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Abstract
In National Innovation Systems (NIS), knowledge is generally understood to be produced and accumulated through an interactive innovation process that is embedded in a national context which in turn may help determine propensity for innovation. This paper aims to verify how product and process innovation in the European food and drink industry are affected by: i) NIS structure ii) NIS output in terms of WoS indexed publications and the supply of graduates iii) NIS fragmentation and coordination and iv) NIS scientific impact and specialisation. The main source of data on innovation by firms is the EU-EFIGE/Bruegel-UniCredit dataset. This is supplemented by information from the International Handbook of Universities, Eurostat and the bibliometric analysis of academic research output. The results obtained suggest that large research institutions in the public sector may well be detrimental to interaction between university and industry and that the indicators used for public research assessment are not necessarily the most appropriate proxies of local knowledge spillovers.

Keywords: university–industry interaction, firm R&D collaboration, product and process innovation, academic research quality, university education

Classification JEL: O3, I23, D22, R1

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1. Introduction

The importance of academic knowledge production for industrial innovation has been widely acknowledged since the ground-breaking work of Mansfield (1991, 1995), Lundvall (1988), Freeman, Lundvall and Nelson (1988), and is considered especially important for science and technology-based sectors. Universities generally play the principal role in the production of knowledge generated in the public sector and are among the actors of the National Innovation Systems (NIS), which comprise all agents involved in the innovation process, their actions, interactions and the formal and informal rules that regulate the system (Nelson, 1993). Nation-based mechanisms of production and diffusion of technology seem particularly important to the food and drink (F&D) industry of developed countries which relies heavily on technology provided by public research institutions and complementary sectors (Rama, 1999, 2008). Knowledge resources available in universities and research institutes within the nation provide the key to explaining the remarkable international F&D industry performance of even relatively small countries such as the Netherlands and Denmark (Andersen and Lundvall, 1988). Furthermore, shared background, a common language, accessibility to local knowledge providers and geographical proximity facilitate the interconnectivity of enterprises, industries and public research institutions, thus promoting R&D collaboration, product upgrading and innovation.

The effect of university scientific production on industrial innovation has already been extensively investigated with the production-function approach in the study of academic spillover. There is also a growing corpus of empirical literature regarding university–industry collaboration focussing on the benefits as perceived by the firms themselves (De Fuentes and Dutrénit, 2012). Various kinds of study have also been carried out to determine the impact of university–industry collaboration in terms of outcome variables, particularly innovation and proxy for innovative performance. However, the direct impact of university knowledge production on innovation by firms, while being implicitly acknowledged by studies which have included academic research quality among the determinants of university–industry collaboration, has been only sporadically examined. Mansfield and Lee (1996) report the citations of academic researchers concerning innovation in certain high-tech industries; Jiang *et al*. (2010) explain the number of patents of incumbent firms in terms of co-authorships with university scientists and citations of scientific articles and Baba *et al*. (2009) analyse the impact on patents of collaborations with academic scientists differentiated according to their publication and patenting profiles.

The above-mentioned studies have generally dealt with technologically advanced sectors, using patents as innovation proxy and assuming that the number of scientific publications in high-ranked journals is the best indicator of academic research quality to assist firms in their choice of R&D partners. However, it has been found that for a relatively low-tech sector, such as the F&D industry, a large number of scientific publications in high-ranked local journals may even be negatively related to product innovation (Maietta, 2015).

This evidence suggests that local knowledge spillovers and scientific publications in high-ranked journals cannot be assumed to be joint-output. Indeed many university scientists feel their publication profiles and hence their academic careers might be compromised, were they to publish specific industry-oriented research. Although academic careers continue to be conditioned by traditions of academic self-governance within national regulations, the international standard of American universities, where publications play a vital role (*publish or perish*), is gradually taking root all over Europe (Robin and Schubert, 2013).

Tendencies towards such international convergence are particularly strong for the publicly supported, decentralised agri-food research system (Ruttan, 2001), not only in terms of scientific output indicators but also in terms of NIS structure. This is the case with the EU agri-food research system where the Standing Committee on Agricultural Research (SCAR) (EEC Reg. No 1728/74) periodically monitors the NIS fragmentation and coordination.

The present study aims to contribute to the relatively small amount of literature on the determinants of R&D investment and of product and process innovation by firms in the F&D sector (Acosta et. al, 2015; Maietta, 2015). The paper also contributes to the extant literature on industry-science linkages in an international framework. To this end the integrated empirical approach proposed by Maietta (2015) is adopted which examines demand-side factors regarding knowledge, drawn from firm-specific variables, environmental considerations and supply-side factors regarding knowledge drawn from NIS variables. The paper analyses the factors that influence the probability of linkages between firms and universities alongside the assessment of the efficiency of such interactions in terms of innovation by firms. Indicators of trans-national assessment of both NIS structure and output, which are a new feature in this field, are included in the analysis since the identification of appropriate indicators of research inputs and outputs are crucial for impact assessment (Ekboir, 2003).

More specifically, the aims of this paper are to verify how collaboration and innovation by firms and enterprises in the European food and drink industry are affected by: i) NIS structure in terms of universities; publicly funded research labs; faculty/department mix and size ii) NIS output in terms of WoS indexed publications; supply of graduates (ISCED97 levels) iii) NIS structure in terms of fragmentation and coordination iv) assessment of NIS output in terms of scientific impact and specialisation.

The methodology adopted consists of a simultaneous multi-equation approach that addresses both the endogeneity of R&D decisions and the simultaneity of internal and external R&D investment. Since the dependent variables are dummy, the simultaneous approach is a multivariate probit model. The dependent variables refer to the choice of: investing in internal R&D, investing in external R&D in university/research labs and other firms/consultants and innovating products and processes. The determinants of firm innovation are those that have been used successfully in preceding studies alongside several specifications of variables reflecting the NIS structure, output and assessment. Since they are highly correlated, they are tested alternately.

The source of data on firm innovation is the EU-EFIGE/Bruegel-UniCredit dataset which is a survey, carried out in 2010, that provides comparative trans-national data on manufacturing firms in seven European countries and covers quantitative as well qualitative information including data on R&D and in particular on R&D collaborations and innovation. Information on the universities is gathered from a range of sources: the International Handbook of Universities, Eurostat and the bibliometric analysis of academic research output sourced from the EU AGRI MAPPING report.

The present overview is followed by five further sections. The second section reviews the literature that addresses the issues mentioned in Section One. Section Three focuses on specific elements of the European public agri-food research system and outlines the characteristics of the European F&D industry. Section Four describes the methodology and the sources of the data that have been used and Section Five presents the results of the analysis. Section Six provides concluding remarks, and the robustness check follows in the Appendix.

2. Studies in National Innovation Systems at a glance

An approach frequently adopted when considering the economic performances at national level in scholarly studies is to apply the NIS concept, framing innovative activities and the way firms act within the national institutional context (Freeman, 1988; Lundvall, 1988; Nelson, 1993). It assumes that a firm’s innovative capabilities depend upon its ability to communicate and interact with external sources of knowledge such as other firms, customers and scientific institutions that act as knowledge providers; indeed, the rules and regulations under which the agents of the innovation system operate play an important, if not decisive, role in explaining innovation behaviour.

According to Goto (2000), the NIS model embraces three main components: industry, universities, and government, with each component interacting with the other two, while at the same time pursuing their own institutional objectives. Indeed, the main institutions and agents within the NIS include universities, research institutes, innovative companies and entrepreneurs which foster and promote learning and innovation (Audretsch et al., 2015a, 2015b). The government also plays an important role, stimulating, fostering and shaping the complementary qualities of these institutions and agents (Audretsch et al., 2016; McCann and Ortega-Argile´s, 2016). It is important to note that these activities take place within a specific national institutional context (Filippetti and Archibugi, 2011) and sectoral dimensions of patterns of innovation are country-specific (Malerba and Orsenigo, 1996, 1999) as well as the firms' ability to continue to innovate (Cefis and Orsenigo, 2001). Accordingly, the innovation systems approach assumes that relationships and linkages between societal actors are central to their innovation behaviour, highlighting the importance of science–industry-government relations. In the so-called Triple Helix literature of academic-industry-government relations (Etzkowitz, 1983), universities are seen as engines of growth, since they assume a leading role in the creation of technological innovation (Etzkowitz and Leydesdorff, 1998, 2000; Leydesdorff, 2000).

More specifically, the NIS concept (Filippetti and Archibugi, 2011) rests on three suppositions: 1) that countries exhibit systemic differences in terms of their respective economic performances 2) that these performances depend not only on the development of their institutions but also on their technological and innovation capabilities and finally 3) that innovation policies are an effective tool to stimulate national economic performance.

In addition to the NIS approach, the literature also encompasses the development of regional and sectoral applications. Among the sectoral applications, Hall et al. (2001, 2006) define Agricultural Innovation Systems (AIS) as "a network of organisations, enterprises, and individuals focused on bringing new products, new processes, and new forms of organisation into economic use, together with the institutions and policies that affect the way different agents interact, share, access, exchange and use knowledge". The AIS concept places the emphasis on the influence of institutions and learning and innovation infrastructure, including relevant organizations beyond agricultural research and extension systems (Klerkx et al., 2012; Menrad, 2004; Dutrénit and Vera-Cruz, 2016).

The interaction between industry and science is one of the most prominent institutional interfaces for knowledge diffusion. Although knowledge transfer can occur through a variety of channels (Schartinger et al., 2002), close collaboration between firms and research institutions plays a crucial role in creating international competitive research environments and networks for needs-driven and interdisciplinary research (Robin and Shubert, 2013). This is also the case in relatively low-tech sectors such as the F&D industry (Avermaete et al., 2004; Christensen et al, 1996; De Grunert et al, 1997; Gellynck et al., 2007; Rama, 1999; Devitiis et al., 2009; Muscio and Nardone, 2012; Maietta, 2015); F&D firms may even find it more profitable to invest in *extra muros* than in *intra muros* R&D (Alarcón and Sánchez, 2013). The majority of firms with publicly supported innovations state that the universities are their most important source, while publicly financed laboratories get almost as many citations (see Beise and Stahl 1999). F&D firms collaborate with universities and public research labs to access new ideas and government funding, develop internal technical expertise and reduce time to market with new technologies, particularly for process innovation and new market penetration. Informal contacts and training courses, in quality control, for instance, also act as important channels for knowledge transfer (Avermaete et al., 2004; Kelly et al., 2008; Minarelli et al., 2015).

Firms play the predominant role in the innovation system. They innovate by means of interaction with other firms as well as with knowledge providers, including universities and technological institutes. Since they play such an important role, it is crucial to analyse what takes place inside the firms themselves in terms of innovation and competence building and to analyse the way in which they interact with other firms as well as with publicly-funded knowledge institutions (Lundvall, 2005). The ways in which firms carry out innovation activities and set their learning processes is affected by a number of specific national factors (Archibugi and Pianta, 1992; Archibugi and Michie, 1997; Lorenz and Lundvall, 2006), including the nature of the scientific and technological institutions, the education and training system, the financial system, the structure of the labour market, industrial specialization and the protection of intellectual property rights (Filippetti and Archibugi, 2011). The environmental and institutional context thus contributes to systemic cross-national disparities in university-industry interactions and the effectiveness of knowledge transfer (Bellucci and Pennacchio, 2015; Cardamone and Pupo, 2015). A firm's absorptive capacity shapes its demand for knowledge and technology transfer because firms with low absorptive capacity (Laursen et al., 2011) and/or in a low-tech sector (Huiban and Bouhsina, 1998) depend more on high quality local universities for industrial research needs and for the expertise and training that are offered to the local market for skilled labour. This latter acts as a medium for the diffusion of academic knowledge spillovers (Beise and Stahl, 1999) which may particularly benefit small and medium sized firms with a lower capacity to compete in the national labour market. This helps explain why, in the case of family-run firms, the owners' children often choose to attend a degree programme at a local university. Furthermore, institutional changes may contribute to reinforcing the importance of certain NIS actors as local providers of external firm knowledge (Robin and Schubert, 2013). Firms which adopt "open" search strategies and invest in R&D are more likely than other firms to build links with university research (Laursen and Salter, 2004), to conduct more productive technological searches (Fleming and Sorenson, 2004) and ultimately to innovate (Feldman, 1994).

Since R&D activities improve technological opportunities at regional level, there is a strong case in favour of public funding for industrial R&D (Breschi and Lissoni, 2001; Rodriguez-Pose and Crescenzi, 2008; Laursen et al. 2011). Taking into account the connection between the quality of the university on the propensity of firms to support its academic research and development activities (Mansfield and Lee, 1996) shorter distances between the firm and the university facilitate interaction, lowering the costs of knowledge exchange (Cardamone et al., 2015; Giunta et al.; 2015; Maietta, 2015); considering the relationship between the number of references to universities in firms' patents, the greater this distance, the lower will be that firm's rate of exploitation of public science (Fabrizio, 2006). The recently acquired entrepreneurial orientation and the communication activities of universities may also increase knowledge transfer from academia to firms (Bellucci and Pennacchio, 2015).

The role of close collaboration between firms and universities in strengthening industrial competitiveness has also struck a chord in the public debate and is now an issue in mainstream policy as outlined by the Lisbon agenda and the EU Report Europe 2020 (European Commission, 2007, 2010). In line with a strategy of economic growth based on knowledge, many European countries have implemented NIS reforms, aiming to reinforce cooperation between universities, research institutions and industry, through contracting-out or collaborative projects, and to increase the commercialization of research. Since discrepancies between national systems may hamper transnational knowledge transfer, EU universities and public research labs are recommended to adopt a common code of practice for knowledge transfer activities (European Commission, 2008). Furthermore, as a result of the Bologna Process, the higher education system has been reformed and universities have started being financed according to their productivity and academic excellence. "Formulas to allocate public funds to higher education institutions are now related to performance indicators such as graduation or completion rates" and "research funding has also increasingly been allocated to specific projects through competitive processes rather than block grants" (OECD 2008). However, domination of agricultural research funding by competitive grants is associated with a reduction of agricultural productivity (Huffman and Just, 1994) and of local public goods' production (Huffman and Just, 1999). The allocation of resources from government to universities is increasingly based on research and teaching performance indicators. This funding system may tend to favour large universities, which benefit from scale and scope in costly and speculative research proposal writing (Huffman and Just, 1999). It is based on a model of university-firm collaboration tailored for countries whose firms are large or associated in firm networks which facilitate university-government-firm interactions (Klerkx and Leeuwis, 2008a, 2008b). In the case of weaker economic areas, where the main knowledge provider is public and the gap in university performance also depends on external economic conditions, the adoption of a single university-firm collaboration model (Isaksen and Karlsen, 2010) may present a cost in terms of tacit knowledge spillovers, which are the base of the NIS perspective (Acs et al., 2016). It may thus be detrimental to small and medium firm innovativeness, feeding a cumulative poverty trap. For example, Cardamone et al. (2015) have shown that while technology transfer activities of Italian universities *do* impact positively upon local manufacturing firm innovation, this effect is stronger in prosperous territorial areas, in science based and scale intensive sectors and amongst large-sized firms. Maietta (2015) points out that the citations in WoS-Scopus journals, which positively impact university-firm R&D collaboration, have a negative correlation with product innovation of local F&D firms.

3. The F&D industry and the agri-food research sector in Europe

In the EU in 2011, 4.25 million people were employed in the F&D industry (Food Drink Europe National Federations report) representing the largest EU manufacturing sector in terms of direct employment (15%). The F&D industry shows the characteristics of a stable, non-cyclical and resilient sector. Indeed, throughout the economic downturn following the 2007 banking crisis, the F&D industry continued to grow, while a sharp decrease was observed in other key manufacturing sectors. In the seven countries considered in the analysis, according to Eurostat data, the F&D industry accounts for 10.8% of value added manufacturing and 13.8% in terms of overall employment in 2011 (Pasetto, 2011). As a key sector in the EU Member State economies, the F&D industry ranks first in France, Spain and the United Kingdom in terms of turnover and features in the top three manufacturing activities in several Member States. Germany, France, Italy, the United Kingdom and Spain are the largest EU F&D producers.

Table 1 summarizes some descriptive statistics concerning the importance of the F&D industry for the countries selected for our analysis.

[Table 1 here]

In 2007, R&D expenditure in the 27 EU Member States amounted to 1.85 % of GDP. The EU allocated € 228 bn. to R&D, compared with € 269 bn. spent by the United States and € 118 bn. by Japan. Within the EU 27, four Member States — Germany, France, Italy and the United Kingdom

— accounted for more than half of total EU 27 R&D expenditure. Germany alone, with € 61.5 bn., accounted for more than one quarter of the total. France, the United Kingdom and Italy followed, with € 39.3 bn. € 36.7 bn. and € 16.8 bn. respectively. Tables 2 reports the R&D expenditure for the sample of EU countries in the agricultural science sector on higher education sectors and government personnel.

[Table 2 around here]

The agri-food research system in the EU is publicly funded and decentralised as in other advanced economies but in the last fifteen years, agri-food research in the EU has undergone a decrease in government funding (Alston et al., 1998; Chartier, 2007; Ruttan, 2001). The countries which invested most in the agricultural sciences in the period 2007-2009 are, in decreasing order, Germany, Spain, the United Kingdom and Italy (Table 2), however only Germany and Spain continue to show an upward trend. The agri-food research sector in the EU relies both on universities and public research institutes but there is a trend in which the role of the universities is becoming more important. A notable exception, however, is France where other public research institutions play a dominant role. Among the seven sample countries, Italy and Austria are the biggest contributors of public money to agricultural sciences in higher education institutions.

The Standing Committee on Agricultural Research (SCAR), established by EEC Reg. No 1728/74, periodically monitors the agri-food research sector structure assessing its fragmentation, in terms of number of research organisations and research groups, its coordination, its medium-term strategy and the importance of the research council with its multi-annual research programs (Chartier, 2007). In recent years, the EU agri-food research sector has been subjected to a process of rationalisation and consolidation with the merging of research entities and the imposition of better coordination consequent to the establishment of research councils, the setting-up of pluri-annual research programmes and the allocation of financial support through competitive programmes. Important reforms have already taken place in the United Kingdom and in the North of Europe. Reforms have also been planned within global NIS changes in Spain or are being discussed in Germany, Italy and Hungary. The agri-food research capacity is considered concentrated (few research entities) in France and fragmented (many research entities) in Austria, Germany, Italy, Spain, Hungary and the United Kingdom. The level of coordination of the agri-food research sector, estimated according to the presence of medium-term strategy and the importance of the research council with multi-annual research programmes is poor in Germany, Italy and Hungary, good in the United Kingdom and fair in the remaining countries (Chartier, 2007).

Among the world leading countries in agricultural and veterinary sciences in terms of scientific papers indexed in the Scopus database over the 2003-2010 period the United Kingdom ranks third, Germany sixth, France ninth, Spain tenth and Italy eleventh. Among the seven countries analysed, Spain is the most specialised[1] in agricultural and veterinary sciences, since its specialisation index is higher than 1, whereas the United Kingdom has the highest scientific impact as measured by the average citations per article (Roberge and Côté, 2012).

[Table 3 around here]

Table 3 reports the number of innovative enterprises with innovation cooperation during 2006-2008 in the manufacture of food products, beverages and tobacco products, sourced from the Community Innovation Survey (Eurostat). The number of innovation cooperations is given separately for the seven countries analysed and for the EU-27. In the years analysed, universities were important F&D firm partners for innovation cooperation being generally more frequently chosen than other public research institutes and in Germany and Italy were the undisputed first choice of partners. Important national patterns emerge in Austria, Germany, Hungary, Italy and the United Kingdom, where universities are more chosen than research labs while the contrary holds for Spain and they are equally chosen in France.

4. The empirical framework

4.1. The econometric approach

To trace the influence of different types of university-firm interaction mechanisms on different types of impact outcome is not an easy task because of the complex and intertwined relationships between interaction mechanisms (Schut et al, 2014).

The literature on the subject concurs that the empirical framework in the analysis of mechanisms for knowledge creation and transfer passing from academic institutions to firms should take into account the interdependencies between innovations and external collaborations in R&D

[1] Specialization index (Roberge and Côté, 2012) is defined by:

$$SI = \frac{Xs/Xt}{Ns/Nt}$$

X = No. publications
N = World publications
s = research area
t = total research areas

while addressing simultaneity between innovations and (internal and external) R&D investment decisions and the simultaneity of different forms of external collaborations in R&D.

Bearing this in mind, the econometric model of the present paper consists of five simultaneous equations related to the following dependent variables: (the existence of) *intra muros* R&D investment, R&D collaboration with universities and/or research labs, R&D collaboration with other firms and/or consultants, process innovation and product innovation. Among these, the variables of R&D collaboration with universities/research public labs, and R&D collaboration with private firms/consultants are also used as regressors. All these indicators are binary variables.

The simultaneous equations of the econometric model are jointly described by a multivariate probit model. The model follows a five-equation structure in which the estimation results of the second and third equations are used as regressors in the fourth and fifth equations, as follows:

$$\begin{cases} y_{1i}^{*}= \mathbf{x}_{1i}^{'}\boldsymbol{\beta}_1+\epsilon_{1i} \\ y_{2i}^{*}= \mathbf{x}_{2i}^{'}\boldsymbol{\beta}_2+\epsilon_{2i} \\ y_{3i}^{*}= \mathbf{x}_{3i}^{'}\boldsymbol{\beta}_3+\epsilon_{3i} \\ y_{4i}^{*}= \gamma_{24}\, y_{2i}^{*} + \gamma_{34}\, y_{3i}^{*}+ \mathbf{x}_{4i}^{'}\boldsymbol{\beta}_4+\epsilon_{4i} \\ y_{5i}^{*}= \gamma_{25}\, y_{2i}^{*} + \gamma_{35}\, y_{3i}^{*}+ \mathbf{x}_{5i}^{'}\boldsymbol{\beta}_5+\epsilon_{5i} \end{cases} \qquad (1)$$

The five latent variables are defined as follows: y_1* is *intra muros* R&D investment; y_2* are R&D collaborations with universities and/or research labs; y_3* are R&D collaborations with other firms and/or consultants; y_4* are product innovations and y_5* are process innovations; $\mathbf{x}_{ki}$ are vectors of exogenous variables, which influence those probabilities for firm *i*; $\boldsymbol{\beta}_k$ are parameter vectors; γ_{kl} are scalar parameters; and ε_{ki} are error terms, which are assumed to be jointly normal with unknown correlation coefficients, ρ_{kl}.

The realisation of the latent variables y_{ki}*, is not observed; however, the realisation of the binary variables, y_{ki}, is observed, and these are linked to the former according to the following rule:

$$\begin{cases} y_{ki} = 1, & \text{if } y_{ki}^{*} > 0 \\ y_{ki} = 0 & \text{otherwise; } k = 1, \ldots, 5 \end{cases} \qquad (2)$$

The dependent variables are equal to 1 when: *intra muros* R&D investment>0 for y_1, *extra muros* R&D expenditure with partner$_m$>0 for y_k where m = universities/research labs or other firms/consultants and k = 2, 3; and product and process innovation are present, respectively for y_4 and for y_5.

The equations that refer to y_1, y_2 and y_3 have been included to identify the determinants of the *intra muros* and *extra muros* R&D investment that aims at introducing product or process innovation and to take into account the simultaneity of decisions by firms relating to the type of *intra muros* and *extra muros* R&D investment. Furthermore, the common latent factor structure of the multivariate probit framework makes it possible both to control for the potential endogeneity of the R&D investment decision and to correct the potential sample selection. The resulting recursive multivariate probit model can be described as an instrumental variable framework for categorical variables and can be estimated using the simulated maximum likelihood method (Wilde, 2000).

4.2. The data

In order to explore university-firm R&D collaboration and firm innovation, different sources of data have been used. At the heart of the project is the EFIGE (European Firms in a Global Economy) database; it consists of a representative sample at country level for the manufacturing industry of almost 15,000 surveyed firms with over 10 employees in the sample group of the seven European economies: Austria, France, Germany, Hungary, Italy, Spain and the United Kingdom. The data was collected in 2010, covering the years 2007-2009. Since the focus of the present paper is on the European F&D industry, the F&D firms have been extracted using the NACE-CLIO classification, resulting in a sample of 1,520 firms.

The database contains quantitative and qualitative information on R&D and innovation. More specifically, firms are asked whether process and product innovation were introduced during the previous three years (2007-2009). Product innovation is defined as the "introduction of a good which is either new or significantly improved with respect to its fundamental characteristics; the innovation should be new to the firm, not necessarily to the market" whereas process innovation is defined as the "adoption of a production technology which is either new or significantly improved; the innovation should be new to the firm; the firm has not necessarily to be the first to introduce the new process".

The questionnaire also collects information regarding whether the R&D was *intra muros* or acquired from external sources such as universities, research labs, other firms or consultants. No distinction is made between universities and research labs but from Table 3 it is possible to argue that universities were more frequently chosen. Information on what percentage of total turnover the firm has invested in R&D on average in the previous three years (2007-2009), on whether the firm benefits from tax allowances and financial incentives for these R&D activities and on whether part of these financial incentives are provided by the public sector, are also available and have been used.

The firms are classified according to their size as measured by the number of employees as follows: 10-19 employees, very small; 20-49 employees, small; 50-100 employees, medium; 100-250 employees, large and over 250 employees, very large. Other characteristics of firms that have been included as regressors are the presence of skilled employees (i.e. graduates), age and gender of the current CEO or company head, the firm's age, its current legal form, whether in the last three years it has applied for a patent, registered an industrial design or a trademark or claimed copyright.

In order to explore whether the national knowledge context in which the firm operates affects the university-firm R&D collaboration and firm product and process innovations, the following information was also gathered and used: number of agricultural faculties; average number of citations in agri-food science, number of publications in the scientific area of "food technology, human nutrition and consumer concerns" using the WoS production of European agri-food research in the period 1996-2004 from the EU AGRI MAPPING report; number of universities offering agriculture as a field of education (using Eumida); number of engineering and science faculties as listed in the International Handbook of Universities; average government sector R&D expenditure 2003-2009 on agriculture (expressed in millions of Euros) (using Eurostat and Sorrentino and Capozzi, 2010, for France); number of scientists and engineers (annual average 2006-2008) in agriculture, forestry and fishing, mining and quarrying and low-technology manufacturing (using Eurostat); number of new graduates (average 2006-2009) in agricultural and veterinary science by ISCED97 levels 5 and 6 (using Eurostat). The former is the first stage of tertiary education, with 5A degree programmes that are theoretically based/research preparatory or giving access to professions with high skills requirements and 5B degree programmes which are practically oriented and occupationally specific; level 6 is the second stage of tertiary education leading to an advanced research qualification.

The analysis is also completed with the use of some indicators of the levels of NIS fragmentation and of coordination. The level of fragmentation (number of research organisations and research groups) is equal to 0 if the research capacity of the national agri-food research sector is considered concentrated, 1 if its defined rather fragmented and 2 if the capacity is considered highly fragmented in the EU AGRI MAPPING report. Analogously, the level of coordination (presence of medium-term strategy and importance of research council with multi-annual research programs) is equal to 0 if defined poor, 1 fair and 2 good in the EU AGRI MAPPING report.

The level of rurality of the province (or region) where the firm is located, which is sourced from OECD, is used as a proxy for the distance between firms and universities/research labs since there are relatively few research centres in rural areas. Following the OECD criterion, based on population density, provinces and regions are classified as predominantly urban (rurality level sets equal to 0), intermediate (rurality level set equal to 1) and predominantly rural (rurality level sets equal to 2). The number of years the region, where the firm is located, has been in the EU is used as a proxy for the institutional setting surrounding the firm.

4.3. The empirical specification and the descriptive statistics of the variables

The empirical specification of the five equations can be summed up as follows:

Intra muros R&D investment = f_1 (Public subsidies, skilled employees, protection of intellectual property dummies, CEO firm age and gender, firm age, firm size dummies, legal form dummies, rurality level of the province or region, number of years in the EU, country dummies or NIS characteristics).

R&D collaboration with partner_m = f_k (R&D intensity, dummy for R&D acquired abroad, dummy for R&D subsidies, skilled employees, protection of intellectual property dummies, age and gender of firm CEO, age of firm, firm size dummies, legal form dummies, rurality level of the province or region, number of years in the EU, country dummies or NIS characteristics), where m = universities/research labs or other firms/consultants and k = 2, 3.

Innovation j = f_j (R&D collaboration with universities/research labs, R&D collaboration with private firms/consultants, R&D intensity, public subsidies, skilled employees, protection of intellectual property dummies, CEO firm age and gender, firm age, firm size dummies, legal form dummies, rurality level of the province, number of years in the EU, country dummies or NIS characteristics), where j = product or process.

Descriptive statistics of the variables are reported in Table 4 below. Among all the firms in the sample 4% have R&D collaborations with a university or research lab, while 8% of them have R&D collaborations with other firms or consultants, probably because public research institutions have lengthy working times, a technology push mindset and a higher orientation towards academic publications than towards customer need problem-solving. Very few technologically leading firms employ international knowledge sourcing strategies since only 1% of firms in the sample have foreign R&D partners confirming the nation-oriented knowledge transmission of F&D firms, even in formal collaborations, evidenced in the past (Christensen et al., 1996). This evidence supports the NIS approach choice for the analysis of the F&D firm innovation behaviour in that F&D firms are more familiar with knowledge generated in their home country and privilege national technology.

Among all firms in the sample, 52% have introduced product innovation, and 44% have introduced process innovation. A higher presence of product than process innovation may be explained by the industry product direction (Furtan and Sauer, 2007; Ziggers, 2005), the high pace of product innovation due to short product life cycles (Ciliberti et al., 2015) and by the presence of protected designation of origin, protected geographical indication and traditional speciality guaranteed trademarks (Mancini and Consiglieri, 2016). The R&D intensity, which is measured as the percentage of the total turnover that the firm invested in R&D on average in the three years (2007-2009) is around 2%; during the same time span, only 12% of the firms undertook *intra muros* R&D activities probably because of the economic crisis in the years analysed. Patented innovation is low (only 6% of sampled firms) whereas 22% of firms have registered trademarks.

As far as the legal form is concerned, most firms are limited liability partnerships (Sarl, *société a responsabilité limitée*), 15% are public companies (Sarl, *société anonyme*), 5% are proprietorships, 4% are cooperatives and the remaining ones are limited liability sole proprietorships (Eurl, *entreprise unipersonnelle à responsabilité limitée*) or other forms.

Nearly 12% of firms received benefits from tax allowances and financial incentives for R&D activities while 21% benefited, for the overall activity, from financial incentives provided by the public sector. Taking into account the human capital composition of the firms, the average age of the firm CEO is around 50 years, astonishingly, as regards gender parity, only 10% of those CEOs are women. Within the workforce fewer than 10% of employees are graduates.

[Table 4 around here]

The key regressors in all the equations are related to the national "knowledge context" represented by the presence and the characteristics of higher education institutions and by other NIS actors. On average over the period 2006-2008, around 39,000 scientists and engineers are operating in agriculture, forestry and fishing, mining and quarrying and low-technology manufacturing areas; the agri-food research system produces around 436 food science articles. On average, 26 universities offer agriculture as a field of studies and educational objective. The average number of faculties is approximately 10 for agricultural studies, 80 for engineering studies and 83 for science studies. In the specific agriculture and veterinary disciplines, the system produced 3,000 new graduates on average, over the period 2006-2008, completing the first stage of tertiary education (ISCED97 5a).

The description is completed by indicators measuring NIS fragmentation and coordination. The number of research organisations and research groups, measuring the level of fragmentation, is

1.02 indicating that the research system is, on average, not fragmented but, since the dummy relative to the presence of medium-term strategy and importance of research council with multi-annual research programs it is equal to 0.67, it may be considered, on average, poorly coordinated.

Several specifications of variables reflecting the NIS structure, output and assessment have been tested alternately. The baseline specification is Model 1 which includes only national dummies. Model 2 tests the role of universities versus public research labs (proxied by government R&D) and the size of research institutions (proxied by the number of scientists). Model 3 and Model 4 analyse the university composition respectively in terms of agriculture *vs* engineering faculties and in terms of agriculture *vs* science faculties. Model 5 tests the effect of research institution outputs: the number of WoS articles on food science topics and the number of graduates, differentiated by ISCED97 levels; the output of the public research labs is proxied by government R&D. Finally, Model 6 includes the assessment of the NIS fragmentation and coordination, the specialization index in food science production and the scientific impact of WoS publications in terms of average citation number. Multicollinearity among the regressors is assessed by computing the variance inflation factor (VIF) and no evidence of a problem in any model was found.

5. The empirical evidence

The marginal effects of the multivariate probit regressions are reported for various specifications in Tables 6–10. The standard errors (not reported) of the coefficients have been clustered around the rurality of the province in which the firm is located because the institutional setting and the economic dynamism, which are homogeneous within the same area, may affect the innovativeness behavior of firms located there (see i.e., Chevassus-Lozza and Galliano, 2003).

The likelihood ratio test, which was conducted on the hypothesis that the ρs are jointly null, is highly significant and supports the multivariate five-equation framework (see Table 5). The correlation coefficients are very high and significant for the internal and external R&D investment choice in that the presence of *intra muros* R&D is correlated with R&D collaboration with universities/research labs and R&D collaboration with other firms/consultants. The two equations related to external collaborations are also highly correlated and the two equations related to product and process innovation.

[Table 5 around here]

Table 6 reports the marginal effects for Equation 1 when the existence of *intra muros* R&D investment has been used as a dependent variable. The dummy for R&D subsidies is positive and highly statistically significant; receiving financial incentives to boost R&D activities induces *intra muros* R&D investment. A firm's large size, male CEO and trademark registration are highly significant and positive determinants whereas proprietorship is a negative one. French F&D firms are more likely to invest in *intra muros* R&D.

Among the NIS factors and the environmental characteristics, the number of universities with agriculture as a field of education, and government R&D are not conductive to *intra muros* R&D investment whereas larger R&D institutions, in terms of scientist numbers, and the number of years in the EU are positive and highly significant determinants. Among the other NIS structure variables, the presence of engineering and science faculties favours R&D *intra muros* whereas the presence of agriculture faculties does not. The number of WoS food science articles is positive and weakly significant, whereas the number of ISCED5 (a and b) graduates in agriculture is always positive and highly significant. NIS fragmentation is detrimental to firm *intra muros* R&D investment; the marginal effect is relatively high. A negative sign is also observed for NIS coordination which is explained by the outsourcing of firm R&D investment in a coordinated NIS.

[Table 6 around here]

Table 7 reports the marginal effects for Equation 2 where R&D collaboration with universities/research labs has been used as a dependent variable. R&D intensity is positive and weakly significant whereas R&D subsidies are positive and highly significant. Foreign universities/research labs may be chosen as firm R&D partners because the dummy for R&D acquired abroad is positive and significant whereas it is not for the dependent variable R&D collaboration with other firms/consultants (see Table 8). No direct firm size effect emerges; a firms' male CEO is highly significant and positive whereas proprietorship and limited liability proprietorship are negative determinants. Registering a trademark and claiming a copyright are positive and highly significant since they guarantee appropriability of jointly developed innovation taking into account that competitors may even collaborate with the same research institution.

The level of rurality, meaning geographical distance from firms to research institutions, increases the likelihood of R&D collaboration with universities/research labs, as already observed in the literature and explained by the so-called "stray dog syndrome" (Howells *et al*., 2012; Maietta, 2015). For firms which are more distant from universities, the absence of local universities prevents them from collaborating via direct interactions or through informal contacts with academics that could act as spearheads for other collaborations that are knowingly planned and not necessarily local since new and even international knowledge providers may be successively discovered within the firm's existing network (Laursen and Salter, 2006; Laursen et al., 2012). British F&D firms are more likely to collaborate with universities/research labs. The number of years the region, where the firm is located, has been in the EU, is highly significant and positive in the specification with the indicators of the NIS structure and output assessment, suggesting convergence paths towards a common science policy.

R&D collaborators with firms are more likely to be universities since the number of universities with agriculture as a field of education is the only variable reflecting the NIS structure to be positive and highly significant. The number of agriculture faculties is positive but only weakly significant. The NIS fragmentation is also positive even if weakly significant. These results corroborate the idea that a territorially dispersed knowledge system may be beneficial for university collaborations of small F&D firms, which are numerous in countries such as Germany and Italy. The number of WoS food science articles is positive and highly significant whereas the number of ISCED 5b graduates is highly significant but negative, probably because of a lower knowledge-intensive profile when firms hire practically oriented and occupationally specific employees. Regarding the other NIS characteristics, coordination is positive and highly significant whereas both specialisation and scientific impact are negative and significant. The explanation may be the presence of conflicting interests and goals between star scientists and firms. While the former focus on developing innovations that could lead to publications in highly-ranked journals, the latter require multidisciplinary academic competencies in order to investigate practical problems and increase the applicability and profitability of user-oriented research projects.

[Table 7 around here]

Table 8 reports the marginal effects for Equation 3 where R&D collaboration with other firms/consultants has been used as a dependent variable. Neither R&D intensity nor skilled employees are significant, probably because many of these collaborations are with market research institutes and most innovations are incremental (Ciliberti et al., 2016). The presence of R&D subsidies is still positive and highly statistically significant with a higher marginal impact than for R&D collaboration with universities/research labs. Limited liability proprietorship is negative and highly significant. British F&D firms are more likely to collaborate with other firms/consultants.

The number of universities increases the probability of these collaborations, whereas public research labs, as proxied by the amount of government R&D, seem to substitute other firms/consultants as firm R&D partners. The number of WoS articles on food science topics appears to be beneficial for R&D collaboration with other firms/consultants.

[Table 8 around here]

Table 9 reports the marginal effects for Equation 4 where product innovation has been used as a dependent variable. Product innovation is strongly determined by whether the firm receives public incentives. R&D collaboration with universities/research labs, as already evidenced for European F&D firms (Minarelli et al. 2015; Maietta, 2015), and R&D collaboration with other firms/consultants are not statistically significant. Firm age has a positive and statistically significant effect on product innovation. After having accounted for firm participation in research investment, no residual size effect is observed (Furtan and Sauer, 2007; Karantininis et al., 2010). As already evidenced (Traill and Meulenberg, 2002), co-operatives are less likely to innovate their products probably because they tend to be traditional and quality *niche* products, whose origin is guaranteed by member localization (Bertolini, and Giovannetti, 2006). On the other hand, registering a trademark or an industrial design is a positive and highly significant determinant of product innovation.

The number of universities as well as the number of agriculture, engineering and science faculties favours product innovation. However, government R&D appears to be detrimental to product innovation. The WoS food science article variable is positive and highly significant. Among the education variables, the number of ISCED6 graduates is positive and statistically significant, in line with the idea that the supply of graduates from tertiary programs leading to the award of an advanced research qualification is an important channel for product innovation. The NIS coordination is positive and weakly significant whereas specialised knowledge production hinders product innovation. A possible explanation is that many innovative products have protected designation of origin, protected geographical indication and traditional speciality guaranteed trademarks (Mancini and Consiglieri, 2016) which mostly rely on tacit knowledge transfer and interdisciplinary knowledge spillovers.

[Table 9 around here]

Finally, Table 10 reports the marginal effects for Equation 5 where process innovation has been used as a dependent variable. Process innovation is strongly determined by R&D collaboration with other firms/consultants while R&D collaboration with universities/research labs is not statistically significant. R&D intensity is also positive and highly significant. Skilled employees are positive and significant. Process innovation is also favoured by public incentives but not by the number of years the region, where the firm is located, has been in the EU, probably because of conflicting incentives given to the firm by national science and innovation policies and the Common Agriculture Policy. Small and very small firms are less likely to innovate whereas limited liability proprietorships are more likely to do so. Trademark registration is positive and highly significant.

Large R&D institutions have a beneficial effect on process innovation. The influential research institutions are research labs, as proxied by government R&D, whereas engineering and science faculties exert a detrimental effect, even if after the introduction of the education variables, the variable related to public research labs becomes only weakly significant. Probably, this may be because scientists of public research labs, who are close to locally important research problems, may train graduate students through research assistantships in long-term research projects (Huffman and Just, 1999). The supply of ISECED 5a graduates is positive and significant, since technicians of this kind play an important role in process innovation (Huiban and Bouhsina, 1998), whereas the supply of ISECED 5b graduates, who are practically oriented and occupationally specific, is highly significant but negative. Specialisation is positive and highly significant.

[Table 10 around here]

Summing up the results from all the equations, considering the European F&D industry over the period 2007-2009, the empirical evidence suggests that a high number of universities favours R&D collaborations and product innovation, while large research institutions hinder process innovation and government R&D is not conducive to product innovation. Furthermore, with regard to the NIS structure, science faculties favour product innovation and engineering faculties are not conducive to process innovation. With regard to NIS output, the results also show that WoS articles favour R&D collaborations and product innovation but not process innovation; the supply of ISCED 5a graduates is conducive to process innovation whereas that of ISCED 6 graduates favours product innovation. Taking into account the NIS assessment, specialised knowledge production hinders product innovation but favours process innovation. University-firm R&D collaboration is hampered by both scientific impact and specialised knowledge production.

In order to check for unobserved heterogeneity in firms, the multilevel approach has been applied as a robustness check. The multilevel approach involves relationships between variables which are measured at different hierarchical levels, thus modelling simultaneously the micro and macro level. This makes possible the evaluation of whether, and to what extent, variance in the dependent variable can be attributed to inter-firm variance or to, in our case, inter-country variance. Secondly, multilevel models check for unobserved heterogeneity by including a random intercept and allow assessment of whether relationships vary across contexts through the inclusion of random coefficients. The results of the random intercept multilevel probit regressions, which have been separately estimated for the five dependent variables, are reported in the Appendix. The coefficients and the standard errors of the random countries intercepts, shown at the bottom of Tables 6bis-10bis, do not indicate significant inter-country variance for the dependent variables to run five multilevel probit models as an alternative econometric strategy. Thus the findings previously described are confirmed.

6. Concluding remarks

New knowledge from public research institutions can provide firms with competitive advantage speeding up new product and process development. Understanding how European universities and research institutions impact firm innovation is important for the development of a more tailored knowledge-based growth strategy in which university-industry knowledge transfer can be advantageous both for firms and academics. Of course, it is unrealistic to think in terms of an ideal NIS model since the NIS is endogenously determined and shaped and today's NIS configurations are the result of historical and path-dependent processes. However, in Europe there is now increasing convergence of national research assessment indicators towards a single universal criterion, whose adoption, however, may be costly in terms of development of weaker areas, small-sized firms and tacit knowledge-based industries. Furthermore, the allocation of national funding to universities, through performance-oriented indicators, and university autonomy, which enables it to allocate funding to degree programs and to select research and teaching staff, have led universities to compete for scholars, students, public and private funds. Students may prefer to migrate to prestigious universities far from home thus diminishing the possibility of local tacit knowledge spillover.

The conclusions of the present study are that large scale public research institutions are detrimental to interaction between university and industry and that the supply of practically oriented and occupationally specific graduates hampers university-firm R&D collaboration as well as process innovation. The parameters used for academic research output assessment are not good proxies for local knowledge spillover. This is also the case for publications in high ranking academic journals which do not appear to have any effect on process innovation. Education acts as a channel of knowledge transfer both for product and process innovation.

More generally, further surveys to evaluate how research institutions may have a positive impact on innovation by firms and enterprises in the F&D industry would be of considerable benefit in what is, after all, a vital sector.

TABLES

Table 1 - Food and drink industry turnover, value added, employees and companies in 2011

Countries	Turnover (€ billion)	Value added (€ billion)	Number of employees (1.000)	Number of companies
Austria	12.6	4.7	58	3921
Germany	163.3	11.5	550	5960
France	157.2	29.3	500	10000
Hungary	8.3	2.0	97	6556
Italy	127.0	24.2	408	6300
Spain	83.8	20.0	446	30000
United Kingdom	87.6	23.7	370	6500

Source: FoodDrinkEurope National Federations, 2011

Table 2 - Total R&D expenditure by sectors of performance – Agricultural sciences sector

	2007	2008	2009	2007	2008	2009
	Expenditures			Personnel		
Government						
Austria	40.852	\\	44.646	1099	\\	1053
Germany	429.97	483.854	563.37	7041	7296	7035
France	\\	\\	\\	\\	\\	\\
Hungary	37.020	35.543	28.898	1828	1494	1279
Italy	280.4	282.1	176.6	4755	4674	4287
Spain	358.68	443.729	538.36	6628	7334	8778
United Kingdom	\\	381.38	347.62	2864	\\	2686
Higher education						
Austria	70.648	\\	90.436	1197	\\	1722
Germany	328.31	392.48	411.79	10766	10847	11005
France	\\	\\	\\	\\	\\	\\
Hungary	20.812	21.113	22.842	1619	1626	1710
Italy	225.7	220.9	223.3	5367	7051	8130
Spain	90.37	106.92	102.65	3884	4183	4237
United Kingdom	\\	140.27	133.46	3965	\\	3723

Source: Eurostat

Table. 3 - Number of innovative enterprises with innovation co-operation during 2006-2008 in the manufacture of food products, beverages and tobacco products

Countries	Suppliers of equipment, materials, components or software	Clients or customers	Competitors or other enterprises of the same sector	Consultants, commercial labs, or private R&D institutes	Universities or other higher education institutions	Government or public research institutes
Austria	64	33	26	27	36	14
Germany	276	364	291	208	544	190
France	519	368	245	300	267	268
Hungary	83	69	34	32	49	18
Italy	105	38	49	172	196	40
Spain	249	77	47	126	160	166
United Kingdom	532	639	200	240	170	158
EU-7	1,828	1,588	892	1,105	1,422	854
EU-27	3,359	2,681	1,450	1,951	2,021	1,252

Source: Eurostat - CIS6

Table 4 - Variables and descriptive statistics

Variable	*Mean*	*Std. Dev.*
Firm characteristics		
Intra muros R&D	*0.12*	*0.32*
R&D collaboration with other firms/consultans	*0.08*	*0.27*
R&D collaboration with universities/research labs	*0.04*	*0.20*
Product innovation	*0.52*	*0.50*
Process innovation	*0.44*	*0.50*
Dummy for R&D acquired abroad	*0.01*	*0.10*
R&D intensity (%)	*2.14*	*6.07*
R&D subsidy dummy	*0.12*	*0.32*
Subsidiy dummy	*0.21*	*0.40*
Skilled employees (%)	*8.07*	*11.76*
CEO age	*51.04*	*10.52*
CEO gender	*0.90*	*0.29*
Firm age	*41.79*	*37.67*
Very small firm size	*0.34*	*0.47*
Small firm size	*0.40*	*0.49*
Medium firm size	*0.10*	*0.31*
Large firm size	*0.08*	*0.27*
Proprietorship/Ownership dummy	*0.05*	*0.22*
Sa Dummy	*0.17*	*0.37*
Sarl dummy	*0.66*	*0.47*
Eurl dummy	*0.004*	*0.06*
Coop Dummy	*0.04*	*0.20*
Patent dummy	*0.06*	*0.23*
Industrial design dummy	*0.05*	*0.22*
Trademark dummy	*0.22*	*0.42*
Copyright dummy	*0.04*	*0.19*
Territorial and university characteristics		
Rurality of the province where firm is located	*0.88*	*0.71*
No. years in UE	*34.20*	*15.60*
No. scientists (th)	*39.44*	*22.68*
No. Universities	*26.45*	*17.77*
No. agriculture faculties	*10.41*	*7.56*
No. science faculties	*83.70*	*71.92*
No. engeneering faculties	*80.63*	*56.11*
Government R&D (ml €)	*275.42*	*99.94*
No. WoS food science articles	*436.79*	*143.96*
No. Isced 5b graduates	*1720*	*1882.53*
No. Isced 5a graduates	*2964*	*1261.63*
No. Isced 6 graduates	*421*	*322.90*
Fragmented NIS	*1.02*	*0.54*
Coordinated NIS	*0.67*	*0.64*
Specialization index	*1.22*	*0.36*
Average citations	*8.02*	*1.59*

Table 5 – Significance and value of the correlation coefficients among the errors of the Eqs. (1) – (5)

Coefficients	***Model 1***	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
Rho21	*0.631****	*0.619****	*0.566****	*0.563****	*0.629****	*0.607****
Rho31	*0.770****	*0.782****	*0.752****	*0.753****	*0.769****	*0.754****
Rho41	*0.242**	*0.269***	*0.227*	*0.238*	*0.247**	*0.204*
Rho51	*0.178*	*0.161**	*0.156*	*0.155*	*0.185*	*0.148*
Rho32	*0.480****	*0.528****	*0.477****	*0.475****	*0.485****	*0.498****
Rho42	*0.182*	*-0.026*	*0.117*	*0.122*	*0.195*	*0.147*
Rho52	*0.146*	*-0.164*	*0.128*	*0.129*	*0.147*	*0.118*
Rho43	*0.067*	*0.199*	*0.048*	*0.066*	*0.079*	*0.044*
Rho53	*0.007*	*-0.064*	*-0.068*	*-0.068*	*0.002*	*-0.051*
Rho54	*0.381****	*0.372****	*0.383****	*0.382****	*0.380****	*0.383****

Table 6 - Multiprobit regression. Marginal effects for the dependent variable (existence of) intra muros R&D investment

Variable	***Model 1***	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
	dF/dX	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*
R&D subsidy dummy	*0.147****	*0.153****	*0.153****	*0.153****	*0.147****	*0.146****
Skilled employees (%)	*0.001**	*0.001**	*0.001**	*0.001**	*0.001**	*0.001**
CEO age	*0.001**	*0.001**	*0.001***	*0.001***	*0.001**	*0.0006*
CEO gender	*0.00****	*0.018*	*0.00****	*0.00****	*0.00****	*0.00****
Firm age	*-0.0004*	*-0.0005****	*-0.0005***	*-0.0005***	*-0.0004***	*-0.0003***
Very small firm size	*-0.032***	*-0.034*	*-0.033*	*-0.034*	*-0.032*	*-0.022*
Small firm size	*0.002*	*0.0003*	*0.002*	*0.002*	*0.002*	*0.005*
Medium firm size	*-0.006*	*0.004*	*0.002*	*0.002*	*-0.005*	*-0.004*
Large firm size	*0.046***	*0.044***	*0.043***	*0.043***	*0.045***	*0.047***
Proprietorship/Ownership dummy	*-0.599****	*-0.549****	*-0.592****	*-0.597****	*-0.635****	*-0.533****
Sa dummy	*0.007*	*0.014*	*-0.006*	*-0.008*	*0.007*	*0.014*
Sarl dummy	*-0.023*	*-0.017*	*-0.024*	*-0.025*	*-0.021*	*-0.032*
Eurl dummy	*-0.084*	*-0.082*	*-0.085*	*-0.086*	*-0.083*	*-0.084**
Coop dummy	*0.039*	*0.052**	*0.036*	*0.036*	*0.042*	*0.032*
Patent dummy	*-0.028*	*-0.039*	*-0.029*	*-0.029*	*-0.029*	*-0.027*
Industrial design dummy	*-0.002*	*0.005*	*0.012*	*0.014*	*-0.002*	*-0.0004*
Trademark dummy	*0.067****	*0.071****	*0.065****	*0.065****	*0.066****	*0.062****
Copyright dummy	*-0.005*	*-0.0003*	*-0.009*	*-0.008*	*-0.002*	*-0.002*
Rurality of the province where firm is located	*-0.010**	*-0.008*	*-0.008*	*-0.008*	*-0.010**	*-0.008*
France dummy	*0.221****					
Germany dummy	*0.036*					
Hungary dummy	*-0.044*					
Italy dummy	*0.021*					
Spain dummy	*-0.050***					
UK dummy	*0.078*					
No. universities		*-0.001****				
Government R&D (ml €)		*-0.0005****	*-0.0005****	*-0.0005****	*-0.0005****	
No. scientists (th)		*0.002****				
N. years in UE		*0.003****	*0.004****	*0.004****	*0.0005*	*-0.0001*
N. agriculture faculties			*-0.006****	*-0.006****		
No. engineering faculties			*0.0004****			
No. science faculties				*0.0002****		
N. WoS food science articles (100)					*0.00006**	
No. isced5a graduates (th)					*0.0002****	
No. isced5b graduates (th)					*0.0003****	
No isced6 graduates (th)					*0.0003*	
Fragmented NIS						*-0.291****
Coordinated NIS						*-0.125****
Specialisation index						*0.026*
Average citations						*0.008*

*** Significant at 1% level.
** Significant at 5% level.
* Significant at 10% level.

Table 7 - Multiprobit regression. Marginal effects for the dependent variable R&D collaboration with universities/research labs

Variable	***Model 1***	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
	dF/dX	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*
R&D intensity (%)	*0.001**	*0.008**	*0.0009**	*0.0009**	*0.0009**	*0.0008**
Dummy for R&D acquired abroad	*0.036**	*0.37*	*0.043***	*0.043***	*0.037***	*0.042***
R&D subsidy dummy	*0.077****	*0.080****	*0.074****	*0.073****	*0.076****	*0.079****
Skilled employees (%)	*0.0004*	*0.0005**	*0.0004**	*0.0004**	*0.0005**	*0.0005**
CEO age	*0.00*	*-0.0004*	*-0.00008*	*-0.0007*	*0.00008*	*0.0001*
CEO gender	*0.00****	*0.019*	*0.00****	*0.00****	*0.00****	*0.00****
Firm age	*-0.00003*	*-0.00001*	*-0.00005*	*-0.00005*	*-0.0001*	*-0.0001*
Very small firm size	*0.009*	*0.004*	*0.003*	*0.003*	*0.004*	*-0.001*
Small firm size	*0.009*	*0.007*	*0.006*	*0.006*	*0.007*	*0.006*
Medium firm size	*0.025*	*0.026**	*0.019*	*0.019*	*0.026*	*0.023*
Large firm size	*0.008*	*0.005*	*0.007*	*0.007*	*0.005*	*0.003*
Proprietorship/Ownership dummy	*-0.301****	*-0.297****	*-0.273****	*-0.275****	*-0.320****	*-0.267****
Sa dummy	*-0.035**	*-0.018*	*-0.020*	*-0.019*	*-0.037**	*-0.030*
Sarl dummy	*-0.036**	*-0.027*	*-0.028*	*-0.028*	*-0.036**	*-0.024*
Eurl dummy	*-0.249****	*-0.259****	*-0.250****	*-0.252****	*-0.264****	*-0.238****
Coop dummy	*-0.001*	*0.002*	*0.005*	*0.006*	*-0.005*	*0.007*
Patent dummy	*-0.003*	*-0.004*	*-0.004*	*-0.004*	*-0.003*	*-0.004*
Industrial design dummy	*-0.006*	*-0.005*	*-0.008*	*-0.008*	*0.0008*	*0.001*
Trademark dummy	*0.027***	*0.027***	*0.026***	*0.026***	*0.026***	*0.026***
Copyright dummy	*0.043****	*0.046****	*0.038***	*0.038***	*0.037***	*0.037***
Rurality of the province where firm is located	*0.014****	*0.016****	*0.012****	*0.012****	*0.015****	*0.012****
France dummy	*-0.006*					
Germany dummy	*0.027*					
Hungary dummy	*0.048*					
Italy dummy	*0.030*					
Spain dummy	*0.025*					
UK dummy	*0.047***					
No. universities		*0.0006****				
Government R&D (ml €)		*-0.00002*	*-0.00005*	*-0.00006*	*-0.00004*	
No. scientists (th)		*-0.0002*				
N. years in UE		*0.00006*	*-0.0001*	*-0.0001*	*0.0008**	*0.001****
N. agriculture faculties			*0.001**	*0.001*		
No. engineering faculties			*0.0006*			
No. science faculties				*0.00006*		
N. WoS food science articles (100)					*0.00007****	
No. isced5a graduates (th)					*-0.00001**	
No. isced5b graduates (th)					*-0.00001****	
No isced6 graduates (th)					*0.00001*	
Fragmented NIS						*0.048**
Coordinated NIS						*0.047****
Specialisation index						*-0.033***
Average citations						*-0.010***

*** Significant at 1% level.
** Significant at 5% level.
* Significant at 10% level.

Table 8- Multiprobit regression. Marginal effects for the dependent variable R&D collaboration with private firms/consultants

Variable	***Model 1***	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
	dF/dX	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*
R&D intensity (%)	*0.0007*	*0.009*	*0.0007**	*0.0007**	*0.0007*	*0.0006*
Dummy for R&D acquired abroad	*-0.002*	*-0.008*	*0.007*	*0.007*	*-0.001*	*0.010*
R&D subsidy dummy	*0.127****	*0.121****	*0.125****	*0.125****	*0.126****	*0.133****
Skilled employees (%)	*0.0005*	*0.0005*	*0.0005*	*0.0005*	*0.0005*	*0.0005*
CEO age	*-0.00006*	*0.00*	*-0.0001*	*-0.0001*	*-0.00002*	*0.0002*
CEO gender	*-0.022*	*-0.014*	*-0.018*	*-0.018*	*-0.022*	*-0.022*
Firm age	*0.0002*	*0.0001*	*0.0001*	*0.0001*	*0.0002*	*0.0002*
Very small firm size	*0.021*	*0.007*	*0.003*	*0.004*	*0.019*	*0.007*
Small firm size	*0.033*	*0.021*	*0.017*	*-0.018*	*0.033*	*0.028*
Medium firm size	*-0.019*	*-0.024*	*-0.031*	*-0.031*	*-0.018*	*-0.022*
Large firm size	*0.017*	*0.012*	*0.008*	*0.008*	*0.017*	*0.011*
Proprietorship/Ownership dummy	*-0.036*	*-0.026*	*-0.031*	*-0.031*	*-0.034*	*-0.024*
Sa dummy	*-0.023*	*0.011*	*-0.004*	*-0.003*	*-0.023*	*-0.024*
Sarl dummy	*-0.044*	*-0.023*	*-0.029*	*-0.028*	*-0.043*	*-0.027*
Eurl dummy	*-0.497****	*-0.482****	*-0.478****	*-0.481****	*-0.522***	*-0.480****
Coop dummy	*-0.006*	*0.003*	*0.008*	*0.009*	*-0.007*	*0.009*
Patent dummy	*0.027*	*0.025*	*0.029*	*0.029*	*0.027*	*0.028*
Industrial design dummy	*0.037***	*0.022*	*0.027*	*0.027*	*0.039***	*0.039***
Trademark dummy	*0.028*	*0.030*	*0.030*	*0.030*	*0.027*	*0.029*
Copyright dummy	*0.017*	*0.022*	*0.013*	*0.013*	*0.016*	*0.014*
Rurality of the province where firm is located	*0.004*	*0.004*	*-0.0007*	*-0.0006*	*0.004*	*0.001*
France dummy	*0.054*					
Germany dummy	*0.061*					
Hungary dummy	*0.047*					
Italy dummy	*0.080*					
Spain dummy	*0.061*					
UK dummy	*0.148****					
No. universities		*0.001****				
Government R&D (ml €)		*-0.0001***	*-0.0001*	*-0.0001*	*-0.0003****	
No. scientists (th)		*-0.00009*				
N. years in UE		*0.0006*	*0.0003*	*0.0004*	*0.0005*	*0.0009*
N. agriculture faculties			*0.001*	*0.001*		
No. engineering faculties			*0.0001*			
No. science faculties				*0.0001*		
N. WoS food science articles (100)					*0.0002****	
No. isced5a graduates (th)					*0.00*	
No. isced5b graduates (th)					*0.00*	
No isced6 graduates (th)					*0.00003*	
Fragmented NIS						*0.029*
Coordinated NIS						*0.035*
Specialisation index						*-0.010*
Average citations						*0.003*

*** Significant at 1% level.
** Significant at 5% level.
* Significant at 10% level.

Table 9 - Multiprobit regression. Marginal effects for the dependent variable product innovation

Variable	***Model 1***	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
	dF/dX	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*
R&D collaboration with universities/research labs	*-0.087*	*0.067*	*-0.049*	*-0.047*	*-0.093*	*-0.070*
R&D collaboration with other firms/consultants	*0.102*	*-0.028*	*0.115*	*0.100*	*0.094*	*0.127*
R&D intensity (%)	*0.005*	*0.004*	*0.005*	*0.005*	*0.005*	*0.005*
Subsidy dummy	*0.071***	*0.071***	*0.072***	*0.071***	*0.073***	*0.070***
Skilled employees (%)	*0.00*	*0.0001*	*0.00002*	*-0.00001*	*-0.00001*	*-0.00006*
CEO age	*-0.002**	*-0.002*	*-0.002**	*-0.002*	*-0.002**	*-0.002*
CEO gender	*0.049*	*0.052*	*0.055*	*0.00****	*0.031*	*0.051*
Firm age	*0.0009***	*0.0009****	*0.0009****	*0.0009****	*0.0009****	*0.0009***
Very small firm size	*0.008*	*-0.002*	*-0.001*	*-0.007*	*0.005*	*-0.012*
Small firm size	*0.043*	*0.038*	*0.034*	*0.031*	*0.042*	*0.035*
Medium firm size	*0.063*	*0.062*	*0.058*	*0.054*	*0.063*	*0.057*
Large firm size	*0.095*	*0.092*	*0.089*	*0.086*	*0.094*	*0.087*
Proprietorship/Ownership dummy	*-0.070*	*-0.061*	*-0.059*	*-0.066*	*-0.070*	*-0.045*
Sa dummy	*-0.069*	*-0.050*	*-0.049*	*-0.052*	*-0.068*	*-0.062*
Sarl dummy	*-0.064*	*-0.048*	*-0.046*	*-0.052*	*-0.064*	*-0.020*
Eurl dummy	*-0.042*	*-0.035*	*-0.035*	*-0.039*	*-0.043*	*-0.035*
Coop dummy	*-0.182****	*-0.165****	*-0.167****	*-0.168****	*-0.180****	*-0.142***
Patent dummy	*0.130**	*0.134***	*0.135**	*0.135**	*0.137**	*0.136**
Industrial design dummy	*0.258****	*0.273****	*0.256****	*0.254****	*0.260****	*0.255****
Trademark dummy	*0.291****	*0.282****	*0.293****	*0.292****	*0.291****	*0.294****
Copyright dummy	*0.026*	*-0.005*	*0.024*	*0.025*	*0.029*	*0.032*
Rurality of the province where firm is located	*-0.001*	*-0.005*	*-0.005*	*-0.004*	*-0.001*	*-0.003*
France dummy	*-0.141****					
Germany dummy	*-0.156****					
Hungary dummy	*-0.027*					
Italy dummy	*-0.135****					
Spain dummy	*-0.205****					
UK dummy	*0.044*					
No. universities		*0.003****				
Government R&D (ml €)		*-0.0006****	*-0.0008****	*-0.0008****	*-0.001****	
No. scientists (th)		*0.0005*				
N. years in UE		*0.0005*	*-0.00001*	*0.0002*	*0.0008*	*0.001*
N. agriculture faculties			*0.003***	*0.002**		
No. engineering faculties			*0.0007****			
No. science faculties				*0.0006****		
N. WoS food science articles (100)					*0.0003****	
No. Isced5a graduates (th)					*-0.00001*	
No. Isced5b graduates (th)					*-0.00001*	
No isced6 graduates (th)					*0.0001****	
Fragmented NIS						*0.031*
Coordinated NIS						*0.109**
Specialisation index						*-0.151****
Average citations						*-0.029**
Sub_sector dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

*** Significant at 1% level.
** Significant at 5% level.
* Significant at 10% level.

Table 10 - Multiprobit regression. Marginal effects for the dependent variable process innovation

Variable	***Model 1***	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
	dF/dX	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*
R&D collaboration with universities/research labs	*0.009*	*0.184*	*-0.001*	*-0.0006*	*0.004*	*0.009*
R&D collaboration with other firms/consultants	*0.202**	*0.223****	*0.267***	*0.268***	*0.202**	*0.243***
R&D intensity (%)	*0.013****	*0.014****	*0.014****	*0.014****	*0.014****	*0.014****
Subsidy dummy	*0.180****	*0.172****	*0.177****	*0.177****	*0.183****	*0.179****
Skilled employees (%)	*0.002***	*0.001***	*0.002***	*0.002***	*0.002**	*0.002***
CEO age	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*	*0.001*
CEO gender	*0.083**	*0.115***	*0.095***	*0.083***	*0.00****	*0.084**
Firm age	*-0.0001*	*-0.0002*	*-0.00008*	*-0.00009*	*-0.00003*	*-0.0001*
Very small firm size	*-0.165****	*-0.166****	*-0.177****	*-0.179****	*-0.169****	*-0.164****
Small firm size	*-0.090***	*-0.101***	*-0.106***	*-0.107***	*-0.094***	*-0.090***
Medium firm size	*-0.025*	*-0.030*	*-0.038*	*-0.039*	*-0.031*	*-0.028*
Large firm size	*0.029*	*0.020*	*0.016*	*0.015*	*0.022*	*0.026*
Proprietorship/Ownership dummy	*-0.012*	*-0.036*	*-0.0006*	*0.00008*	*-0.011*	*-0.007*
Sa dummy	*-0.093***	*-0.057*	*-0.068*	*-0.063*	*-0.095***	*-0.097***
Sarl dummy	*-0.053*	*-0.044*	*-0.030*	*-0.027*	*-0.058*	*-0.039*
Eurl dummy	*0.273****	*0.296****	*0.277****	*0.275****	*0.266****	*0.276****
Coop dummy	*-0.055*	*-0.038*	*-0.025*	*-0.022*	*-0.046*	*-0.034*
Patent dummy	*0.062*	*0.058*	*0.065*	*0.065*	*0.063*	*0.064*
Industrial design dummy	*0.118**	*0.112**	*0.096*	*0.093*	*0.106*	*0.100*
Trademark dummy	*0.054***	*0.048***	*0.060****	*0.061****	*0.054***	*0.056****
Copyright dummy	*0.022*	*0.007*	*0.031*	*0.028*	*0.035*	*0.030*
Rurality of the province where firm is located	*-0.002*	*-0.007*	*-0.008*	*-0.008*	*-0.002*	*0.00002*
France dummy	*-0.126****					
Germany dummy	*-0.149****					
Hungary dummy	*-0.189****					
Italy dummy	*-0.022*					
Spain dummy	*0.052*					
UK dummy	*-0.021*					
No. universities		*0.0008*				
Government R&D (ml €)		*0.0002*	*0.0005***	*0.0005***	*0.0003**	
No. scientists (th)		*0.0002****				
N. years in UE		*-0.002*	*-0.001****	*-0.002****	*-0.001**	*-0.001***
N. agriculture faculties			*0.002*	*0.002**		
No. engineering faculties			*-0.001****			
No. science faculties				*-0.001****		
N. WoS food science articles (100)					*0.00004*	
No. isced5a graduates (th)					*0.00003***	
No. isced5b graduates (th)					*-0.00002****	
No isced6 graduates (th)					*-0.0002*	
Fragmented NIS						*0.062*
Coordinated NIS						*0.056**
Specialisation index						*0.176****
Average citations						*0.015*
Sub_sector dummies	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

*** Significant at 1% level.
** Significant at 5% level.
* Significant at 10% level.

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APPENDIX

Table 6 bis - Multilevel regression for the dependent variable (existence of) intra muros R&D investment

Variable	***Model 1***	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
	dF/dX	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*
R&D subsidy dummy	*0.16****	*0.06**	*0.16****	*0.16****	*0.16****	*0.16****
France dummy	*0.17****					
Germany dummy	*-0.03***					
Hungary dummy	*-0.10****					
Italy dummy	*-0.06****					
Spain dummy	*-0.11****					
UK dummy	*0.024***					
No. universities		*-0.002****				
Government R&D (ml €)		*-0.0005****	*-0.0006****	*-0.001****	*-0.001****	
No. scientists (th)		*0.002****				
N. years in UE		*0.003****	*0.005****	*0.005****	*0.00*	*0.00*
N. agriculture faculties			*-0.007****	*-0.007****		
No. engineering faculties			*-0.0006****			
No. science faculties				*0.0004****		
N. WoS food science articles (100)					*0.0001**	
No. isced5a graduates (th)					*0.00003****	
No. isced5b graduates (th)					*0.00*	
No isced6 graduates (th)					*0.00*	
Fragmented NIS						*-0.24*
Coordinated NIS						*0.09*
Specialisation index						*-0.27*
Average citations						*0.005*
ML component (country code)						
Coeff.	*2.30e-35*	*1.74e-32*	*8.90e-33*	*2.3e-31*	*5.4e-35*	*0.013*
SE	*1.49e-34*	*3.15e-32*	*1.51e-32*	*2.8e-29*	*4.0e-34*	*0.11*

*** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level.

Table 7 bis - Multi regression. Marginal effects for the dependent variable R&D collaboration with universities/research labs

Variable	***Model 1***	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
	dF/dX	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*
Dummy for R&D acquired abroad	*0.08****	*0.08***	*0.08***	*0.08***	*0.07***	*0.08***
R&D subsidy dummy	*0.08****	*0.07****	*0.07****	*0.07****	*0.07****	*0.07****
France dummy	*-0.005****					
Germany dummy	*-0.006*					
Hungary dummy	*0.02*					
Italy dummy	*-0.009*					
Spain dummy	*-0.012**					
UK dummy	*0.016***					
No. universities		*0.0008****				
Government R&D (ml €)		*0.00*	*-0.00007***	*-0.0001***	*-0.0001***	
No. scientists (th)		*0.00*				
N. years in UE		*-0.0004**	*-0.0006**	*-0.0005**	*0.00*	*0.0007****
N. agriculture faculties			*0.001***	*0.001***		
No. engineering faculties			*0.0001****			
No. science faculties				*0.0001****		
N. WoS food science articles (100)					*0.0001****	
No. isced5a graduates (th)					*-8.90e-06***	
No. isced5b graduates (th)					*-0.00001****	
No isced6 graduates (th)					*0.00004***	
Fragmented NIS						*0.044*
Coordinated NIS						*0.04****
Specialisation index						*-0.042****
Average citations						*-0.009****
ML component (country code)						
Coeff.	*4.26e34*	*2.26e33*	*2.75e-33*	*2.2e-33*	*6.54e-35*	*8.0e-33*
SE	*1.02e-33*	*6.61e-33*	*5.09e-33*	*6.0e-33*	*2.84e-34*	*2.4e-32*

*** Significant at 1% level; ** Significant at 5% level; * Significant at 10% lev

Table 8 bis - Multi regression. Marginal effects for the dependent variable R&D collaboration with other firms/consultants

Variable	***Model 1***	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
	dF/dX	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*
Dummy for R&D acquired abroad	*0.17****	*0.16****	*0.16****	*0.16****	*0.16****	*0.17****
R&D subsidy dummy	*0.11****	*0.11****	*0.011****	*0.11****	*0.11****	*0.11****
France dummy	*-0.015*					
Germany dummy	*0.018*					
Hungary dummy	*0.009*					
Italy dummy	*0.027***					
Spain dummy	*0.011*					
UK dummy	*0.09****					
No. universities		*0.002****				
Government R&D (ml €)		*-0.0001****	*0.00*	*0.00*	*-0.0003****	
No. scientists (th)		*0.00*				
N. years in UE		*0.00*	*0.00*	*0.00*	*0.0003****	*0.0007***
N. agriculture faculties			*0.00*	*0.00*		
No. engineering faculties			*0.00*			
No. science faculties				*0.00*		
N. WoS food science articles (100)					*0.0002****	
No. isced5a graduates (th)					*-0.00001**	
No. isced5b graduates (th)					*0.00*	
No isced6 graduates (th)					*0.00006***	
Fragmented NIS						*0.045*
Coordinated NIS						*0.036**
Specialisation index						*-0.03*
Average citations						*0.004*
ML component (country code)						
Coeff.	*2.41e-34*	*9.84e-34*	*0.0007*	*5.3e-29*	*5.1e-35*	*3.2e-35*
SE	*3.66e-34*	*6.71e-34*	*0.0608*	*1.4e-27*	*3.3e-34*	*1.8e-34*

*** Significant at 1% level; ** Significant at 5% level; * Significant at 10% leve

Table. 9 bis - Multiprobit regression. Marginal effects for the dependent variable product innovation

Variable	***Model 1***	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
	dF/dX	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*
R&D collaboration with universities/research labs	*0.02*	*0.02*	*0.02*	*0.01*	*0.02*	*0.02*
R&D collaboration with other firms/consultants	*0.10*	*0.11*	*0.10*	*0.10*	*0.09*	*0.11*
Subsidy dummy	*0.07****	*0.07****	*0.07****	*0.00***	*0.07****	*0.06***
France dummy	*-0.09*					
Germany dummy	*-0.09*					
Hungary dummy	*0.005*					
Italy dummy	*-0.08*					
Spain dummy	*-0.14***					
UK dummy	*0.09*					
No. universities		*0.003****				
Government R&D (ml €)		*-0.0005****	*-0.001****	*-0.001****	*-0.001****	
No. scientists (th)		*0.0004**				
N. years in UE		*0.00*	*0.00*	*0.00*	*0.00*	*0.0*
N. agriculture faculties			*0.003***	*0.002***		
No. engineering faculties			*0.001****			
No. science faculties				*0.001****		
N. WoS food science articles (100)					*0.0004****	
No. Isced5a graduates (th)					*-0.00001**	
No. Isced5b graduates (th)					*0.00*	
No isced6 graduates (th)					*0.0001****	
Fragmented NIS						*0.003*
Coordinated NIS						*0.11**
Specialisation index						*-0.15***
Average citations						*-0.03**
ML component (country code)						
Coeff.	*1.39e-35*	*1.54e-59*	*8.62e-34*	*3.7e-32*	*1.1e-34*	*1.8e-30*
SE	*3.97e-34*	*4.50e-58*	*2.62e-33*	*5.4e-32*	*1.3e-34*	*5.7e-30*

*** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level.

Table 10 bis - Multiprobit regression. Marginal effects for the dependent variable process innovation

Variable	***Model 1***	***Model 2***	***Model 3***	***Model 4***	***Model 5***	***Model 6***
	dF/dX	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*	*dF/dX*
R&D collaboration with universities/research labs	*0.07*	*0.07*	*0.07*	*0.07*	*0.07*	*0.07*
R&D collaboration with other firms/consultants	*0.19****	*0.20****	*0.20****	*0.20****	*0.19****	*0.19****
Subsidy dummy	*0.16****	*0.16****	*0.16****	*0.16****	*0.16****	*0.16****
France dummy	*-0.11****					
Germany dummy	*-0.13****					
Hungary dummy	*-0.18*					
Italy dummy	*0.00*					
Spain dummy	*0.07****					
UK dummy	*-0.004*					
No. universities		*0.00*				
Government R&D (ml €)		*0.00*	*0.00*	*0.00*	*0.0004****	
No. scientists (th)		*-0.002****				
N. years in UE		*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
N. agriculture faculties			*0.00*	*0.00*		
No. engineering faculties			*0.00*			
No. science faculties				*0.00*		
N. WoS food science articles (100)					*0.0004****	
No. Isced5a graduates (th)					*-0.00003***	
No. Isced5b graduates (th)					*0.00*	
No isced6 graduates (th)					*-0.0002****	
Fragmented NIS						*0.01**
Coordinated NIS						*0.085****
Specialisation index						*0.15***
Average citations						*0.01****
ML component (country code)						
Coeff.	*1.15e-35*	*0.0177*	*0.0174*	*0.022*	*7.0e-33*	*3.2e-05*
SE	*2.41e-34*	*0.0120*	*0.0203*	*0.018*	*2.1e-32*	*3.2e-04*

*** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level.