The Roles of Research at Universities and Public Labs in Innovation Systems: a Perspective from the Italian Food and Drink industry

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Abstract

The objective of the paper is to determine the role that R&D networking, through the collaboration of firms with universities, plays among the determinants of product and process innovation in the Italian food and drink industry and how geographical proximity to a university affects both R&D university-industry collaboration and innovation. The data are sourced from the 7th (1995-1997), 8th (1998-2000), 9th (2001-2003) and 10th (2004-2006) waves of Capitalia survey. The approach is a trivarate probit analysis in which the dependent variables are R&D collaboration with a university, process and product innovation; the independent variables are firm, territorial and university characteristics.

1. Introduction

The roles of universities in society have been of interest to scholars in different scientific fields. Beginning in the mid-1960s, the objectives of universities have been considered to be the production and transmission of knowledge, mainly through the channels of research, teaching and consultancy (Sonka and Chicoine, 2004).

Recently, the role that universities play as incubators of new technology-based firms, through spin-off effects, attraction of external investments and technology transfer to firms that belong to high-tech clusters, has been discussed extensively (Mansfield, 1991; Mansfield and Lee, 1996). According to the triple-helix model of university-industry-government relations (Etzkowitz and Leydesdorff, 2000; Etzkowitz, 2004), universities play a further crucial role in a pattern of technology-led local development through the creation of networks between industry and government; these networks foster the conditions for innovation. More precisely, the collaborative partnership between university and industry, which is facilitated by government programs, builds new forms of social capital, in the form of communication and trust, into the national research systems. Empirical evidence for the key role played by the collaboration between university and industry for the success of relatively small high-tech firm systems is found all over the world. A further relevant aspect that is emphasised in literature is that the above-mentioned type of social capital can be particularly important in the presence of cognitive gaps, which make geographical proximity a necessary condition for R&D collaboration (de Jong and Freel, 2010).

Traditional channels of technological transfer from universities to firms are training, through the supply of human capital (which consists of individuals who are highly specialised in terms of their technical and scientific skills), consultancy, and contract and joint research; these forms are more frequent than co-patenting or spin-out activities and may represent important channels of university-firm interaction (D'Este and Patel, 2007). The relative importance of these channels can be sector-specific. For example, training is particularly important for the interaction between university and firms in the food and drink industry (F&D) to conform to food safety law prescriptions and health safety requirements.

The aim of this paper is to assess the effect of universities on innovation in the Italian F&D industry with respect to the other determinants that are customarily used in the literature to explain the adoption of process and product innovation.

The analysis is carried out using data from the time period 1995-2006 regarding F&D firms contained in the 7th (1995-1997), 8th (1998-2000), 9th (2001-2003) and 10th (2004-2006) waves of the Capitalia survey. A quite long period is necessary to determine the effects of collaboration between universities and industry. The approach adopted is a trivariate probit regression in which the dependent variables are the presence of R&D

collaboration with a university, process innovation and product innovation, whereas the independent variables are firm, territorial and university characteristics.

2. The determinants of university-industry collaboration

Several studies have analysed the determinants of university-industry collaboration and identified drivers that can be grouped as proximity, university, firm and territorial characteristics.

Geographical proximity (Boschma, 2005) plays a fundamental role as a determinant of university-industry collaboration, which has been recognised by different bodies of literature: studies of localised knowledge spillovers, studies of the systemic nature of knowledge and innovation, from innovation systems to the triple-helix model, and studies of industrial clusters.

The aforementioned bodies of literature share a similar assumption about geographical proximity: firms that are located nearby universities may frequently collaborate with universities and benefit from knowledge spillovers. Geographical proximity (Morgan, 2004) enables the transmission of tacit knowledge, which, being personal and context-dependent, cannot be easily bought via the market and is difficult to communicate other than through personal interaction in a context of shared experiences. In particular, geographical proximity matters when knowledge spillovers are informal (Audretsch and Feldman, 1996).

On the other hand, codified knowledge, which is explicit and standardised, can be transmitted over longer distances and across organisational boundaries at a low cost. The capability of shared codification creates non-spatial proximity: cognitive proximity, which is the extent to which two organisations share the same knowledge, and organisational proximity, which is due to the accumulation of experience between the same or similar actors. When knowledge is transmitted through formal ties between researchers and firms, geographical proximity is not necessary because face-to-face contact does not occur by chance but instead is carefully planned (Audretsch and Feldman, 1996). Cognitive proximity is generally higher in natural sciences research than is social sciences research because social science knowledge is less codified than that of the natural sciences and is not based on a unified and established scientific methodology. Rather, it is idiosyncratic to very specific disciplines, sub-disciplines and even research approaches. Thus, geographical proximity to universities may be more important for accessing social science research than for accessing natural science research (Audretsch *et al.*, 2005).

Among university characteristics, the determinants of university-industry collaboration that have been identified in the literature are academic research quality, university size and faculty/discipline composition, department size, intermediation and the age, seniority and gender of researchers.

Academic research quality (Mansfield, 1991) is expected to act as a catalyst for industrial labs that are interested in carrying out joint research activities by attracting firms with forefront technologies. D'Este and Iammarino (2010) disentangle the effects of geographical proximity and university research quality on the frequency and distance of university-industry research collaborations. Muscio and Nardone (2012) find that academic research quality positively impacts the private funding of university research activities, particularly in the case of food sciences departments. The age of a university, as measured in years, is also used to control for reputation effects to explain the birth of knowledge-based start-ups located within close proximity to universities (Audretsch and

Lehmann, 2005).

To take into account that academic institutions need a critical mass of researchers to improve their chance of interacting with firms, scholars have also introduced into the analysis the university and department size, which is quantified as the number of researchers (or the percentage of time) devoted to research activities (Landry *et al.*, 2007; D'Este and Iammarino, 2010; Muscio and Nardone, 2012).

The university faculty/discipline composition or the academic scientific specialisation are introduced into the analysis of university spillovers to capture the different amount of tacit knowledge produced and the capability of technology transmission (Landry *et al*. 2007). The latter is also proxied by the presence of a technology transfer office that aims to decrease the cognitive distance between business and academics (Muscio and Nardone, 2012) or by the regional location of university for tacit-knowledge-intensive industries (Fitjar and Rodríguez-Pose, 2012).

Among personal characteristics of scholars, age and carrier status are taken into account because older scientists and full professors are expected to accept multiple offers of firm involvement, whereas younger scientists and research assistants are more likely to be involved with a local firm than with a nonlocal firm or to be not involved at all (Audretsch and Stephan, 1996; Landry *et al*., 2007). Gender is also used as a control variable (Landry *et al.*, 2007).

The firm characteristics that are identified in the literature as drivers of university-industry R&D collaboration are the size, ownership, public subsidies for the promotion of innovation and multi-purpose nature of university-firm collaboration (Piga and Vivarelli, 2004; Medda *et al*., 2005; Bodas Freitas *et al*., 2011).

3. The issues that this paper addresses

Following the suggestion of the aforementioned studies, the first question addressed in this paper is the following: how does geographical proximity explain the choice of R&D university-industry collaboration and the choice of product and process innovation?

No effect of geographical proximity is expected for the variable university-industry collaboration because this collaboration is carefully planned, whereas geographical proximity is expected to be significant for product and/or process innovation to the extent they are based on a certain amount of personal and context-dependent tacit knowledge. If geographical proximity is significant, what is the distance from a university that enables innovation? Which type of innovation is more sensitive to geographical proximity?

The second question is the following: how does academic research quality affect university-industry collaboration and product and process innovation? Is firm perception of academic quality the same for these three choices? We use several indicators of academic research quality because the standard measure of reputation used in the literature (the number of citations of the faculty research staff) is unavailable for the entire period examined.

Complementary to the first two questions, the third question is as follows: how does codified knowledge affect product and process innovation? An indicator of codified knowledge is constructed using a weighted average of the faculty scientific production obtained using the annual scientific disciplinary composition of the faculty; the number of articles of the corresponding scientific discipline is taken to be the median of the scientific production of the population of Italian full professors over the 2002-2012 period.

The fourth question relates to the impact of training at universities on university-industry collaboration and whether the impact of university training on innovation is stronger than the impact of formal and informal university-industry collaboration.

4. The data

The firm data used in the paper are sourced from the "Survey of Italian manufacturing firms", which was formerly run formerly by Mediocredito Centrale and currently by Capitalia, two Italian credit institutions. The analysis is built on four waves, which cover the periods 1995-1997 (7^{th}), 1998-2000 (8^{th}) 2001-2003 (9^{th}) and 2004-2006 (10^{th}); each wave includes over 4000 firms. The corresponding samples are stratified by firm size, by sectors and by geographical area; they are representative of Italian manufacturing firms with more than 10 employees.

In the Capitalia Surveys firms are asked whether product and/or process innovation was introduced during the previous three years. The questionnaire also collects information, together with other firms' characteristics, on the presence of *extra-moenia* collaborations in R&D with universities and other public research labs. Only in the last wave, related to the 2004-2006 period, information was provided whether these universities are regional or not[1].

Using their ATECO classification, F&D firms have been extracted, thereby resulting in a pool of 1,744 firms for the 1995-2006 period.

Size classes have been defined following the AGRA (2004) classification, with respect to turnover thresholds, which are expressed in constant 2006-based €: very small-sized: < 5 ml €; small-sized: ≥ 5-25 ml €; medium-sized: ≥ 25-50 ml €, large-sized: ≥ 50-100 ml € and very large-sized ≥ 100 ml €.

Information about the municipality (or, in its absence, of the province) in which the firm is located has been used to identify the first three closest faculties of agriculture. The choice of focusing on these faculties is supported by the evidence that most of the university collaborations of F&D firms is with the regional faculty of agriculture; furthermore, a firm that has university collaborations is likely to have multiple university or public research lab partners (Bodas Freitas *et al*., 2011) and the probability that one of these partners is the regional faculty of agriculture is very high. Consequently, three distances, as the crow flies[2], in kilometres for each firm are present in the data set. A fourth variable for geographical proximity is a dummy that takes the value 1 if the closest faculty of agriculture is more than 150 kms away; this value was chosen after testing different thresholds.

With respect to the closest faculty of agriculture, further information was gathered: whether the faculty is extra-regional; whether it is public; its birth year; its annual size in terms of scholars[3]; the annual composition of scholars in terms of: i) gender, ii) birth year, iii) carrier status (researchers, associate and full professors), and iv) group of scientific disciplines (ISTAT, Statistiche sulla Ricerca Scientifica; http://www.cnvsu.it/); the annual faculty reputation, which was kindly offered by Censis for the year 1998-2006; the presence of a food technologist degree 5-year course and the presence of a food technologist degree 3-year course (Ministero dell'Università e della Ricerca Scientifica, several years). The number of biotechnologist degree courses are relative to the university regional supply (Ministero dell'Università e della Ricerca Scientifica, several years; ISTAT, several years; INEA, several years).

The academic research quality is measured through the grades given by the Italian

[1]According to this information, only 4 F&D firms had R&D collaborations with extra-regional universities.
[2] http://distanzechilometriche.net/
[3] http://cercauniversita.cineca.it and http://www.cnvsu.it/

Evaluation of Research Quality, hereafter VQR, for the 2001-2003 and 2004-2010 periods. The VQR grade is a composite indicator of the quality of the research output produced by universities or public research labs under the supervision of the Higher Education Department in the evaluation period. Groups of Experts of Evaluation, coordinated by the National Agency for the Evaluation of Universities and Research Institutes, evaluated the research output using both bibliometric analysis and informed peer review. Two other indicators of faculty reputation that are used in this paper, are the following annual grades supplied by Censis for the period from 1998 to 2006: the research grade, which is based on the number of research projects financed by national and international institutions, and the international grade, which is based on the international mobility of scholars and students. This information is missing for the 1995-1997 period, thus the two grades for 1998 have been used for the first period; for the remaining periods, the two grades are the average of the grades for the three corresponding years.

The mentioned indicator of codified knowledge is built using the medians of the ISI-Scopus indexed scientific production of the populations of full professors of the Italian faculties of agriculture grouped by scientific discipline over the 2002-2012 period[4].

The descriptive statistics of the sample are not reported for space reasons.

5. Methodology and results

The econometric model consists of three simultaneous processes. The first one explains the decision of R&D collaboration with universities or public research labs, the second one explains the decision of innovating firm products and the third one explains the decision of innovating firm processes. These three processes are jointly described by a trivariate probit model because the dependent variables (R&D collaboration with universities or public research labs, product and process innovation) are dummy variables. The common latent factor structure of the trivariate probit framework allows us both to control for the potential endogeneity of the decision of R&D collaboration with universities and to correct the potential sample selection.

The results of the trivariate probit regression are reported for several variable specifications in tables 1, 2 and 3 where the standard errors (not reported) of the coefficients have been clustered around the regions where the firm is located. The likelihood ratio test, which was conducted on the hypothesis that rho_{21} and rho_{31} are jointly null, supports the trivariate framework.

Table 1 reports the marginal effects for the first equation where R&D university or public research labs-firm collaboration is the dependant variable.

With regard to geographical proximity, the 1st and the 2nd (not reported) distances are not significant while the 3rd (not reported) is weakly significant and a distance from the closest faculty of agriculture higher than 150[5] km is highly significant. The interpretation of these results is that isolated firms, distant more than 150 kms from the faculty of agriculture, choose to collaborate with the closest faculty while less isolated firms have more chances to choose in relation to the expertise they need and their choice could be to collaborate with the staff of the third closest faculty.

Positive determinants of R&D university-firm collaboration are: R&D collaboration with private firms, skilled employees, R&D intensity, subsidies and non standard jobs.

[4] http://abilitazione.miur.it/

[5] This value has been selected by comparison with the results of the dummies, alternatively tested, for 50, 75, 100 and 200 km. All these dummies are not significant.

Very small-sized firms and co-ops are negative determinants. Public research is complementary to and not a substitute for private research, as was already found for Italy (Fantino *et al*., 2013).

Among the university characteristics, the public status of the university and the number of faculties of agriculture, within the same region, are significant but negative (in the regressions run for the entire period; however, they lose significance in the regression run for the period 2001-2006).

Among the faculty characteristics, the age is significant and negative: younger faculties are more available for R&D collaboration with F&D firms, probably as the consequence of less hierarchical structures and of fund-raising needs; however, the age loses significance in the regression run for the period 2001-2006. The size is significant and positive only in absence of research quality indicators. The presence of geologists induces collaboration, in the regressions run for the entire period, while the presence of chemicals always discourages them. The presence of physicians loses significance when the amount of codified knowledge is introduced into the regression. Among the training variables, the 5-year food technologist degree course is a channel for R&D University collaboration while both the 3-year food technologist degree course (particularly in the previous period) and the biotechnologist degree courses (in the last period) have discouraged R&D university collaboration.

Among the personal characteristics of scholars, the absence of gender segregation (the presence of women on full professors), proxy of a meritocratic institution, induces R&D university collaboration while the presence of researchers on total scholars prevent them, as suggested by the literature; both the variables lose significance in the last period.

Finally, we introduce the indicators of research quality into the regressions: the research grade is weakly significant, because it is a too generic indicator of academic research quality, while the amount of codified knowledge is highly significant and the VQR grade is weakly significant. If the number of journal articles, on average produced by full professors, increase by, let' say 10, the increase in the probability of R&D collaboration with F&D firms is 0.10.

Table 2 reports the marginal effect for the dependant variable product innovation.

Product innovation is determined by subsidies, R&D intensity, R&D *extra moenia* from private firms and skilled employees. Very small-sized and small sized firms are less innovative.

With regard to geographical proximity, the 1st distance from the faculty of agriculture is highly significant and negative while the 2nd and 3rd distances (not reported) are not significant. Analogously, a distance from the closest faculty of agriculture higher than 150[6] kms is highly significant and negative: a firm that is in the radius of 150 kms far from a faculty of agriculture has 0.19 more probability of product innovation than a more distant firm.

Firms locate in agricultural districts are less product-innovative.

Among university and faculty characteristics, the number of regional faculties of agriculture and the number of disciplines present in the closest faculty of agriculture are highly significant and positive. Size tends to be significant and weakly negative, probably because larger faculties tend to promote the commercial exploitation of academic research results and may inhibit informal technology transfer, as found by Landry *et al*. (2007). Among disciplines, no clear predominance emerges.

[6] This value has been selected by comparison with the results of the dummies, alternatively tested, for 50, 75, 100 and 200 kms. All these dummies are not significant except for the dummy relative to a distance higher than 100 kms which is significant at the 4% level with a marginal effect equal to 0.08.

The indicators of research grade and of codified knowledge are significant and negative: faculties more involved in projects, aimed at codified knowledge production, have less resources to devote to consultancies or to informal collaboration and scholars tend to concentrate on academic publications because industry-oriented research may deteriorate their publication profile (Bonaccorsi *et al*., 2006). The VQR grade is not significant.

It is interesting to notice that for product innovation the geographical distance from the faculty of agriculture is significant while the R&D collaboration with university is not and the amount of codified knowledge produced by the closest faculty of agriculture is negative, confirming that when innovation is produced by tacit knowledge, geographical distance from university matters.

The marginal effects for process innovation are reported in table 3. Process innovation is determined by R&D *extra moenia* from university or public research labs, subsidies, R&D *extra moenia* from private firms, R&D intensity and sales through distribution chain agreement; no size effect is significant.

Geographical distances from the faculty of agriculture are not significant while the number of disciplines, present in the closest faculty of agriculture, is significant and positive.

Finally, the research grade is significant and positive: the projects financed at universities have effects on process innovation of local firms. The codified knowledge production is not significant: the amount of codified knowledge, produced by the closest faculty of agriculture is not directly relevant for process innovation but only through the selection of a university as an R&D partner.

6. Concluding remarks

Objective of the paper is to verify which role the collaboration of firms with universities and public research labs plays among the determinants of product and process innovation in the Italian food and drink industry and how geographical proximity to university explains both the choice of collaborating in R&D with universities or public research labs and of innovating.

The results obtained show that isolated firms, distant more than 150 kms from university, choose to collaborate with the closest university while less isolated firms have more chances to choose in relation to the expertise they need and their choice is not affected by geographical proximity. Product innovation is affected by geographical proximity to university since a firm in the radius of 150 kms from university has 0.19 more probability of product innovation than a more distant firm. Process innovation is not affected by geographical proximity to university.

The academic research quality indicator relevant for university-industry collaboration is the amount of codified knowledge, potentially produced by the closest university. The amount of codified knowledge, however, negatively affects product innovation; it is not directly relevant for process innovation but only indirectly through the selection of R&D university partners. Process innovation is directly affected by the number of projects financed to university by national and international sources.

Training can be an important channel for R&D collaboration, even stronger than the presence of subsidies, and it is a direct channel of technological transfer for product innovation.

Some implications for a public research policy can be derived from these results. First of all, the supply of degree courses, which satisfies the demand for high skills of the local labour market, has impact on the probability of firm innovation and of university-firm interaction. An appropriate choice of degree courses and a good teaching, particularly for large faculties, are not only as tools for local development spillovers but also a potential future source for private funding to universities. As a consequence, universities should carefully plan the supply of degree courses through direct contacts with firms and monitor scholars' teaching performance using the information on the evaluation of degree courses and/or the placement of graduated students, which are generally annually surveyed.

Product innovation in the Italian F&D industry seems to be a tacit knowledge-intensive activity since co-location with a faculty of agriculture increases the probability of product innovation. For this kind of activities, firm small size can still represent a problem mainly related to difficulties in developing successful university-industry-regional government relations. On the other hand, process innovation appears as a codified-knowledge-intensive activity because it is determined by R&D university collaboration without the requirement of co-location with a faculty of agriculture. For this kind of activities, size is not limiting since firms can acquire R&D *extra-moenia*, particularly from universities or public research labs, or through distribution chain agreements.

The role played by university-firm collaboration is different for these two innovation activities and, as a consequence, also public research policy interventions should be tailored to different needs.

In the case of product innovation, appropriate incentives should be given to universities to increase their involvement in this kind of collaborations. Some indicators of this product should be discussed and included into the national evaluation of university output if universities have to pursue its 'third mission'.

In the latter case, resources devoted to projects in multi-disciplinary faculties, which reach a high research quality level, may guide both university-firm collaborations and process innovation.

Variables	dF/dx	dF/dx	dF/dx	dF/dx	dF/dx
	model 1	***model 2***	***model 3***	***model 4***	***model 5***
R&D collaborations with private firms	0.08***	0.08***	0.09***	0.09***	0.07**
Skilled employees	0.002**	0.002**	0.002**	0.002**	0.003***
R&D intensity	0.01**	0.01**	0.01**	0.01**	0.00
Co-op firm	-0.05**	-0.05**	-0.05**	-0.05**	-0.04*
Subsidies	0.05***	0.05***	0.05***	0.05***	0.05**
Non standard jobs	0.03***	0.03***	0.02**	0.02**	-0.01
Firm age	0.00	0.00	0.00	0.00	0.0005**
Very small-sized firm	-0.09**	-0.07***	-0.08**	-0.08**	-0.10***
Small-sized firm	-0.02	-0.02	-0.02	-0.02	-0.02
Medium-sized firm	-0.02	-0.02	-0.02	-0.02	-0.04
Large-sized firm	-0.07	-0.07	-0.07	-0.07	-0.04
North	0.01	0.01	-0.03	-0.02	-0.03
South	-0.01	-0.01	-0.05**	-0.04**	-0.02
Food district	-0.02	-0.02	-0.02	-0.02	-0.04
Agricultural district	0.00	0.00	0.01	0.01	0.07
1st distance	0.00				
Distance > 150 kms		0.06***	0.05***	0.05***	0.04
Biotechnologist degree courses			-0.01	-0.02	-0.08**
Food technologist degree 5-year course			0.07***	0.07***	0.04**
Food technologist degree 3-year course			-0.04***	-0.05***	-0.02
Extra-regional faculty of agriculture			0.00	0.00	0.02
Faculty of agriculture 's age			-0.002**	-0.002**	-0.001
N. of scholars			0.001**	0.001*	0.00
N. of graduates			0.00	0.00	0.00
Industrial engineers on total scholars			0.00	0.00	0.01
Biologists on total scholars			0.00	0.00	0.004**
Chemicals on total scholars			-0.004***	-0.01***	-0.01**
Physicians on total scholars			0.0003**	0.00	0.01
Geologists on total scholars			0.01**	0.01**	0.01
N. of scientific macro-fields			0.00	0.00	0.00
Women on full professors			0.002***	0.002***	0.00
Researchers on total scholars			-0.002**	-0.003**	0.00
Average age of scholars			0.00	0.00	0.00
N. of regional faculties of agriculture			-0.002**	-0.02**	0.00
Public univerisity			-0.13**	-0.12**	-0.11
Technological transfer office			0.02	0.01	-0.03
International grade				0.00	
Research grade				0.0001*	
Codified knowledge indicator				0.01**	
VQR grade					0.005*
Year dummies	Yes	Yes	Yes	Yes	Yes
N. obs.	1535	1535	1535	1535	722
LogL	-2083	-2082	-2049	-2042	-946
rho21	-0.03	-0.03	-0.01	-0.01	0.17
rho31	-0.14*	-0.14	-0.12	-0.11	0.17**
rho32	0.42***	0.42***	0.43***	0.43***	0.55***
LR	105	103	103	104	88

Table 1 - Triprobit regression. Marginal effects for the dependent variable R&D university and public research labs-firm collaboration

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

Variables	dF/dx	dF/dx	dF/dx	dF/dx	dF/dx
	model 1	***model 2***	***model 3***	***model 4***	***model 5***
R&D university-firm collaboration	0.09	0.10	0.08	0.09	-0.10
R&D collaborations with private firms	0.13***	0.13***	0.13***	0.13***	0.08*
R&D intensity	0.02**	0.02**	0.02**	0.02**	0.02*
Skilled employees	0.003**	0.003**	0.003**	0.003**	0.00
Sales through distribution chain	0.00	0.00	0.00	0.00	0.00
Co-op firm	-0.04**	-0.05**	-0.05**	-0.05**	-0.04
Subsidies	0.17***	0.17***	0.17***	0.18***	0.33***
Non standard jobs	0.03	0.03	0.02	0.03	0.05
Firm age	0.00	0.00	0.00	0.00	0.00
Very small-sized firm	-0.09**	-0.10**	-0.09**	-0.08**	-0.08
Small-sized firm	-0.06**	-0.06**	-0.05	-0.05*	-0.02
Medium-sized firm	0.04	0.04	0.06	0.06	0.09
Large-sized firm	-0.04	-0.04	-0.04	-0.04	-0.11
North	-0.03	-0.03	-0.05	-0.07*	-0.10
South	-0.02	-0.02	0.04	0.04	0.06
Food district	-0.03	-0.04	-0.06	-0.06	0.02
Agricultural district	-0.04	-0.06**	-0.06**	-0.07**	-0.18**
1st distance	-0.001**				
Distance > 150 kms		-0.16***	-0.19***	-0.19***	-0.07
Biotechnologist degree courses			0.00	0.00	0.10
Food technologist degree 5-year course			0.02	0.01	0.09**
Food technologist degree 3-year course			0.05**	0.05**	0.01
Extra-regional faculty of agriculture			0.04	0.05*	0.00
Faculty of agriculture 's age			0.00	0.00	0.00
No. of scholars			-0.001*	-0.001*	-0.001
No. of graduates			0.00	0.00	0.00
Industrial engineers on total scholars			0.01	0.00	0.01
Biologists on total scholars			0.00	0.00	0.00
Chemicals on total scholars			0.00	0.004***	0.00
Physicians on total scholars			0.00	0.00	0.00
Geologists on total scholars			0.01	0.01	0.01
N. of scientific macro-fields			0.03**	0.03***	0.02
N. of regional faculties of agriculture			0.03***	0.04***	0.02
Public univerisity			-0.05	-0.07	-0.11
Technological transfer office			-0.02	-0.01	0.02
International grade				0.00	
Research grade				-0.002**	
Codified knowledge indicator				-0.03***	
VQR grade					-0.005
Year dummies	Yes	Yes	Yes	Yes	Yes
Sub-sector dummies	Yes	Yes	Yes	Yes	Yes
No. obs.	1535	1535	1535	1535	722

Table 2 - Trivariate probit regression. Marginal effects for the dependant variable product innovation
***** significant at 1% level ** significant at 5% level * significant at 10% level**

Variables	**dF/dx**	**dF/dx**	**dF/dx**	**dF/dx**	**dF/dx**
	model 1	***model 2***	***model 3***	**model 4**	***model 5***
R&D university-firm collaboration	0.26**	0.26**	0.26***	0.24**	0.02
R&D collaborations with private firms	0.11*	0.11*	0.10*	0.11*	0.10*
R&D intensity	0.03***	0.03***	0.03***	0.03***	0.03***
Skilled employees	0.00	0.00	0.00	0.00	0.00
Sales through distribution chain	0.0005***	0.0005***	0.0005*	0.0005**	0.001**
Co-op firm	0.01	0.01	0.01	0.01	-0.03
Subsidies	0.20***	0.20***	0.20***	0.21***	0.24***
Non standard jobs	0.01	0.01	0.01	0.02	0.02
Firm age	0.00	0.00	0.00	0.00	0.00
Very small-sized firm	-0.06	-0.06	-0.06	-0.06	-0.05
Small-sized firm	-0.01	-0.01	-0.01	-0.01	-0.05
Medium-sized firm	0.05	0.04	0.04	0.04	0.00
Large-sized firm	0.09	0.09	0.09	0.09	0.01
North	-0.07*	-0.07	-0.07**	-0.06*	-0.07
South	-0.02	-0.02	-0.02	-0.01	-0.11*
Food district	-0.03	-0.03	-0.03	-0.03	0.02
Agricultural district	0.02	0.01	0.01	0.00	-0.11***
1st distance	0.00				
Distance > 150 kms		-0.11	-0.10	-0.09	-0.19
Biotechnologist degree courses			-0.01	0.00	-0.09
Food technologist 5-year degree course			-0.02	-0.02	-0.05
Food technologist 3-year degree course			-0.02	-0.02	-0.03
Extra-regional faculty of agriculture			-0.02	-0.03	-0.07
Faculty of agriculture 's age			0.00	0.00	0.00
No. of scholars			0.00	0.00	0.00
No. of graduates			0.00	0.00	0.00
Industrial engineers on total scholars			0.00	0.00	-0.01
Biologists on total scholars			0.00	0.00	-0.01***
Chemicals on total scholars			0.00	0.00	0.01
Physicians on total scholars			0.00	0.00	0.02**
Geologists on total scholars			0.01	0.01	0.03
N. of scientific macro-fields			0.02**	0.02**	0.05***
N. of regional faculties of agriculture			0.02	0.02	0.01
Public univerisity			-0.26***	-0.26***	-0.42**
Technological transfer office			0.02	0.01	0.00
International grade				0.00	
Research grade				0.002**	
Codified knowledge indicator				0.00	
VQR grade					0.00
Year dummies		Yes	Yes	Yes	Yes
Sub-sector dummies		Yes	Yes	Yes	Yes

Table 3 - Trivariate probit regression. Marginal effects for the dependant variable process innovation
**** significant at 1% level ** significant at 5% level * significant at 10% level*

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