a composite of the number of employees and sales revenue, on the participation in publicly funded concerted projects. Bayona et al. (2001) find a positive, significant effect of dummy variables for large firms, on R&D cooperation. Schartinger et al. (2002) find a significant, negative effect of the proportion of large firms in an economic sector on the frequency of the resource to contract research. Laursen and Salter (2003) find a significant, positive effect of the number of employees, on the degree of use of knowledge created at universities. In summary, four out of six studies that incorporate variables on size find some evidence of its positive relation with the degree of UII.

There are two forms to study the technological level of the firm: one, through its R&D intensity and another one, through its adscription to a concrete economic sector. Beise and Stahl (1999) do not find a significant effect of firm R&D intensity on the generation of innovations that could not have been developed without public research by universities, and neither to belong to high-tech sectors, but to capital goods sectors. Caloghirou et al. (2000) do not find evidence that the intensity of R&D expenditure of firms that have participated in RJV of the EU-FP influences the degree of participation in R&D cooperative agreements with universities, but their proportion of scientists over

¹ There are some other characteristics related to firm managers linkable to UII, e.g. amplitude of the range of products (Beise and Stahl, 1999), cognitive proximity (Schartinger et al.) or motivational factors (Caloghirou et al., 2000, Bayona et al., 2001, Mora-Valentin et al., 2003). We have not considered the latter subjective factors, since we understand that they could be caused by those objective characteristics that we explain in the following sub-sections, and thus to prevent problems of endogeneity.

total staff. Acosta and Modrego (2001) find significant, positive effects of several composed variables, relative to R&D intensity, on the participation in publicly funded concerted projects. Bayona et al. (2001) find positive, significant effects, of most of their variables for R&D capacity on R&D cooperation, as well as of belonging to high technological intensity sectors. Scharfetter et al. (2002) find a significant, positive effect of the average R&D intensity of an economic sector on the frequency of the contract research, although the influence of specific sectors is not significant. Laursen and Salter (2003) find a significant, positive effect of the ratio of R&D expenditure to sales revenue, on the degree of use of knowledge created at universities, as well as belonging to chemistry and machinery sectors. In general, we can find evidence of a positive relation between technological level and degree of UII.

We have not found evidence about belonging to a group of firms. Nevertheless, Patel and Pavitt (1995) show that firms in a group are more prone to perform technological activities, although parent companies tend to decentralize them to a lesser extent than their production activities. It is possible that a greater financial potential lies behind, able to face the investment that performance of R&D demands. It seems reasonable to assume that these groups can also expend more on technology surveillance to lower the marginal cost of externalizing their R&D, so we depart from the idea that a positive relation between belonging to a group and the degree of UII may exist.

The geographic dimension of UII admits two points of view. One on the spatial proximity between firms and universities, studied in sub-section 2.3. Second, on the location of the firm, referred to the characteristics of the environment in which it is located, that we treat next. The geographic context that the studies usually talk about is not homogenous; that is to say, there exist differences inside a country or a region between its subdivisions regarding per capita income, agglomeration of economic activities, provision of infrastructures, etc. It is possible to assume that this phenomenon may condition UII and that the richest regions, with more economic activity and more universities, have greater means to make it fluent. On this issue, Beise and Stahl (1999) do not find significant that the firm belongs to less favoured regions (in their case study, to East Germany). However, since this is the only, scarce evidence found, we preferred to go back to the theoretical reflection to expect a positive relation between belonging to the richest sub-division of a region and the degree of UII.

2.1.2. Firm manager's personal characteristics

Additional reflection becomes necessary to deduce a series of hypothesis on some other interesting variables: years of professional activity, academic degree and position within the firm.

Years of professional activity denote experience in the firm and, therefore, greater probability that the individual has faced the decision to interact outside the firm and, in case of doing it, that he/she has received some feedback, which would reduce the marginal cost of later attempts. In addition, he/she will have had more time to settle the confidence on which UII often relies (Rappert et al., 1999). On the other hand, age may be behind years of professional activity, and if the manager comes from a tradition of scarce interaction, age probably will impose resistance to change and the status quo will continue. These two opposite effects suggest that the relation between years of professional activity and UII is theoretically uncertain.

In every interactive event, at least two parts get involved. Both choose their respective interlocutors, who will settle a process of communication down, subject to their own code. In the context of UII, academic and commercial elements will make this code up, the conjunction of which requires learning from both interlocutors. It is easy to assume that the greater the starting knowledge of this code, the more fluent communication will be. In addition, we can assume that an interlocutor with higher starting knowledge is that who has spent more time and gained a higher reputation in the other's environment. From the point of view of faculty members, their interlocutor in the firm will fulfil those conditions the greater his level of academic training is.

Another bridge between the codes of academic and commercial communication that may enhance UII refers to the position carried out by the firm manager. If this position involves responsibilities on similar activities to those demanded from universities, e.g. R&D, it is probable that both parts reduce the cost to interact. For that reason, the hypothesis that arises is that holding a position of responsibility in R&D activities increases the propensity of the firm manager to interact with universities.

2.2. Interaction with industry by type of faculty member

In parallel with the previous section, sub-sections 2.2.1 and 2.2.2 deal with the type of faculty members who interact with firms, the former focused on institutional and input factors and the latter on personal characteristics.

2.2.1. *Faculty members' institutional and input factors*

To our knowledge, the only econometric attempt to study UII with faculty members as an observation unit is the one by Lee (1996). However, we will use studies quoted in the previous section when they offer comparable results. We focus on the influence of type of university, type of discipline and dedication to R&D activities.²

Lee (1996) finds a negative relation between university prestige and the support for the objectives of collaboration with firms, which he considers a proxy for actual UII.³ However, and although using firms as observation unit, Mora-Valentin et al. (2003) find a significant effect of the perceived reputation of research organisations (mostly universities) on the perceived success of participation in cooperative agreements. Taking into account these considerations, it is recommendable not to impose an a priori vision on the relation between university prestige and degree of UII.

Lee (1996) also finds a positive relation between being a faculty in engineering and technological disciplines and the support for the objectives of collaboration with firms. However, Schartinger et al. (2002), using as unit of observation the crossing between scientific discipline and economic sector, find a greater propensity to interact in natural, technical, farming and economic sciences than in medicine, other social sciences and humanities. That is to say, unlike in Lee's study, neither engineering does not stand out alone at the top nor social sciences stand out alone at the bottom. In any case, that again makes the caution recommendable before raising possible relations between variables.

Finally, Lee (1996) finds some evidence through Pearson tests that the higher dedication to R&D activities, the higher the support for the objectives of collaboration with firms will be, but not after including this dedication as an explanatory variable in a econometric model together with the previous ones (type of university, disciplines). However, it is possible to argue that the difference between Lee's virtual measure of UII and actual UII is sensitive to dedication to R&D activities, since the latter increase the possibility to have something to offer to firms. Thus, before the inconclusive evidence

² There are some other characteristics related to faculty members linkable to UII. Lee (1996) finds a positive relation between the perceived support of the university and a negative relation between the fear to four possible disadvantages of UII and the support for the objectives of UII. We do not include this subjective variables for the reasons exposed in note 1.

³ Lee implicitly assumes that support for the objectives of UII is a necessary condition for actual UII to take place. Azagra et al. (2005) find that it is not a sufficient condition.

of Lee, we prefer to assume that the higher dedication to R&D activities, the higher the degree of UII will be.

2.2.2. Faculty members' personal characteristics

The literature has long studied the idea that some personal characteristics matter in the process of scientific production. Stephan (1996) sums up some findings about the influence of age, e.g. age is inversely related to research productivity and the acceptance of new ideas, but weakly. Kotrlick et al. (2002) find from their bibliographical review evidence that the relation between age and research productivity, if any, is negative, but results are not conclusive and their own finding is that it is not determinant. However, since individual research productivity has cumulative features (Merton, 1968), we believe that a better explanatory factor than age could be a measure taking into account other features of seniority, e.g. teaching rank, research awards, etc.

Regarding sex, Kotrlick et al. (2002) reach similar conclusions as with age. Traditional evidence points to higher research productivity in male faculty, but not conclusively. Xie and Shauman (1998) find that with enough control variables (time between a bachelor's degree and a PhD, marital status, time in classroom teaching, likelihood of securing research funding and research assistance) differences in research productivity disappear.

Both seniority and sex may be related to degree of UII. In addition, two other personal characteristics may deserve some attention. These are holding a managerial position, and having done research abroad. Let us assume that if most faculty members support UII, they will choose managers who lead them to that goal. Let us also assume that faculty members who do research abroad do so to improve their scientific knowledge. Hence, they will tend to travel to leading scientific countries with more to offer, especially if they are from regions with low absorptive capacity. Some of these leading countries also interact more with industry (e.g. the USA). Therefore, faculty who do research abroad may meet a more interactive culture.

2.3. Interaction inside and outside the region

Once listed the characteristics of firm managers that may explain UII, it is possible to clarify what type of UII, i.e. if individuals who show a greater propensity to interact are those who interact more often inside or outside the region. An indication in favour is the existence of much literature justifying that geographic proximity of firms to universities

causes technological innovation (Jaffe, 1989 and, in greater measurement, Acs et al., 1990). In order to confirm if it exerts the same effect on UII, we resorted again to the studies mentioned in sub-section 2.1.1.

Beise and Stahl (1999) do not find a significant effect of the proportion of scientists employed by universities in municipalities less than 100 kilometres far from the municipality of the firm, on the generation of innovations that could not have been developed without public research by universities. Scharfetter et al. (2002) find a (weakly) significant, negative effect of the average of the spatial distance between the departments of a scientific discipline and firms of an economic sector on the frequency of the resource to contract research⁴. Mora-Valentin et al. (2003) do not find a significant effect of the perception of the distance in kilometres and the perception of the time wasted travelling to the partner's address, on the success of the participation in cooperative agreements, so much for firms as for public research organisations.

That is to say, of the three works that have raised the question, only one finds a positive relation between spatial proximity and UII, and it is weak. If proximity does not influence UII, it is possible to argue that the determinants of the propensity of firms to interact will exert the same effect to interact inside and outside the region. Nevertheless, departing from the fact that the other two studies do not find evidence against, but simply non-significant, and from the positive association between proximity and innovation, we raise the hypothesis that firm managers who interact with university do it more often with universities inside the region than outside the region.

Conversely, in the absence of studies analysing this question for faculty members, we assume that faculty members who interact with industry do it more often with firms inside the region than outside the region.

3. Data and methodology

The intention of this section is to explain the methodology followed to test the hypotheses. We have data from the Valencian Community, a Spanish region with a per capita GDP about the national average. However, it has a series of technological weaknesses, e.g. a low level of expenditure on R&D (from 0.25% of GDP in 1987 to

⁴ The authors highlight that contract research is the only type of interaction on which geographic distance matters (p. 324). However, this result relies on a low significant effect, at 10%.

0.70% in 2001), mainly on the part of firms (from 40% of total R&D funds in 1987 to 31% in 2001), a shortage of financial organizations of innovation, and little articulation of institutional links (Fernandez et al., 2001). For these reasons, we define it as a region with low absorptive capacity.

We gathered data on firm managers from the Valencian Community through a survey made in 2001. The population was firms in manufacturing and telecommunications sectors. The distribution by sector was proportional to the number of firms with ten or more employees in each one. We contacted 1,843 firms and obtained a response rate of 38% percent, which allowed us to form a database with 700 observations.

The survey included questions regarding the cooperation in R&D with universities, according to their geographical location. It gave place to the following dependent variables, whose descriptive statistics appear in Table 1:

- ❖ Cooperation: usual cooperation in R&D with universities: 1 if “yes”, 0 if “no”. 10% of firm managers declare to engage in such cooperation.
- ❖ Region: frequency of cooperation in R&D with universities of the Valencian Community: 0 (“never”), 1 (“not often”), 2 (“often”) and 3 (“very often”). The frequency distribution is strongly biased to the left, with most respondents in the first category (91%), followed by the second and fourth categories (3% and 4%, respectively), and finally the second one (2%).
- ❖ Nonregion: minimum of frequency of cooperation in R&D with Spanish universities outside the Valencian Community or with foreign universities: 0 (“never”), 1 (“not often”) and 2 (“often”)⁵. Almost any respondents cooperate outside the region (96%), a few do it but not often (3%) and very few do it more frequently (1%).

Table 1. Firm managers’ sample. Descriptive statistics of dependent variables

Variable	Mean	Standard deviation	Minimum	Maximum	No. of observations
Cooperation	0.0974212	0.296743	0	1	698
Region	0.183381	0.638919	0	3	698
Nonregion	0.0415473	0.226619	0	2	698

We gathered data on faculty members from the five public universities of the Valencian Community through a survey made in 2001. We stratified the population in

⁵ Although the possibility existed, nobody answered “very often”.

three categories: full professors, assistant professors and associate professors⁶. The sample was 10% of the population, or 872 individuals. We obtained a response rate of 44%, so we could build a database with 380 observations.

The survey included questions regarding the participation in contracts with firms, according to their geographical location. It gave place to the following dependent variables, whose descriptive statistics appear in Table 2:

- ❖ **Contracts:** usual participation in contracts with firms: 0 (“no”) and 1 (“yes”). 29% of faculty members declare to participate in such contracts.
- ❖ **Region:** frequency of participation in contracts with firms of the Valencian Community: 0 (“never”), 1 (“not often”), 2 (“often”) and 3 (“very often”). Respondents predominate in the first category (71%), have the same share in the two following categories (12% each) and a few belong to the third one (5%).
- ❖ **Nonregion:** minimum of frequency of participation in contracts with Spanish firms outside the Valencian Community or with foreign firms. It takes the same values as region. Again, most respondents belong to the category that never participates in contracts (81%), some do not often participate (11%) or often participate (6%) and few do it very often (2%).

Table 2. Faculty members’ sample. Descriptive statistics of dependent variables

Variable	Mean	Standard deviation	Minimum	Maximum	No. of observations
Contracts	0.293134	0.45581	0	1	375
Region	0.493609	0.88608	0	3	370
Nonregion	0.289216	0.65744	0	3	357

Weighting variable: teaching scale

The variables that we wish to explain departing from the surveys are of qualitative and indexed nature. *Cooperation* and *contracts* are binary, so we will estimate them through a probit model. *Region* and *nonregion*, as defined for each sample, take more than two values, so we start by regressing them through an ordered probit model.

However, we may consider that individuals take first the decision to interact or not, according to their preferences and possibilities, and then they engage into more or less frequent interaction. Therefore, the appropriate technique of estimation must take into account that the equations for *cooperation* or *contracts* act as selection equations for

⁶ The equivalence between the Spanish original categories and the three categories that we mention is not exact, but it uses more popular terms and captures the intuition behind the original categories.

region and *nonregion*, which should therefore be estimated through an ordered probit model with sample selection.

Finally, we may also consider that the determinants of the frequency of interaction are relevant only for individuals who actually interact, thus those who report no interaction should be withdrawn from the sample. In this case, we would have a subsample of individual from a larger population and the appropriate technique of estimation would be a truncated model.

Next, we explain how we built independent variables on firm managers from the survey, as well as their descriptive statistics that appear in Table 3:

- ❖ Labour: number of employees in the firm: up to 10 employees (8%), 11-50 employees (69%), 51-250 employees (18%), more than 250 employees (3%).
- ❖ Sales: firm's revenue: up to 0.6 million euros (11%), 0.6-1.5 million euros (25%), 1.5-3 million euros (20%), 3-6 million euros (14%), more than 6 million euros (15%). Notice the high number of "don't know" answers for this variable (15%).
- ❖ Science: 1 for science-based sectors ("chemistry" and "telecommunications", 12%), 0 otherwise (88%).
- ❖ Group: 1 for firms within a group (20%), 0 otherwise (80%).
- ❖ Province: 1 for firms in the province with the highest per capita GDP, Valencia (48%), 0 otherwise (52%).
- ❖ Experience: years of professional activity in current and previous firms: less than 5 years (11%), between 5 and 9 years (16%), between 10 and 14 years (18%) and more than 14 years (55%).
- ❖ Training: 1 if the individual has a graduate or post-graduate (e.g. PhD) university degree (35%), 0 otherwise (65%).
- ❖ Position: 1 for directors or heads of R&D in the firm (2%), 0 otherwise (98%).

Table 3. Firm managers' sample. Descriptive statistics of independent variables

Variable	Mean	Standard deviation	Minimum	Maximum	No. of observations
Labour	2.1611	0.608942	1	4	689
Sales	2.97315	1.29613	1	5	596
Science	0.117143	0.32182	0	1	700
Group	0.200288	0.400505	0	1	694
Province	0.48	0.499957	0	1	700
Experience	3.1763	1.05732	1	4	692
Training	0.345428	0.475853	0	1	689
Position	0.0243902	0.154368	0	1	697

We will estimate starting econometric models on faculty members as a function of the following independent variables, originating also from the survey, whose descriptive statistics appear in Table 4:

- ❖ University: univ1, the oldest university (five hundred years old) with the highest scientific prestige, (traditionally) the culture most opposed to UII and the largest number of professors (31%); univ2, a younger university (thirty-five years old), with technological orientation, some reputation of active involvement in UII and next in size (29%); and univ3, a group of the three youngest universities (created during the last twenty years), the least prestigious and smallest ones (40%).
- ❖ Disciplines: ens (exact and natural sciences), et (engineering and technology) and ssh (social sciences and humanities). This last one acts as benchmark. The distribution of the three groups is homogenous, around one third of faculty each one.
- ❖ RDt: proportion of time devoted to R&D activities (30%) and not to other academic activities (teaching, other educational activities, management and other activities).
- ❖ Senior: one if the faculty is older than forty years, his/her teaching experience has lasted at least ten years, his/her teaching scale is the highest (full professor) and he/she has received at least one Spanish six-year term research award (so-called sexenium). 22% of respondents fit our definition of senior faculty.
- ❖ Sex: 1 if the respondent is a man (72%), 0 if she is a woman (28%).

Table 4. Faculty members' sample. Descriptive statistics of independent variables

Variable	Mean	Standard deviation	Minimum	Maximum	No. of observations
Univ1	0.310921	0.463481	0	1	380
Univ2	0.284886	0.451955	0	1	380
Ens	0.35209	0.478258	0	1	376
Et	0.326234	0.469459	0	1	376
RDt	0.298841	0.192734	0	0,9	376
Senior	0.215161	0.411509	0	1	361
Sex	0.723726	0.447743	0	1	380
Management	0.155714	0.363068	0	1	376
Abroad	1.28506	1.37666	0	4	373

Weighting variable: teaching scale

- ❖ Management: 1 if the respondent holds a managerial position within the university (16%), 0 otherwise (84%).
- ❖ Abroad: length of research abroad: ranging from 0 (the shortest) to 4 (the longest). The average length is between our categories 1 (0-5 months) and 2 (6-11 months).

4. Results

The following tables show the results of models reduced after a selection strategy based on minimising the Bayesian Information Criterion (BIC)⁷. Table 5 gathers the estimations on firm managers' R&D cooperation with universities. On the one hand, neither to belong to a firm located in Valencia nor to a firm that forms part of a group exerts an effect significant on the propensity to cooperate in R&D with universities. On the other hand, belonging to larger firms (measured through both number of employees and sales revenue), and in science-based sectors, has a positive, significant influence on the probability of cooperation in R&D with universities.

Regarding personal characteristics, there is no evidence that experience in industry or being head of R& are causes of R&D cooperation with universities. On the contrary, there is some evidence that to have a high academic degree is a significant cause.

Our hypothesis on the regional dimension of firm manager's interaction with university can now be reformulated to include the previous results: the expectation is that firm managers who belong to large firms in science-based sectors, and who have a high academic degree, cooperate more frequently in R&D with universities inside the region and less frequently with universities outside the region.

Columns 2 and 3 in Table 5 offer a first test of the hypothesis, regarding R&D cooperation with universities inside the region. The significant variables in the ordered probit model (column 2) are the same as for the decision to cooperate, indicating that firm managers interact inside the region. Nevertheless, notice that the threshold parameters are not ordered, so the model is not satisfactory. Even more, it is not possible to generate a significant model using the decision equation in column 1 for the selection. In column 3, the truncated model includes only one significant effect, firm size, measured through the number of employees. It is difficult, then, to assure that we fully understand the analysed phenomenon. In any case, it looks as if there was no relation between the decision to cooperate and the frequency to do it inside the region, but if there is any, it relies on the same type of firm managers.

⁷ BIC tends to penalise the entrance of new observations. Hence, final reduced models admit some non-significant variables that, if deleted, incorporate a large number of "don't knows".

Table 5. Discrete choice estimations of firm managers' decision to cooperate in R&D with universities and of their frequency of such cooperation with universities inside and outside the region

	1 Binomial probit model	2 Ordered probit model	3 Truncated model	4 Ordered probit model	5 Ordered probit model with selection
Dependent variable	Cooperation	Region	Region	Nonregion	Nonregion
No. of observations	594	594	62	595	595
Log likelihood	-147.73	-190.86	-76.55	-80.57	-188.22
Prob[$\chi^2 > \text{value}$]	0.00	0.00		0.00	0.01
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Constant	-3.56 (-10.95)	-3.81 (-11.24)	0.98 (1.93)	-3.69 (-8.52)	-0.36 (-0.19)
Labour	0.45 (2.81)	0.49 (3.08)	0.36 (2.06)	0.44 (2.08)	
Sales	0.26 (2.94)	0.27 (3)		0.12 (1)	-0.18 (-0.66)
Science	0.59 (3.03)	0.57 (2.96)			
Group				0.92 (3.89)	1.53 (3.28)
Training	0.39 (2.33)	0.45 (2.67)			
μ_1		0.32 (4.79)		1 (4.52)	1.58 (5.11)
μ_2		0.62 (6.28)			
ρ_{12}					0.06 (0.09)
σ			0.88 (9.67)		

Columns 4 and 5 in Table 5 offer the other side of the coin since they explain R&D cooperation with universities outside the Valencian Community. In the ordered probit model (column 4), there are two significant variables left: size and belonging to a group. Column 5, which gathers the model with sample selection, shows that the coefficient of size is no longer significant, but belonging to a group is. However, the correlation parameter of model in column 5 is only significant at 10%, which suggests that the relation between the decision to cooperate with university and the frequency to do it outside the region is limited. For that reason, there is no clear preference for the model without selection. It was not possible to fit a significant truncated model to find more evidence. In any case, the fact that a majority of significant variables for the decision to cooperate (sales revenue, science-based sector, training level) are not significant for the frequency of cooperation outside the region means additional evidence to support that firm managers interact more often inside the region.

Estimations for the faculty members' sample appear in Table 6. The model on the decision to participate in contracts with firms is in column 1. Beginning with institutional and input variables, we can observe that the type of university does not

significantly affect the probability that faculty members contract with firms. On the contrary, the effect of the type of discipline is significant, since the propensity to contract with firms is larger for faculty in engineering and technology and, to a lesser extent, in exact and natural sciences. In addition, more time dedicated to R&D activities, increases the probability that faculty members contract with firms.

Regarding personal characteristics, to be a senior, to be man, and to hold a managerial position increase the probability of contracting with firms. On the other hand, to spend more years doing research abroad does not exert any significant effect.

Given the previous results, the expectation now is that faculty members who belong to engineering and technology (and a bit less those of exact and natural sciences), dedicate more time to R&D activities, who are senior, men and hold a managerial position participate more frequently with in contracts with firms inside the region and less frequently with firms outside the region.

Columns 2 to 4 in Table 6 show the estimations for the variables referred to firms inside the Valencian Community. As expected, the type of university does not exert a significant influence. However, not expected, type of discipline and dedication to R&D activities do not have it either.⁸ This is to say, for faculty members, institutional and input variables are more important for the decision to interact than for the frequency of interaction. About personal characteristics, many unexpected effects occur. To be a senior is not significant anymore, and to be man loses significance. More important, to hold a managerial position has a negative, significant sign, which means that these faculty, although showing greater propensity to interact, do it less frequently inside the region. On the contrary, doing research abroad for longer periods becomes positive and significant for some of the estimations. All this suggests little correlation between the decision to interact and the frequency of doing it inside the region. The negative, significant correlation parameter in column 3 shows evidence in favour of this assertion. However, the model is significant only at 5%, so we cannot reject that the ordered probit without selection is better. However, overall, there seems to be evidence against our assumption that faculty members who interact with industry do it more often inside the region.

⁸ There are some significant effects of some universities and disciplines, but jointly they are not significantly different from the respective benchmarks. If they appear in the ordered probit models is because the BIC indicates a better fit this way. In the truncated model they are finally eliminated.

Table 6. Discrete choice estimations of faculty members' decision to participate in contracts with industry and of their frequency of such cooperation with firms inside and outside the region

	1 Binomial probit model	2 Ordered probit model	3 Ordered probit model with selection	4 Truncated model	5 Ordered probit model	6 Ordered probit model with selection	7 Truncated model
Dependent variable	Contracts	Region	Region	Region	Nonregion	Nonregion	Nonregion
No. of observations	347	341	340	93	335	334	62
Log likelihood	-173.72	-259.95	-262.15	-100.67	-192.16	-250.32	-56.47
Prob[$\chi^2 > \text{value}$]	0.00	0.00	0.04		0.00	0.01	
	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.	Coeff.
Constant	-2.24 (-8.61)	-2.66 (-8.51)	3.35 (7.51)	1.88 (18.18)	-2.67 (-8.31)	2.17 (3.91)	0.56 (1.62)
Univ1		0.53 (2.73)					
Univ2		0.13 (0.67)					
Ens	0.65 (3.11)	0.41 (1.97)	-0.68 (-2.15)		0.76 (3.09)	-0.5 (-1.16)	
Et	0.95 (4.47)	0.91 (3.99)	-0.44 (-1.26)		0.87 (3.48)	-0.95 (-2.41)	
RDt	1.44 (3.28)	1.54 (3.63)			1.36 (2.97)		
Senior	0.51 (2.68)	0.28 (1.53)	-0.39 (-1.71)	-0.13 (-0.73)	0.29 (1.49)	-0.29 (-1.03)	-0.3 (-1.6)
Sex	0.54 (2.77)	0.53 (2.73)	-0.37 (-1.39)		0.79 (3.19)		0.7 (2.18)
Management	0.45 (2.2)		-0.62 (-2.47)	-0.39 (-2.01)		-0.6 (-2.13)	
Abroad		0.16 (2.66)	0.15 (1.91)				0.16 (2.49)
μ_1		0.48 (7.01)	1.6 (4.21)		0.58 (6.54)	0.94 (3.43)	
μ_2		1.18 (9.91)	2.29 (4.54)		1.36 (7.94)	1.78 (2.97)	
ρ_{12}			-0.93 (-8.2)			-0.7 (-1.81)	
σ				0.75 (11.97)			0.63 (9.9)

Weighting variable: teaching scale

Columns 5 to 7 in Table 6 provide evidence on faculty interaction with firms outside the Valencian Community. As expected, type of university has no influence. Type of discipline and dedication to R&D activities are significant only in the ordered probit model without selection. Hence, once again, institutional and input factor seem less important than for the decision to participate in contracts with industry. With concerns to personal characteristics, to be a senior is no longer significant, but to be a man still is, at least in two of the models. Holding a managerial position has a negative, significant effect, but only in one model. The length of research abroad has a positive, significant effect, but only in one model. There is no clear preference for ordered probit with selection over that without selection, because the correlation parameter is significant only at 10%. Overall, evidence on personal characteristics is scattered, but some unexpected effects are worth mentioning: men do not fulfil the expectation to be less prone to interact outside the region, whereas having done research abroad do not fulfil the expectation not to have any effect.

5. Conclusions, limitations and future research lines

Three questions have guided the research developed throughout this work: What type of firm managers interacts more with universities? What type of faculty members interacts more with firms? Does the answer to the previous questions vary according to whether the actors are inside or outside the same region?

Concerning the first question, data of the Valencian Community shows evidence to support that belonging to large firms in science-based sectors has a positive, significant. This constitutes a limit to UIII given the persistent abundance of micro-firms in supplier-dominated sectors in regions alike. Perhaps it is recommendable not to promote R&D contracts so much as other indirect routes to benefit from the results the academic R&D. On the other hand, certain personal characteristics of firm managers, like a higher academic degree positively influences their propensity to interact with universities. Therefore, a policy designed to facilitate the insertion of university graduates and doctors in industry seems suitable to increase UII.

Concerning the second question (“What type of faculty members interacts more with firms”), in the Valencian case, to favour engineering and technology and exact and natural sciences will have a positive effect on contracts with firms, although we may wonder about the cost of taking resources aside from social sciences and humanities, which can provide other benefits. Similarly, to increase time dedicated to R&D acts positively, justifying policies to alleviate the teaching and management load or to harness possible synergies between these and R&D activities. On the other hand, senior, men faculty members who hold a managerial position present higher propensity to contract with firms. We may wonder whether this situation is optimal, e.g., are sex differences due to preferences or to discrimination? Do seniority and holding a managerial position constitute an opportunity or a barrier for the engagement into UIR?

We approached the third question (“Does the answer to the previous questions vary according to whether the actors are inside or outside the same region?”) from the point of view of both firm managers and faculty members.

With regards to firm managers, as far as those in our sample scarcely cooperate in R&D with universities outside the region, the previous results on the decision to interact in general apply here. Beyond that, trying to explain the frequency of cooperation inside the region is arduous and seems to be a sole function of firm size. Yet it is clearer that the frequency of R&D cooperation with universities outside the region depends on

belonging to a group of firms, which indicates that UII is not very decentralized, as increasing globalization in the production of goods and services would suggest.

Concerning faculty members, those with higher propensity to contract do not outstand for their frequency of interaction, some even interact less often than the rest (those who hold a managerial position) or do it more often outside the region (men). On the contrary, faculty members who do not outstand for their propensity to contract, those who have done research abroad for longer periods, interact so frequently with firms inside the region as with firms outside the region⁹.

As issues for discussion, let us recall that firm manager's propensity to interact with university relies on institutional features that most firms in regions like the Valencian Community do not possess. Hence, firm manager's frequency of interaction inside the region is a minor problem, as compared to the possibilities to interact. Improving human capital at firms becomes crucial, since it is the only personal characteristic that enhances UII, and seems a more suitable way for policymaking than trying to change the sticky economic structure. On the other hand, faculty member's propensity to interact relies on personal characteristics that do not ensure that they will interact more often inside the region than outside the region, since firms in regions like the Valencian Community may not be able to absorb academic R&D. This is not necessarily a caveat, because the region may benefit indirectly from interaction taking place outside it. Rather it implies that policymakers and university managers should design conscious strategies to find equilibrium between UII inside and outside the region. In any case, our results aim to be valid only for regions with low absorptive capacity.

There are several ways to widen the scope of this research. First, we should estimate marginal effects of the discrete choice econometric models to obtain coefficients in the form of elasticities, and thus analyse if changes between categories point in the same direction. Second, the surveys allow us to discriminate firm managers as well as faculty members who devote more than 0% of their academic time to R&D activities, and the analysis of these sub-samples would raise new hypothesis on the influence of different types of R&D, R&D budget and share of external funding. Third, our results on faculty members' sex, managerial position, and having done research abroad require additional

⁹ Exploratory evidence suggests that the former need firms with greater technological level to contract with, and they do not find them inside the region, while the latter compensate the lower technological level of the firm, if they find an interlocutor with high academic degree.

evidence, perhaps through interviews. Fourth, we should build a theory to introduce optimality criteria in order to provide more robust policy recommendations.

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