University and inter-firm R&D collaborations: propensity and intensity of cooperation in Europe

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Abstract

This paper investigates the determinants of firms' decision to cooperate in R&D with universities and the intensity of the cooperation effort, in relation to the engagement in inter-firm R&D collaborations.

Using novel survey data for seven EU countries between 2007 and 2009, our analysis accounts for unobservable factors influencing R&D cooperation forms and addresses the main endogeneity issues. We find that internal knowledge, appropriability conditions and incoming spillovers explain large variation in the probability and in the intensity of R&D collaborations of European firms with universities (and comparably with unaffiliated companies).

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1. Introduction

Innovation is a primary factor for firms' competitiveness and growth prospects. R&D and other forms of innovation are often supported by governments due to the public nature of knowledge generated by such activities, which leads firms to under-invest in R&D with respect to the socially desirable value. Market failures induced by knowledge externalities and information asymmetries have motivated the adoption of a large spectrum of policy measures (IPRs laws, direct funding, fiscal incentives, low interest rates, public research, etc.). However, due to increasing constraints on public budgets, the focus of innovation policies, particularly in Europe, has recently shifted to strengthening firms' technological competencies by stimulating R&D collaboration with universities (Becker, 2014).

Much is known about the factors driving firms to cooperate in R&D and, in particular, to establish research agreements with research institutions (namely, universities and R&D centres). The evidence shows that these collaborations allow firms to internalize the external (spillover) effects associated with the creation of new knowledge, and to spread costs and risks implied by breakthrough R&D projects (Cassiman and Veugelers 2002). Cooperation agreements also reduce coordination costs and information leakages with partners, which are hindrances to R&D investments (Segarra-Blasco and Arauzo-Carod 2008). Consistent with the predictions of industrial organization models, numerous empirical papers have shown that firms engage in R&D collaborations when the related benefits are above a certain threshold (Veugelers 1998).

There is an important aspect of the relationship between firms and R&D partners which has received less attention in the literature. This relates to the intensity of firms' collaborative effort and to the factors that can affect such intensity. This issue is relevant not only for firms'strategic aims but also for the identification of the best mix of innovation policy instruments, necessary to raise private R&D effort towards the socially optimum value (Becker 2014). The first objective of this paper is to fill this gap in the literature and to analyse the determinants of the intensity of the firms' R&D collaboration with universities, alongside the determinants of the decision to participate in an R&D cooperation agreement. Our study recognises that, besides universities, other partners can be involved in research cooperation and that there are complementarities among different types of agreements, involving different agents. We therefore consider firms' collaboration with companies belonging to the same business group and with unaffiliated firms.

Another distinguishing feature of our analysis is the data used. Unlike the large majority of studies on research cooperation, which rely on the Community Innovation Survey (CIS), we make use of novel survey data on manufacturing firms from seven European countries over the period 2007-2009 (EFIGE survey). These data provide detailed information on several firm- and industry-level characteristics that allow us to correctly identify the factors that influence companies' decision to cooperate in R&D and the intensity of the cooperation.

Our empirical analysis is based on the estimation of a simultaneous equation system for each cooperation type, i.e. with university, affiliated and non-affiliated firms. This method accounts for possible unobservable factors influencing the different forms of collaboration and the intensity of R&D cooperation with different partners. We also control for reverse causality and simultaneity problems by adopting a full-information approach and extend the multivariate models of R&D cooperation with reduced-form equations for the potentially endogenous regressors (namely, firm's knowledge base and appropriation abilities).

We find that firm's knowledge base, appropriation abilities and incoming spillovers determine the intensity of the company's effort in R&D cooperation with universities (and comparably with external group firms). Also, cooperation intensity with institutional actors increases with the costs of innovation and with the pressure of market competition (but only if competition is not based on product quality improvement). Overall, our results indicate that a large portion of the collaborative effort in R&D can be explained by those factors that, in the literature, have been identified as drivers of cooperation probability. Conversely, R&D cooperation among firms belonging to the same business group seems to be affected by the characteristics of the head firm and how it organizes R&D and other activities within the group.

The remainder is organized as follows. Section 2 briefly reviews the literature on university- and inter-firm partnerships in R&D. Section 3 presents data and summary statistics. Section 4 describes the econometric model and the identification strategy. Section 5 reports estimation results, while Section 6 presents some concluding remarks.

2. Overview of the literature

Innovation is among the main drivers of firms' performance and understanding the factors that contribute to an increasing innovative effort has been in the economic agenda for a long period of time. Over this period, the nature of innovation has changed, becoming increasingly demanding in terms of workers' skills and complementarities across different disciplines. This means that entering research cooperation agreements is gaining increasing importance as a way of sharing knowledge and promoting innovations (Cohen et al. 2002). This topic has originated much interest in recent years and several contributions have analysed motivations and firm's characteristics that affect the propensity to engage in research agreements. The importance has also been recognised at the policy level and governments across the OECD have launched initiatives to promote cooperation between university research and industries (Laursen and Salter 2004).

According to the transaction cost theory, firms will perform research in cooperation with other partners to share risks, costs and competencies involved in an R&D project (Williamson 1985, Segarra-Blasco and Arauzo-Carod 2008). Risk is always a large component of R&D activities whose returns (and profitability) are highly uncertain. The presence of asymmetric information between the firm performing R&D and the investors raises the cost of financing R&D and affects the likelihood of obtaining funds from external sources (Hall and Lerner 2009). Cost sharing is particularly important among small and medium sized enterprises (SMEs), which do not always have enough internal funds or collaterals to support their innovative activities (Becker 2014). Cooperation can mitigate the impact of these costs, as well reducing transaction costs via a better control and monitoring of technology transfer. The reciprocal nature of the relationship can also minimize opportunistic behaviours (Belderbos et al. 2004).

Another motivation which has been widely discussed in the literature is the importance of cooperation for technology transfer across different agents, i.e. as a way of channelling knowledge spillovers. There is general agreement among scholars that knowledge spillovers are important as they contribute to the innovative process and to productivity performance (Jaffe 1986, Griliches 1992). But the presence of spillovers reduces the appropriability of research output and can lead to a low level of investments in innovation. The industrial organization literature focuses on this aspect and emphasizes the importance of striking a balance between information sharing and appropriability within research cooperation agreements. Existing results for Belgium show that the benefit from the cooperation increases when spillovers are particularly high. Firms will try to limit free-riding behaviours, both within and outside the agreement, by controlling the flow of information. In fact, even when participating to an R&D cooperation agreement the company has to control the amount of information shared with other partners through some strategic tools of protection; this will increase appropriability and hence the propensity to cooperate (Cassiman and Veugelers 2002). Additionally, increasing incoming spillovers between research partners has been found to raise the profitability and the stability of cooperation (Kesteloot and Veugelers 1995). Results for France, partially support the view that spillovers matter for cooperation. However, proxies for the (contractual) information flows, such as budget spent on paying license fees and patents, have a positive effect on cooperation (Negassi 2004).

Motivations can differ depending on the type of partner involved in the agreement. Universities are driven by the search for funding that can foster further research opportunities. Firms are particularly driven by the commercialization of new ideas, via the creation of new products or processes (De Fuentes and Dutrenit 2012). However, with the exception of some industrial sectors such as biotechnology (Laursen and Salter 2004), university research does not always directly translate into new products or services (Pavitt 2001). Hence, although appropriability issues are less relevant in the relationship between firm and university, differences in objectives and the nature of academic research can be a hindrance to this type of cooperation, and can make the outcome of the research partnership more uncertain. Veugelers and Cassiman (2005) claim that the gap between universities' and firms' objectives is particularly large in Europe, where only a small fraction of innovative enterprises use universities and public research laboratories as input in their innovation process.[1]

Nevertheless, cooperation between firms and universities has been found to play a particularly important role in countries specialized in low-technological industries. Segarra-Blasco and Arauzo-Carod (2008) discuss this issue in relation to Spain, concluding that cooperation between firms and Spanish universities is an important vehicle to increase innovation effort in this country and aid the catching up process with the rest of Europe. Lopez (2008) also claims that the cost-sharing motive is a very important factor in Spain because of the lack of external private finance and venture capital. Acs et al. (1994) also show that SMEs effectively utilize the results of university research to introduce new products into the market.

University-firm collaboration is only one method that the company can exploit to improve knowledge transfer. As discussed in Kaiser (2002), among others, firms can in fact

[1] Evidence from the European Community Innovation Survey shows that in 2000 less than 10% of innovative firms had cooperative agreements with universities (Veugelers and Cassiman 2005).

establish R&D partnership with competitors (horizontal cooperation) and with suppliers and customers (vertical cooperation). The main purpose of competitor cooperation is to reduce costs and risks associated with developing some new technologies; conversely, customer cooperation is targeted to bring adapted or improved products to the market, whilst supplier cooperation is more focused on cost reduction. Appropriability concerns differ according to the agent involved in the agreement, being more relevant in cooperation with competitors than with other agents (Belderbos et al. 2004). The literature has also shown that cooperation with different partners usually complements each other (Veugelers and Cassiman 2005). For example, evidence for the UK supports this claim as firms that use different external sources of knowledge (competitors, suppliers and customers) also tend to use university research more intensively (Laursen and Salter 2004).

There are also some firms' characteristics that affect the decision to participate to an R&D agreement. These are closely related to the factors that affect the propensity to innovate and have been discussed widely in the literature (see the recent surveys by Vivas and Barge-Gil 2014, and Becker 2014). An important determinant of research cooperation is the availability within the firm of the appropriate skills and knowledge necessary to take advantage of the innovation produced elsewhere, i.e. the firm's absorptive capacity (Cohen and Levinthal 1989). Previous innovation experience and previous involvement in R&D cooperation are both considered to positively affect the probability of initiating a new cooperation (Negassi 2004, Laursen and Salter 2004). R&D intensity is frequently found to have a positive impact on the propensity of firms to use universities in their innovative activities (Larsen and Salter 2004).

The size of the firm has a positive and significant effect on cooperation as large firms are generally more attractive to other partners than small firms (Tether 2002, Negassi 2004, Laursen and Salter 2004, Belderbos et al. 2004) and they are more able to combine both internal and external knowledge in their innovation strategy (Veugeler and Cassiman 1999). The evidence is consistent across different countries (Miotti and Sachwald 2003, Negassi 2004, Lopez 2008).[2] However, small firms can particularly benefit from research cooperation as, in isolation, they are unable to compete with large firms in terms of resources. For example, Motohashi (2005) finds that cooperative R&D agreements are becoming particularly important for small firms in Japan.

[2] An exception is Mexico where De Fuentes and Dutrenit (2012) find that firm size, although positive, does not have a statistically significant effect on academia-industry cooperation.

He observes that over the period 1995-2000 SMEs were reducing the dependence of Japan's system of innovation on in-house R&D conducted within large corporations. From a policy point of view, providing support to small firms to enter research agreement can be beneficial for a country's innovative effort (Czarnitzki et al. 2007, Hottenrott and Lopes-Bento 2014).

Among the factors that promote cooperation, industry affiliation also plays an important role. Firms that operate in skill intensive sectors are more likely to cooperate, particularly with universities or research institutes. For example, Veugelers and Cassiman (2005) show that Belgian firms in the chemical and pharmaceutical industry are more likely to have cooperative agreements with universities. Segarra-Blasco and Arauzo-Carod (2008) report similar evidence for Spain.

Cooperation can take different forms, from informal technology consultations to collaborative R&D conducted on a contractual basis. Firms undertaking both process and product innovation are more likely to cooperate in R&D projects. The type of R&D partnership differs according to the size of the enterprise, with larger ones primarily using collaborations for joint research projects, while a higher percentage of SMEs use technical consulting and take part in joint R&D projects targeted to the final product stage (Motohashi 2005).

3. Data

3.1 Description

We use data from the public release of the "*European Firms in a Global Economy*" (EFIGE) survey, which provides harmonised information on nationally-representative samples of manufacturing firms in seven EU countries: Austria, France, Germany, Hungary, Italy, Spain and the United Kingdom. The survey, coordinated by Bruegel and carried out at the beginning of 2010, collects information on several firm features between 2007 and 2009 (R&D and innovation, ownership structure, management practices, workforce profile, international activities, financing and banking relationships, market structure and pricing behaviour).[3]

[3] The EFIGE samples consider only firms with 10 and more employees and are stratified across industries (11 NACE-CLIO industry codes), regions (at the NUTS-1 level of aggregation) and size classes (10-19; 20-49; 50-250; more than 250 employees), for a total of about 15,000 firms. To preserve firm's confidentiality, data on workforce have been censored for firms with more than 500 employees, whilst turnover and age are provided only as categorical variables. Furthermore, randomised regional identifiers have been used to classify the NUTS1/2 region where the firm is localised, whilst randomised industry identifiers have been used to indicate the sector in which the

In line with the literature (e.g. Bolli and Woerter 2013), we consider only innovating firms, defined as those having carried out R&D activities in the period 2007-2009 (7,545 firms).[4] Our main goal is to identify the key determinants of R&D cooperation with universities and research institutions, using two specifications: the propensity to cooperate and the intensity of R&D projects performed in partnership. Our analysis also recognises that university cooperation agreements are not the sole component of a company's innovation strategy. Unlike the Community Innovation Survey, which is the data source of most papers in the field, the EFIGE dataset does not distinguish R&D partners between competitors, customers and suppliers. However, we are able to consider cooperation with companies belonging to the same business group or with unaffiliated firms.

The dependent variable in the analysis of R&D cooperation propensity is a binary indicator of the firm's decision to undertake projects in collaboration with universities (DRDUNI), with unaffiliated firms (DRDOTH), or with firms within the same business group (DRDGRO). These decisions are not mutually exclusive as the firm may pursue a multiple cooperation strategy. The intensity of R&D cooperation is proxied by the ratio of this R&D investment to firm's turnover. This variable is constructed for collaborations with universities (PRDUNI), external companies (PRDOTH) and group members (PRDGRO).[5]

The EFIGE survey provides information from which we build proxies for key determinants of R&D cooperation, such as appropriability conditions and incoming knowledge spillovers, and to control for a much broader set of firm's characteristics than in earlier studies. When research output cannot be fully appropriated or knowledge spillovers are generated by technological collaborations, firms are stimulated to cooperate. Conversely, by collaborating, firms might lose their proprietary knowledge because of information leakages in favour of R&D partners. Following Veugelers and Cassiman (2005) we assess the impact of appropriability conditions by looking at whether the company uses legal instruments to protect innovation and by considering the industry-level effectiveness of the legal framework on intellectual property

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firm operates. For more detailed information on the EFIGE dataset see Altomonte and Aquilante (2012).

[4] This choice is motivated by the fact that information on relevant explanatory variables (like appropriability and spillover measures) is available for R&D active firms only. As Belderbos et al. (2004) point out, since we do not correct for a possible sample selection bias on R&D participation, our results only refer to R&D active firms.

[5] Specifically, binary indicators of cooperation propensity are based on questions C20 and C23 of the EFIGE questionnaire, while the intensity of each R&D cooperation type is obtained by combining information on firm's R&D investment (question C21) and R&D composition (questions C22 and C23).

rights (IPRs). Appropriability at the firm level is measured by a variable indicating whether the company exploited patents, trademarks, industry designs or copyrights to protect innovation (APPROF). This variable is built by summing up a set of dummies created for each form of protection, and is rescaled so that it ranges from 0 (no protection) to 1 (all forms of protection). Legal appropriability conditions in the market (APPROI) are measured by the industry-by-country mean of APPROF: the rationale is that the larger the number of firms protecting innovation, the stronger is the legal regime of IPRs protection. Notice that APPROI is taken at country and industry level as IPRs regimes change (*de jure)* across countries but their enforcement is (*de facto)* more stringent in those industries in which patents, trademarks, etc. are more effective in protecting innovation (see Aghion et al. 2014).

Under imperfect appropriability, innovation may generate an outflow of knowledge from R&D performers to other firms, a situation that can promote cooperation. To control for this effect, we adopt proxies for incoming knowledge spillovers and account for the source-specific nature of knowledge generated by various forms of R&D collaboration. Specifically, we consider the industry-by-country percentage of companies engaging in each form of R&D collaboration, as the more numerous the collaborating firms, the higher the probability of knowledge transfers and information leakages. INSPGRO is the percentage of firms undertaking within-group R&D collaborations, whilst INSPEXT refers to companies cooperating with external units (both unaffiliated firms and universities). For completeness, we also include the industry-by-country percentage of companies undertaking internal R&D activities (INSPINT). As these firms do not necessarily cooperate, the impact of this variable on R&D collaborations is uncertain.

The endowment of an internal knowledge base promotes R&D cooperation because it facilitates the absorption of knowledge generated by others and it allows the firm to correctly assess the potential of research partnership, in terms of technological opportunities, costs, profitability, etc. On average, the effect of absorptive capacity is stronger for firms which are involved in basic R&D and cooperate with universities, and weaker for those companies establishing technological cooperation with competitors due to a higher risk of knowledge leakages (Cassiman and Vuegelers 2006; Belderbos et al. 2004). We approximate the firm's endowment of internal knowledge with the share of R&D workers on firm employment (RDINT).

The role played by obstacles to innovation is accounted for by two dummy variables, which capture costs and risks associated with research projects (COST and RISK). COST identifies firms that consider regulation, lack of appropriate finance or personnel and organizational rigidities as main obstacles to innovation. These factors raise the cost of research and the need to share these costs can promote cooperation. The variable RISK identifies those companies indicating excessive economic risks, lack of information on markets, and the lack of customer responsiveness to new products, as main impediments to research engagement. Although a higher risk should increase firms' propensity to collaborate in R&D, the impact of this variable has been found to vary greatly in relation to the nature of technological collaboration. For instance, risk constraints are found to increase the probability of cooperation with competitors and customers in Belderbos et al. (2004), whereas negative effects arise for R&D collaborations with universities in Cassiman and Veugelers (2002).

Market competition is another factor that may shape the firm's attitude to R&D agreements. Generally, the market structure determines the firm's incentives to innovate (Aghion et al. 2005, Boone 2008). The impact of competition on innovation might however vary in relation to the market where the firm is active and to the nature of the competitive strategy pursued (Bolli and Woerter 2013). To control for the intensity of competition we use the percentage of firms having competitors abroad (COMPINT). Referring to foreign competitors mitigates the risk of estimation bias induced by possible feedbacks from innovation and R&D cooperation to the market structure (Czarnitzki et al. 2014), as successful innovators may become the market leader and increase their market share. This distortion is more plausible in home markets dominated by one or few big firms (national champions), or in small niche market. To assess the nature of the prevailing competitive strategy, we use the percentage of companies that compete on product prices, i.e. stating that the price of their products is set by the market (PCOMP), and the percentage of innovative sales, which can be used as a proxy for product quality competition (QCOMP). All these variables, measured as industry-by-country means, avoid the potential estimation bias associated with the firms' subjective evaluation of competition, which characterizes works based on CIS data.

We also consider a broad set of firm's characteristics. Generally, innovation activities and R&D collaborations impose high fixed costs of setting up research labs and accessing ad-hoc funds, which only larger firms can afford (Cassiman and Vuegelers 2002). Also, large firms may be engaged in multi-product productions or deal with multiple technologies and, hence, have greater incentives to undertake R&D cooperation. We control for firm size using the level of firm employment, expressed in logs (SIZE), and we assess the presence of non-linear effects by introducing the square of employment (SIZE2). The style of firm management may also determine both the nature and the intensity of R&D partnership and hence we consider a dummy variable indicating whether the firm adopts a decentralised decisional pattern (DEMANAG). These companies are expected to establish more research agreements as they adopt practices for performance monitoring, target setting and incentives, which altogether favour profit-seeking activities such as R&D (Bloom et al., 2014).

An additional characteristic that we include in our analysis is the age of the firm. Although younger firms are generally considered to face higher organizational and financial barriers when engaging in external R&D agreements, they may also be more sensitive to the opportunities offered by collaborating in specialised research niches or in emerging technological fields. For example, dynamic start-ups are particularly capable of transferring university research into commercial innovation and universities support the creation of such start-ups by providing human capital and scientific competences (Laursen and Salter 2004). As a result, it is not easy to predict the impact of age on R&D cooperation, especially if one controls for firm size and managerial practices. In the regression analysis, we consider two dummy variables identifying firms less than 6 years old (YOUNG) and those aged between 7 and 20 years (MEDAGE).[6]

Belonging to a business group influences how the firm organises internal activities and interacts with other firms. This effect clearly depends on the nature of the leading firm (national or multinational) and on how R&D tasks are planned and managed within the group, i.e. whether they are concentrated in few companies or spread out across different R&D active units. Affiliated firms can usually draw on larger resources, although this does not necessarily imply that they have higher opportunities to cooperate (Belderbos et al. 2004). As in Bolli and Woerter (2013), we use a dummy variable to indicate foreign ownership (FOROWN). To fully account for the degree of firm internationalisation we also construct a dummy that indicates whether companies are active abroad due to importing, exporting, offshoring or FDI activities (ABROAD). The use of FOROWN and ABROAD should guarantee that COMPINT, as

[6] These are the only age variables that are available in the EFIGE dataset.

described above, genuinely captures the intensity of foreign competition faced by the firm.

We also assess how the financial structure of the firm influences the way R&D activities are organized. Financial resources available to the firm usually rise with its size due, for instance, to a greater cash-flow or having more tangible assets to collateralize. Moreover, companies may differ in how they exploit external funds (bank credit, bonds, stock market, etc.). There is some evidence documenting that firms largely dependent on external finance innovate more, and grow faster, than those relying on internal resources (Brown et al. 2009, 2012). We therefore include a dummy identifying firms using external sources to finance their (general) activities (EXTFIN).

Finally, we account for whether firms that benefit from public support for R&D engage more in technological collaborations. On average, these firms are more aware of risks and costs of innovation, and better evaluate returns to R&D cooperation. However, we note that R&D public support weakens financial constraints, hence reducing the firm's incentives to cooperate (Belderbos et al. 2004). We consider two types of public incentives to R&D, namely R&D tax credit and R&D subsidy. Fiscal incentives are systematic policy instruments consisting of tax discounts proportional to the amount spent by the firm for carrying out R&D (labs, researchers, scientific equipment, etc.); in practice, firms anticipate funds to perform R&D and then claim tax deductions from liabilities. Conversely, R&D subsidies are discretionary measures that reflect the awarding criteria chosen by the public agency arranging the R&D programme. To be eligible for the R&D grant, applicant firms might also be forced to cooperate with other R&D active units (Czarnitzki et al. 2007, Hottenrott and Lopes-Bento 2014). Therefore, we expect that R&D subsidies are more likely to affect the choice and the intensity of research cooperation, while fiscal incentives might not influence firms' decisions to cooperate. We measure the impact of both types of R&D public support with two dummy variables, denoted by RDSUB and RDTAX.[7]

3.2 Summary statistics

Table 1 shows descriptive statistics. Our sample of innovating firms is composed mainly by companies localised in Italy (22%), Germany (21%) and France (20%). The number of Austrian and Hungarian companies is rather low and the performance of these countries may be somewhat

[7] A full description of the variables used in the regression analysis is provided in Table A.1 of the Appendix.

biased. On average, 9.6% of firms undertake research projects in collaboration with universities. This percentage ranges from 20.7% in Austria to 6.6% in France. The propensity to collaborate within the business group is higher than any other mode of R&D cooperation (17.5% for the total sample), especially for British companies (24%). Establishing R&D cooperation agreements with unaffiliated firms is clearly more problematic, especially when these involve competitors, as appropriability concerns become more severe. This explains why the number of firms involved in this type of technological collaborations is low (5%). Only firms in Austria and France reveal a relatively high propensity towards R&D cooperation with unaffiliated firms (between 8 and 10%).

EU firms do not significantly differ in terms of R&D intensity, as measured by the ratio of research expenditure to sales (7.2% for R&D active firms). Notably, Germany stands out for the highest share of turnover spent for formal innovation (8%). The intensity of cooperation with universities, as the share of turnover of the firms engaged in such type of cooperation, is less than 2%. Amongst the largest economies (which are better represented in the sample), this percentage rises to 2.02% in Italy and 2.54% in Spain. The intensity of R&D collaboration is higher for external partnerships, namely 3.22% with unaffiliated firms and 2.76% with affiliated firms.

Average values for the explanatory variables are reported in Table 2. Some brief points are in order. Firstly, firms engaging in R&D agreements with universities are more R&D intensive, make a wider use of IPRs tools and are very active abroad. Moreover, these companies rely more on external sources of finance and take larger benefits from R&D public support, either in the form of direct funding or fiscal incentives. Secondly, companies collaborating in R&D with unaffiliated firms adopt less decentralized management practices, are less active abroad and are more dependent on external finance. Lastly, the size of companies involved in within-group R&D cooperation are considerably larger than the rest of the sample. These firms are more likely to be foreign owned and to decentralise decision-making.

4. Empirical model

4.1 Specification

We investigate the drivers of firm R&D collaborations with universities, in relation to the other forms of R&D partnership, in terms of the propensity to cooperate and the intensity of cooperation efforts. To account for unobservable factors that may simultaneously influence how companies organise external R&D, we estimate a system of three equations in which each dependent variable corresponds to a type of R&D cooperation, namely, cooperation with universities, with unaffiliated firms and within the business group (Belderbos et al. 2004, Bolli and Woerter 2013). Assuming a common set of determinants, each equation is expressed as:

$$\begin{aligned} y_{im} = f\Big(& RDINT_i, APPROF_i, APPROI_{cj}, INSPINT_{cj}, INSPEXT_{cj}, INSPGRO_{cj}, \\ & COMPINT_{cj}, PCOMP_{cj}, QCOMP_{cj}, COST_i, RISK_i, Other_i\Big) + \varepsilon_{im} \end{aligned} \tag{1}$$

with i, c and j denoting firm, country and industry, respectively. y_{im} is the outcome indicator observed on the m-th type of cooperation. This indicator is expressed as a binary variable in the estimation of the cooperation propensity; in the analysis of cooperation intensity, the indicator represents the ratio of R&D investment performed in partnership over firm turnover. The set of explanatory variables in equation (1) includes the main factors identified in the literature as determinants of R&D cooperation (*R&D intensity*, *Incoming Spillovers*, *Appropriability*, *Innovation Obstacles and Competition*). *Other* is a vector collecting additional firm-specific characteristics. Each specification includes a set of country dummies to account for the effect of unobserved nation-wide confounding factors (institutional setting, general competition policies, asymmetries in business cycle, etc.). The impact of industry characteristics is assumed to be country-specific and is captured by the set of indicators denoted by the subscript *cj*.

The error terms ε_{im} are allowed to be correlated across the m equations, with a non-diagonal covariance matrix Σ. This correlation may be due to unobservable factors that influence whether, and how, firms undertake research projects with external R&D active units. If significant cross-equation dependence exists, the univariate estimation would lead to biased and inefficient parameter estimates. Positive correlation would indicate complementarity between cooperation types, whilst a negative correlation would suggest substitutability. Complementarity effects may arise when the marginal costs of entering an additional form of R&D cooperation are low compared to the fixed costs necessary to initiate external collaborations. Substitutability effects may be determined, for instance, by financial constraints or (locked-in) technological capabilities which are specific to cooperation types. As pointed out by Belderbos et al. (2004), a shortcoming of the (recursive) simultaneous multivariate approach is that it does not distinguish the sources of correlation among equations. The dependence between R&D cooperation types may indeed be due to firm-specific characteristics, to factors common only to a sub-sample of companies, or to general idiosyncratic shocks that influence firm's R&D collaborations in a heterogeneous way.[8] Unlike earlier studies, we are able to control for a larger set of firm-specific characteristics, thus reducing the risk of omitted variables problems and leaving only a small proportion of cross-equation correlation unexplained.

In order to analyse the firm's propensity to engage in different types of R&D cooperation, we consider a multivariate (three-equation) binary choice (probit) model:

$$\begin{aligned} y_{im}^{*} &= x_{im}'\beta_m + \varepsilon_{im}, \\ y_{im} &= 1 \ \text{ if } y_{im}^{*} > 0 \text{ and } 0 \text{ otherwise} \end{aligned} \tag{2}$$

with $m = 1, ..., 3$ and where y_{im} is the observed binary indicator for the firm's cooperation choice. x_{im} are $k \times 1$ vectors of explanatory variables, β_m are conformable parameter vectors and, ε_{im} is a set of error terms which are distributed as standard multivariate normal with covariances $\rho_{jk} = \rho_{kj}$ (for $j,k = 1, ..., 3$ and $j \neq k$). For each firm, we observe whether it cooperates with universities, with unaffiliated firms or within the business group. Each combination can be then represented as a 3-tuple of values of the vector ($DRDUNI_i$, $DRDOTH_i$, $DRDGRO_i$) with probability:

$$\begin{aligned} P(DRDUNI_i, DRDOTH_i, DRDGRO_i) &= P(y_{i1}, y_{i2}, y_{i3} \mid x_{i1}', x_{i2}', x_{i3}') \\ &= \Phi_3(k_{i1}x_{i1}'\beta_1, k_{i2}x_{i2}'\beta_2, k_{i3}x_{i3}'\beta_3; R) \end{aligned} \tag{3}$$

$\Phi_3(\cdot)$ is the trivariate cumulative standard normal distribution, $k_{im} = 2y_{im} - 1$, are sign variables (equal to 1 or –1 depending on whether the binary dependent variable is equal to 1 or 0) and the covariance matrix R has elements defined as $R_{jk} = R_{kj} = k_{ij}k_{ik}\rho_{jk}$ (for $j,k = 1, ..., 3$ and $j \neq k$). The log-likelihood function of the trivariate probit model is given by $L = \sum_{i=1}^{N} \log \Phi_3(k_{i1}x_{i1}'\beta_1, k_{i2}x_{i2}'\beta_2, k_{i3}x_{i3}'\beta_3; R)$ and can be evaluated by means of maximum

[8] A fully simultaneous multivariate model (i.e., a model in which each R&D cooperation indicator also enters the other cooperation equations of the system as an explanatory variable) would be more appropriate to disentangle complementarity/substitutability effects from residual correlations. Though, this approach is unfeasible for the present analysis due to the lack of valid restrictions on the parameters (and support) of error terms. These restrictions are necessary to rule out regions of incoherency/incompleteness and ensure parameter identifiability (Lewbel 2007).

simulated likelihood (MSL) methods (Cappellari and Jenkins 2003).[9]

Similar to the analysis of cooperation propensity, we jointly model the determinants of cooperation intensity for the three different forms of technological collaboration. To accommodate for the fact that the dependent variables are censored at zero, and to allow for cross-equation correlation, we consider a trivariate Tobit system (Amemiya 1974). As its univariate counterpart, this system is based on the assumption that censoring is governed by the same stochastic process determining the value of the dependent variables, and can be formalised as follows:

$$\begin{aligned} y^*_{im} &= x'_{im}\beta_m + \varepsilon_{im}, \\ y_{im} &= y^*_{im} \;\; \text{if } y^*_{im} > 0 \text{ and } 0 \text{ otherwise} \end{aligned} \tag{4}$$

y_{im} now represents the intensity of the m-th cooperation type, and the error terms ε_{im} are distributed as multivariate normal with zero means, variances σ_m and covariances $\sigma_{jk} = \sigma_{kj}$ (for $j, k = 1, ..., 3$ and $j \neq k$). The $k \times 1$ vectors x_{im} include the same set of explanatory variables used for cooperation propensity. As shown in Arias and Cox (2001), the contribution to the likelihood function of an observation in which the first r equations out of m are censored at zero is:

$$L_i = \int_{-\infty}^{-x'_{i1}\beta_1} \cdots \int_{-\infty}^{-x'_{ir}\beta_r} \phi(u_1, \ldots, u_m)\, du_1 \ldots du_r \tag{5}$$

where $\phi(\cdot)$ is the multivariate normal probability density function. The previous expression represents a portion of the likelihood function with a r-dimensional definite integral, which does not have a closed form solution and has to be evaluated numerically. As for the multivariate probit, estimation of the trivariate Tobit system is performed with MSL methods.[10]

4.2 Endogeneity issues

The empirical models outlined above assume that all covariates are exogenous with respect to the firm's choice to cooperate. This hypothesis may be too strong and estimates may be biased in presence of reverse causality or simultaneity feedbacks. To avoid these problems, we adopt a

[9] The MSL estimation procedure is based on the Geweke-Hajivassiliou-Keane (GHK) multivariate normal simulator, with 200 random draws for each observation. Estimation has been carried out using the Stata conditional mixed process estimator (*CMP*) developed by Roodman (2011).

[10] The GHK multivariate normal simulator, with 200 random draws for each observation, is used to obtain MSL estimates of the trivariate Tobit model.

full-information approach and consider a mixed-process system of equations, which combines the trivariate probit (or Tobit) model with additional reduced-form equations for the potentially endogenous regressors. This estimation strategy is more efficient, despite being potentially less robust and computationally more complex, than limited-information and two-stages approaches commonly used in earlier studies (see, e.g., Veugelers and Cassiman 2005; Belderbos et al. 2004).

Within this mixed-process system, a formal test of endogeneity can be obtained by testing the statistical significance of the estimated correlation coefficients (ρ_{rm}) between the errors of the reduced-form equations and the three structural equations for the R&D cooperation types. If the unobserved factors affecting the potentially endogenous regressors also influence the firm's R&D cooperation, it will show up in significant cross-equation correlation. Therefore, a preliminary step of our analysis consists in assessing the endogeneity of the explanatory variables in the full mixed-process model. After testing for endogeneity, consistent and efficient estimates are obtained by means of the conditional maximum likelihood estimation, imposing appropriate restrictions on the correlation "structure" between the errors of the structural and reduced-form equations. In this way, our multivariate mixed-process model allows to address endogeneity and obtain efficient estimates (see Lopez 2008).

Following previous studies, we focus on two potentially endogenous (firm-level) explanatory variables: internal knowledge (RDINT) and appropriability (APPROF). Firms may exploit technological knowledge and managerial expertise developed in research collaborations to increase returns to in-house R&D. As a result, these companies may be induced to allocate further resources to internal research projects. In this case, causality would run from R&D cooperation to internal knowledge. Similarly, when research collaborations bear breakthrough innovations, which have the potential for further technological developments or immediate market exploitation, the firm is more likely to use IPRs tools to appropriate returns to research.

Appropriate exclusion restrictions have to be imposed to improve identification of the system. A set of factors, assumed to be orthogonal to R&D cooperation forms, is thus included in the equations of potentially endogenous regressors (RDINT and APPROF). The impact of these variables on R&D cooperation is identified by exploiting variation in firms' response to the market collapse of late 2008 (REDSALE), as it can be considered as broadly exogenous with respect to the decision to cooperate in R&D, Specifically, we use a dummy variable for those companies experiencing a reduction in sales between 2008 and 2009.

In addition, to better assess the impact of internal knowledge on R&D cooperation, we include the average value of R&D intensity of the firms localised in the same NUTS administrative area of the company.[11] This variable should capture regional variation in the conditions which make it profitable to invest in R&D, namely a better higher education sector, a more efficient government,[12] better communication infrastructures, a more structured credit system, etc. As discussed below, this proximity indicator (denoted by RDREG) is unrelated to the firm's attitude to cooperate in R&D as we adopt spillover proxies that are more relevant for this type of company decision. Therefore, RDREG can be safely used to predict the effect of internal knowledge on R&D cooperation (RDINT).

The impact of appropriability is predicted by the number of banking relationships, used here as a proxy for the firm's attitude to disclose confidential information. Companies fearing the loss of proprietary knowledge usually diversify their relationship with banks and other financial institutions (Hernández-Cánovas and Köeter-Kant, 2010). This strategy aims to prevent possible leakages of confidential information, preserve decision-making independence, and reduce rent appropriation by banks, which characterize single-bank relationships (Detragiache et al., 2000). It is reasonable to expect that firms with multiple-bank relationships adopt conservative strategies in technological knowledge management and protect their innovation by legal mechanisms. Hence, in addition to sales' reduction, we use the number of banking relationships maintained by the firm (NBANKS) as a predictor of appropriability.

[11] For each firm, we compute a regional mean of R&D intensity excluding the value of its RDINT.
[12] For instance, regional governments may facilitate firm R&D by efficiently managing EU regional funds for competitiveness, technology and employment targets.

5. Results

5.1 The Probability of cooperating in R&D

Table 3 shows estimates for the multivariate probit model.[13] The table displays the marginal effects of the explanatory variables obtained after controlling for the endogeneity of firm knowledge (RDINT) and appropriability capacity (APPROF).

In the Appendix, we report the reduced form estimates, together with the residual correlation coefficients between the reduced-form and structural equations of the system (Table A.3). The reduced form estimates indicate that instruments significantly influence, and with the expected impact, both internal knowledge and appropriability.[14] The residuals' structure of such estimates reveals that significant correlation exists only between the equations for R&D intensity and for R&D partnership with unaffiliated firms ($\rho_{RDINT,DRDOTH} = -0.2583$). Conversely, appropriability is exogenous to all cooperation choices. Based on these results, our estimates for R&D cooperation probabilities are obtained imposing this "structure" of endogeneity on the multivariate mixed-process model.[15]

Results in Table 3 show that all pair-wise residual correlations are significant and positive, suggesting that there is complementarity between R&D cooperation choices, and that university cooperation cannot be analysed separately from the other forms of collaboration. Our findings indicate that internal knowledge, appropriability and incoming spillovers significantly influence the probability of participating in an R&D cooperation agreement, even though these factors have a differentiated impact on cooperation types. R&D intensity (RDINT) positively influences the decision to cooperate with universities and with other firms, but this variable has no effect on cooperation among firms belonging to the same business group.[16] Within group

[13] All regressions use sampling weights and robust standard errors clustered at the regional (NUTS1 or 2) level.

[14] Instruments are jointly significant with LR test statistics equal to 11.88 (*p*-value = 0.002) and 25.46 (*p*-value = 0.000) in the equations for R&D intensity and appropriability, respectively. The appropriateness of instrumental variables is further assessed by testing their exogeneity with respect to R&D cooperation choices. To this aim, we adopt the "informal" approach devised by Evans and Schwab (1995): we include the instruments, together with R&D intensity and appropriability indicators, in all the cooperation equations and then test for their joint significance. Results indicate that instrument exclusion cannot be rejected, with *p*-values equal to 0.4953, 0.6992 and 0.2227, respectively.

[15] Estimates of the multivariate mixed-process model with unconstrained covariance structure (i.e., assuming both internal knowledge and firm appropriability as endogenous), not reported but available from the authors, show a substantial efficiency loss.

[16] In the exogenous model (see Table A.2), R&D intensity is insignificant in the equation for cooperation with unaffiliated firms, suggesting that our treatment of endogeneity helps remove important measurement errors in such

cooperation is more likely to be determined by the leader company, its technological capabilities and management practices. The insignificance of firms' R&D intensity for within-group R&D cooperation would suggest that the bulk of R&D activities are concentred in few companies and only minor research tasks are assigned to affiliates, irrespective of their knowledge base.

Better appropriability conditions (APPROF) stimulate firms' engagement in R&D collaboration with universities and unaffiliated firms, as they are likely to reduce the extent of outgoing spillovers (Abramovsky et al. 2009). Conversely, the degree of enforcement of IPRs (APPROI) is negatively related to R&D agreements with unaffiliated firms. A high effectiveness of the IPRs system usually discourages free-riding behaviours and stabilizes cooperative agreements; however, strict legal protection of innovation output also limits the scope for internalizing information flows, reducing technological collaborations (Lopez, 2008).

Another valuable finding in our analysis concerns the importance of knowledge spillovers in raising the probability of cooperating. The propensity to establish R&D agreements with universities rises with the amount of knowledge created within external collaborations, taken as whole (institutional cooperation and cooperation with unaffiliated firms). However, the impact of external knowledge appears slightly larger for the probability of R&D cooperation with unaffiliated firms (0.55 vs 0.43). Notably, the share of firms performing in-house R&D (INSPINT) is unrelated to R&D cooperation. This suggests that information leakages generated by such firms are irrelevant for the decision of the other companies to undertake external research projects.

Among obstacles to innovation, only cost factors (COST) are found to significantly stimulate firms to cooperate in R&D. This effect is limited to research agreements with universities and unaffiliated firms, corroborating the view that the characteristics of the leader company prevail over cost and risk factors in shaping collaborations within the business group.

Our indicators of market structure indicate that the intensity of market competition influences firms' participation in R&D collaborations with institutional partners, such as universities or research centres. More specifically, the propensity to engage in institutional R&D agreements increases with the competitive pressure of the industry (COMPINT). This suggests that, via university cooperation, companies aim to obtain breakthrough innovations while, at the

variable that, otherwise, would attenuate towards zero the parameter.

same time, avoiding knowledge leakages to competitors. Given the general nature of knowledge underlying institutional research projects, firms are less inclined towards these collaborations when competition is based on product quality improvement (QCOMP), which mainly relies on applied research and incremental innovation. Price competition (PCOMP) does not exert a significant impact on any form of cooperation. The insignificant effect of price competition on external group R&D partnerships may be due to the opposite effect that this explanatory variable has on collaborations with customers, suppliers and competitors that are considered altogether in our analysis.

Further interesting insights emerge from the assessment of other firms's characteristics. Firm size is crucial for all cooperation types.[17] There is also evidence that management practices allowing for decentralized decision-making (DEMANAGE) are associated with a greater engagement in technological collaborations with universities and, comparably, with affiliated companies. Within-group collaborations involve more middle-aged firms and fewer young firms (MEDAGE and YOUNG). The fact that younger companies have no preferential attitude to cooperate in R&D suggests that their difficulties mostly derive from a lack of financial resources and managerial competences (Laursen and Salter 2004). These arguments are corroborated by the significance of the dummy for external finance dependence (EXTFIN). On average, firms using external funds are more prone to external research collaborations. Conversely, this financial condition is unrelated to R&D partnerships among affiliated firms as fund transfers may be arranged within the group by the leader company, limiting the dependence of affiliates on external finance. The leadership of a multinational group (FOROWN) is influential for the organization of R&D tasks across group members. Foreign-owned firms are not necessarily active in international markets with imports, exports or other activities. This explains why ABROAD is not significant for within-group R&D cooperation. On the other hand, internationally active firms are more prone to undertake university cooperation; perhaps, these companies have greater awareness of the potential offered by the international market, in terms of commercial purposes or knowledge transfers, and therefore seek to develop breakthrough innovations in collaboration with institutional partners.

A wide heterogeneity emerges in the impact of R&D policy instruments. R&D

[17] In Table 3 and 4, the reported marginal effects of firm size account for non-linearity associated with the quadratic terms.

cooperation is unaffected by fiscal incentives to R&D (RDTAX) due to the automatic nature of such instruments, which do not alter firm incentives to innovate and to initiate technological collaborations. Rather, there is some (weak) indication that firms benefiting from R&D tax credits have a lower propensity to cooperate with external group firms, probably because they are less financially constrained. A different picture emerges for direct R&D funding (RDSUB). On average, firms receiving R&D subsidies are more likely to establish research collaborations with universities and unaffiliated companies. Finally, country effects mainly influence collaboration with universities and with firms external to the business group. In particular, firms in Austria and Germany have a higher propensity to establish research agreements with universities, while companies in France, Germany, Hungary, Italy and Spain cooperate less with unaffiliated firms, compared to the reference country (UK).

5.2 Intensity of R&D cooperation

As a novel contribution to the literature, we estimate the impact of our set of explanatory variables on the intensity of R&D performed in cooperation. Table 4 reports the marginal effects on the conditional intensities of R&D cooperation obtained from the trivariate Tobit system, after addressing the endogeneity issues.[18] Estimated correlations of unobservables across equations indicate the presence of complementarity also in the intensity of R&D cooperation forms, which is particularly significant between collaborations with universities and with unaffiliated firms.

Most variables influencing the probability of cooperation are also found to affect the extent of technological collaborations. This finding suggests that these factors not only lead firms to reach the critical threshold to initiate R&D cooperation, but also explain variation in their cooperative effort. There are nonetheless a few interesting differences with respect to the probit estimates. Although firm size positively affects the effort in each cooperation form, the magnitude of this effect is larger for within-group collaborations. Also, the proportion of R&D performed with universities is not significantly higher for firms active abroad. Albeit these

[18] Coherently with multivariate probit results, estimates of reduced form equations reported in Table A.5 show that there is endogeneity only between internal knowledge and R&D performed in cooperation with unaffiliated firms ($\rho_{RDINT,PRDOTH} = -0.3690$). Our instruments are jointly significant in the equations for R&D intensity and appropriability, with LR test statistics equal to 12.57 (p-value = 0.002) and 24.27 (p-value = 0.000), and do not significantly affect R&D collaboration decisions as their exclusion from cooperation equations cannot be rejected, with p-values equal to 0.3240, 0.3226 and 0.3565, respectively. Table A.4 reports estimates assuming exogenous covariates.

companies are more likely to explore new ways to increase competitiveness through R&D collaborations with universities, probably they do not have the competencies necessary to engage intensively in such research projects. Furthermore, and consistently with the results in Table 3, estimates in Table 4 indicate that firms benefiting from R&D tax credit cooperate less in R&D with unaffiliated firms (i.e., customers, suppliers and competitors), as they are likely larger, less financially constrained and with more research experience (Busom et al. 2012).

Because of lower appropriability concerns, knowledge circulates more easily among firms belonging to the same business group, increasing the share of R&D that these companies perform together. The magnitude of this spillover effect (INSPGRO) is between 40 and 80% as large as the one estimated for external knowledge on the intensity of R&D cooperation with unaffiliated firms and universities. A unitary increase in the spillover measure (i.e. the percentage of firms involved in a given cooperation type) raises the intensity of R&D cooperation within the group by 4.3%, the intensity of university cooperation by 2.4% and other R&D collaborations by 3.1%. The stimulus of internal knowledge (RDINT) is much higher for cooperation with unaffiliated firms than for university cooperation, in line with the results of the probability model (Table 3). Focusing on the impact of market competition on university R&D cooperation (COMPINT), the effect of competitive pressure appears sizeable, as an unitary increase in this variable (to say from 54 to 55% of firms facing foreign competitors) causes a 0.75% increase in the intensity of institutional cooperation. However, this effect is counterbalanced by the impact exerted by product quality competition. To mimic the strategy of analysis followed by Bolli and Woerter (2013), who find an inverted U-shaped relation between university cooperation and price competition, and an U-shaped relationship with quality competition, we also included the square of PCOMP and QCOMP, but these quadratic terms were insignificant (and hence omitted). Another interesting finding is that there are systematic differences also in the intensity of R&D cooperation between firms localised in different countries, with Austrian and German companies being more intensively engaged in institutional R&D agreements. This is consistent with Cunningham and Link (2014) who document that large cross-country differentials persist in Europe in R&D collaborations between universities and the business sector. This variation can be largely explained by the university deficiency of R&D funds and infrastructures, as well as by the firms' concern about the loss of their intellectual property. All these factors reduce the extent of university-firm R&D collaborations, whilst the collaborative effort is higher when universities can more easily access business-sector R&D facilities.

Overall, our analysis shares some traits with Carboni (2012) who estimates the determinants of total expenses on R&D collaboration (in per worker terms) on a sample of Italian manufacturing firms over the period 2001-2003. Differently from such work (and abstracting from the sample composition), we are able to distinguish between the intensity of R&D cooperation types and treat them jointly in a multiple-equation system. Our study also addresses the endogeneity issue of the main explanatory variables.

6. Concluding remarks

Following the literature on R&D cooperation choices, this paper has investigated the drivers of university cooperation among EU firms. Our analysis has accounted for possible complementarity or substitutability effects between institutional R&D partnerships and alternative cooperation strategies, i.e. technological collaborations with firms belonging to the same business group or with unaffiliated companies. Furthermore, we have addressed endogeneity issues associated with the main determinants of R&D cooperation (internal knowledge and appropriation abilities).

The paper makes some important contributions to the literature. First, to our knowledge, this is the first study investigating the drivers of the intensity of R&D cooperation. Second, the analysis exploits information from a novel dataset (EFIGE) that provides richer information on firm characteristics than the Community Innovation Survey (i.e., the main data source for the studies in the field). Third, the examination of the drivers of R&D cooperation uses variables which do not reflect the firms' subjective assessment of relevant sources of knowledge and protection methods, thus limiting reverse causality problems.

Our empirical model is sufficiently general to explain quite well both the propensity and the intensity of firm cooperation in R&D with different partners. We find that European firms perform a larger share of R&D in cooperation with research institutions, the larger their knowledge base and appropriation abilities. Incoming spillovers are another crucial factor determining the extent of university cooperation. Firms' effort in university cooperation increases with the costs of innovation and with the competitive pressure of the market (except when competition is based on product quality improvement). On average, larger firms and those relying on external finance or public R&D funding perform a larger proportion of their research in partnership with universities.

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TABLES

Table 1 – Average Propensity and Intensity of R&D Cooperation

	Country:							
	AUT	FRA	GER	HUN	ITA	SPA	UK	Total
R&D firms (number)	246	1506	1598	131	1661	1303	1100	7545
(% of total sample)	*3.3*	*20.0*	*21.2*	*1.7*	*22.0*	*17.3*	*14.6*	*100*
Cooperating firms (in %):								
University	20.7	6.6	11.1	18.3	7.7	10.0	10.2	9.6
Other firms	9.8	7.8	3.4	6.9	3.6	3.2	6.7	5.0
Group	19.9	13.0	16.1	13.0	18.7	17.7	24.1	17.5
R&D expenses on turnover	6.8	6.2	8.0	6.3	7.3	7.5	6.9	7.2
R&D cooperation intensity on turnover (conditional on cooperating):								
University	2.85	1.66	1.84	2.54	2.02	2.54	1.22	1.97
Other firms	3.35	2.02	2.96	4.68	4.11	3.98	2.54	3.22
Group	2.61	2.14	4.16	1.99	2.75	4.54	1.84	2.76

Notes: cooperation frequencies and average intensities are computed using sample weights.

Table 2 – Determinants of R&D Cooperation: Cross-Country Mean

Variables	All R&D firms	Firms collaborating with: Universities	External firms	Group
Main explanatory variables				
RDINT	11.6	12.9	11.8	9.45
APPROF	0.16	0.26	0.21	0.22
APPROI	0.10	0.11	0.10	0.11
INSPEXT	0.93	0.93	0.93	0.94
INSPGRO	0.22	0.24	0.23	0.22
INSPINT	0.05	0.05	0.05	0.07
COST	0.17	0.20	0.20	0.15
RISK	0.24	0.24	0.24	0.23
COMPIN	0.54	0.54	0.53	0.59
PCOMP	0.36	0.37	0.36	0.38
QCOMP	21.3	21.3	21.6	20.9
Other firm characteristics				
SIZE (log)	3.79	4.10	3.81	4.62
DEMANAG	0.33	0.42	0.36	0.48
YOUNG	0.07	0.06	0.07	0.04
MEDAGE	0.33	0.33	0.33	0.35
FOROWN	0.11	0.15	0.10	0.48
ABROAD	0.89	0.94	0.89	0.94
EXTFIN	0.48	0.53	0.55	0.37
RDSUB	0.19	0.27	0.21	0.24
RDTAX	0.17	0.28	0.20	0.19

Notes: descriptive statistics are computed using sample weights.

Table 3 – Probability of R&D cooperation; Multivariate Probit Model with Endogenous Explanatory Variables: Marginal Effects

Explanatory Variables	**(1) University cooperation**	**(2) Other firms cooperation**	**(3) Within group cooperation**
RDINT	0.0006**	0.0054***	-0.0002
	(0.0002)	(0.0011)	(0.0001)
APPROF	0.1014***	0.1425***	0.0075
	(0.0150)	(0.0183)	(0.0065)
APPROI	-0.0272	-0.3837**	0.0292
	(0.1193)	(0.1708)	(0.0628)
INSPEXT	0.4573***	0.5376***	-0.0237
	(0.0998)	(0.1413)	(0.0351)
INSPGRO	0.1145	-0.2239	0.3446***
	(0.1576)	(0.2124)	(0.0617)
INSPINT	0.0310	-0.2699	-0.0705
	(0.1474)	(0.2508)	(0.0730)
COST	0.0579***	0.0693**	-0.0014
	(0.0163)	(0.0286)	(0.0085)
RISK	0.0281	0.0171	0.0142
	(0.0341)	(0.0409)	(0.0155)
COMPIN	0.1217***	-0.0062	-0.0249
	(0.0460)	(0.0627)	(0.0196)
PCOMP	0.0783	0.0577	-0.0069
	(0.0854)	(0.1328)	(0.0388)
QCOMP	-0.0027***	0.0000	0.0002
	(0.0009)	(0.0012)	(0.0005)
SIZE (log)	0.0192***	0.0220**	0.0153***
	(0.0062)	(0.0110)	(0.0039)
DEMANAG	0.0153**	0.0114	0.0139***
	(0.0065)	(0.0113)	(0.0034)
YOUNG	-0.0042	-0.0053	-0.0187*
	(0.0180)	(0.0191)	(0.0096)
MEDAGE	-0.0001	-0.0081	0.0092**
	(0.0083)	(0.0104)	(0.0040)
FOROWN	0.0077	-0.0140	0.0530***
	(0.0100)	(0.0143)	(0.0063)
ABROAD	0.0244**	-0.0097	-0.0063
	(0.0124)	(0.0156)	(0.0067)
EXTFIN	0.0297***	0.0432***	-0.0053
	(0.0070)	(0.0106)	(0.0052)
RDTAX	0.0142	-0.0262*	-0.0010
	(0.0100)	(0.0146)	(0.0053)
RDSUB	0.0480***	0.0429***	0.0006
	(0.0109)	(0.0153)	(0.0047)
AUT	0.0403**	-0.0580	-0.0109
	(0.0175)	(0.0410)	(0.0167)
FRA	-0.0127	-0.0712**	0.0043
	(0.0232)	(0.0340)	(0.0099)
GER	0.0660***	-0.0579**	-0.0154*
	(0.0137)	(0.0254)	(0.0086)
HUN	0.0435	-0.1870***	-0.0228
	(0.0394)	(0.0604)	(0.0196)
ITA	0.0144	-0.0592**	-0.0020
	(0.0184)	(0.0292)	(0.0098)
SPA	0.0242	-0.0797**	-0.0108
	(0.0211)	(0.0329)	(0.0102)
ρ_{12}	0.6365***		
	(0.0424)		
ρ_{13}	0.1223**		
	(0.0488)		
ρ_{23}	0.1491***		
	(0.0444)		
Significance of country fixed effects	56.32*** [0.0000]	15.82** [0.0148]	8.17 [0.2262]
Obs.	7545		
Log-likelihood	-32734.02		

Notes: Robust standard errors, clustered at the regional level, are reported in parentheses below the estimates. *p*-values of the joint significance of country fixed effects are reported in square brackets. All estimates are obtained using sample weights.
***, ** and * denote significance at 1, 5 and 10 percent levels, respectively.

Table 4 Intensity of R&D cooperation: Multivariate Tobit Model with Endogenous Explanatory Variables: Marginal Effects

Explanatory Variables	(1) University cooperation	(2) Other firms cooperation	(3) Within group cooperation
RDINT	0.0048***	0.0553***	-0.0018
	(0.0017)	(0.0120)	(0.0018)
APPROF	0.5078***	0.8577***	0.1043
	(0.0832)	(0.1362)	(0.0895)
APPROI	-0.2478	-2.3925**	0.8992
	(0.6629)	(1.1664)	(0.9072)
INSPEXT	2.4362***	3.0774***	-0.5324
	(0.5040)	(1.0331)	(0.4497)
INSPGRO	0.6272	-1.6412	4.3149***
	(0.8677)	(1.3953)	(0.9701)
INSPINT	-0.2121	-2.5566	-1.5531
	(0.8315)	(1.6409)	(1.0627)
COST	0.3371***	0.3967**	-0.0871
	(0.0962)	(0.1990)	(0.1295)
RISK	0.2232	0.1614	0.3612
	(0.2079)	(0.2429)	(0.2534)
COMPIN	0.7483***	0.0871	-0.4203
	(0.2661)	(0.4182)	(0.3045)
PCOMP	0.4261	0.1418	-0.0319
	(0.4455)	(0.8188)	(0.5596)
QCOMP	-0.0123**	0.0031	0.0057
	(0.0053)	(0.0079)	(0.0074)
SIZE (log)	0.0886**	0.1861**	0.2221***
	(0.0365)	(0.0780)	(0.0666)
DEMANAG	0.0772*	0.0015	0.1821***
	(0.0467)	(0.0752)	(0.0631)
YOUNG	0.0358	0.0162	-0.1962
	(0.1077)	(0.1306)	(0.1513)
MEDAGE	-0.0096	-0.0867	0.1661**
	(0.0474)	(0.0672)	(0.0665)
FOROWN	-0.0031	-0.0129	0.7286***
	(0.0519)	(0.1130)	(0.1227)
ABROAD	0.0793	-0.1620	-0.0988
	(0.0764)	(0.1058)	(0.1004)
EXTFIN	0.1581***	0.2423***	-0.0998
	(0.0450)	(0.0782)	(0.0799)
RDTAX	0.0601	-0.2252**	0.0002
	(0.0530)	(0.1098)	(0.0751)
RDSUB	0.2642***	0.2308**	0.0277
	(0.0696)	(0.0946)	(0.0679)
AUT	0.2499**	-0.3006	-0.1918
	(0.1143)	(0.2685)	(0.2253)
FRA	-0.0840	-0.5367**	0.0410
	(0.1253)	(0.2320)	(0.1359)
GER	0.3721***	-0.4239**	-0.2092
	(0.0779)	(0.1789)	(0.1376)
HUN	0.2189	-1.0920***	-0.3771
	(0.2041)	(0.3558)	(0.3001)
ITA	0.0528	-0.3149	-0.0754
	(0.1029)	(0.1959)	(0.1447)
SPA	0.1289	-0.4693**	-0.1584
	(0.1231)	(0.2168)	(0.1459)
ρ_{12}	0.4175***		
	(0.0362)		
ρ_{13}	0.0668		
	(0.0412)		
ρ_{23}	0.0428		
	(0.0324)		
Significance of country fixed effects	39.82*** [0.0000]	14.54** [0.0241]	5.98 [0.4257]
Obs.	7545		
Log-likelihood	-37968.66		

Notes: Robust standard errors, clustered at the regional level, are reported in parentheses below the estimates. *p*-values of the joint significance of country fixed effects are reported in square brackets. All estimates are obtained using sample weights.
***, ** and * denote significance at 1, 5 and 10 percent levels, respectively.

Table A.1 – Variables Description

Label	Definition	Source	Description	Type
Dependent variables				
DRDUNI	University cooperation	Firm-level	Firm cooperating in R&D with Universities and research institutions	Dummy
DRDGRO	Group cooperation	Firm-level	Firm cooperating in R&D with firms of the same business group	Dummy
DRDOTH	Other R&D cooperation	Firm-level	Firm cooperating in R&D with other firms	Dummy
PRDUNI	University R&D cooperation int.	Firm-level	Intensity of university cooperation on turnover	Continuous
PRDGRO	Group cooperation int.	Firm-level	Intensity of within-group cooperation on turnover	Continuous
PRDOTH	External R&D cooperation int.	Firm-level	Intensity of cooperation with unaffiliated firms on turnover	Continuous
Main explanatory variables				
APPROF	Strategic appropriability	Firm-level	Firm relying on legal measures to protect innovation (patents, industrial design, copyright, trademarks)	Continuous
APPROI	Legal appropriability	Industry-by-country	% of firms relying on legal measures to protect innovation	Continuous
INSPINT	Internal incoming spillovers	Industry-by-country	% of firms doing R&D internally	Continuous
INSPGRO	Group incoming spillovers	Industry-by-country	% of firms doing R&D within the group	Continuous
INSPEXT	External incoming spillovers	Industry-by-country	% of firms doing R&D with external firms and institutions	Continuous
RDINT	R&D intensity	Firm-level	% of R&D workers on total employment	Continuous
COST	Cost of R&D	Firm-level	Firm indicating cost factors as obstacle to R&D (regulation, standards; lack of appropriate sources of finance; lack of qualified personnel, organisational rigidities)	Categorical
RISK	Risk of R&D	Firm-level	Firm indicating risk factors as obstacle to R&D (excessive perceived economic risks, lack of information on markets, lack of customer responsiveness to new products)	Categorical
COMPINT	Competition intensity	Industry-by-country	% of firms having competitors abroad	Continuous
QCOMP	Product quality competition	Industry-by-country	Avg % of turnover from innovative products	Continuous
PCOMP	Product price competition	Industry-by-country	% of price-taker firms	Continuous
Other firm characteristics				
SIZE	Firm size	Firm-level	Logs of employees	Continuous
SIZE2	Square of firm size	Firm-level	(Logs of employees)^2	Continuous
DEMANAG	Decentralized management	Firm-level	Firm adopting practice of decentralised management	Dummy
YOUNG	Young firm	Firm-level	Firm being less than 7 years old from the establishment	Dummy
MEDAGE	Medium-aged firm	Firm-level	Firm being between 7 and 20 years old from the establishment	Dummy
FOROWN	Foreign holder	Firm-level	Firm with foreign owner	Dummy
ABROAD	Active abroad	Firm-level	Firm active abroad with exporting, importing, FDI, etc.	Dummy
EXTFIN	Financial dependence	Firm-level	Firm using external funds to finance activities	Dummy
RDSUB	R&D subsidy	Firm-level	Firm receiving public funding to R&D	Dummy
RDTAX	R&D tax incentive	Firm-level	Firm benefiting from fiscal incentives to R&D	Dummy

Table A.2 – Multivariate Probit Model with Exogenous Explanatory Variables: Marginal Effects

Explanatory Variables	(1) University cooperation	(2) Other firms cooperation	(3) Within group cooperation
RDINT	0.0006**	0.0001	-0.0002
	(0.0002)	(0.0004)	(0.0001)
APPROF	0.1013***	0.1370***	0.0075
	(0.0150)	(0.0179)	(0.0065)
APPROI	-0.0276	-0.3192**	0.0293
	0.1013***	0.1370***	0.0075
INSPEXT	0.4561***	0.5500***	-0.0238
	(0.0999)	(0.1413)	(0.0350)
INSPGRO	0.1150	-0.1705	0.3445***
	(0.1576)	(0.2056)	(0.0617)
INSPINT	0.0320	-0.2446	-0.0703
	(0.1475)	(0.2371)	(0.0730)
COST	0.0580***	0.0707**	-0.0013
	(0.0162)	(0.0277)	(0.0085)
RISK	0.0280	0.0301	0.0141
	(0.0340)	(0.0386)	(0.0155)
COMPIN	0.1216***	-0.0188	-0.0250
	(0.0461)	(0.0592)	(0.0196)
PCOMP	0.0774	0.0641	-0.0069
	(0.0853)	(0.1272)	(0.0388)
QCOMP	-0.0027***	0.0013	0.0002
	(0.0009)	(0.0011)	(0.0005)
SIZE (log)	0.0192***	-0.0075	0.0153***
	(0.0062)	(0.0084)	(0.0039)
DEMANAG	0.0153**	0.0145	0.0139***
	(0.0065)	(0.0106)	(0.0034)
YOUNG	-0.0043	0.0006	-0.0187*
	(0.0180)	(0.0179)	(0.0096)
MEDAGE	0.0000	-0.0024	0.0092**
	(0.0083)	(0.0107)	(0.0040)
FOROWN	0.0078	-0.0103	0.0530***
	(0.0100)	(0.0142)	(0.0063)
ABROAD	0.0244**	-0.0079	-0.0063
	(0.0124)	(0.0148)	(0.0067)
EXTFIN	0.0297***	0.0434***	-0.0053
	(0.0070)	(0.0103)	(0.0052)
RDTAX	0.0143	-0.0079	-0.0011
	(0.0100)	(0.0139)	(0.0053)
RDSUB	0.0480***	0.0495***	0.0006
	(0.0109)	(0.0144)	(0.0047)
AUT	0.0408**	-0.0595	-0.0108
	(0.0175)	(0.0406)	(0.0167)
FRA	-0.0128	-0.0564*	0.0043
	(0.0232)	(0.0329)	(0.0099)
GER	0.0662***	-0.0300	-0.0153*
	(0.0137)	(0.0249)	(0.0086)
HUN	0.0438	-0.1809***	-0.0228
	(0.0394)	(0.0555)	(0.0197)
ITA	0.0147	-0.0562**	-0.0020
	(0.0184)	(0.0280)	(0.0098)
SPA	0.0242	-0.0750**	-0.0108
	(0.0211)	(0.0331)	(0.0102)
ρ_{12}	0.6855***		
	(0.0295)		
ρ_{13}	0.1234**		
	(0.0480)		
ρ_{23}	0.1584***		
	(0.0441)		
Significance of country fixed effects	56.39*** [0.0000]	18.04** [0.0135]	8.19 [0.2248]
Obs.	7545		
Log-likelihood	-6098.59		

Notes: Robust standard errors, clustered at the regional level, are reported in parentheses below the estimates. *p*-values of the joint significance of country fixed effects are reported in square brackets. All estimates are obtained using sample weights.
***, ** and * denote significance at 1, 5 and 10 percent levels, respectively.

Table A.3 – Reduced Form Equations of the Multivariate R&D Cooperation Propensity Model: Coefficient Estimates

Explanatory Variables	**(1) RDINT**	**(2) APPROF**
APPROI	8.9206	0.9799***
	(7.2835)	(0.0917)
INSPEXT	6.2035	0.0306
	(5.9950)	(0.0807)
INSPGRO	11.5097	-0.1003
	(8.2468)	(0.1232)
INSPINT	15.0161	-0.1343
	(11.2503)	(0.1279)
COST	0.3905	0.0338**
	(1.3775)	(0.0160)
RISK	2.3111	0.0228
	(1.8794)	(0.0223)
COMPIN	-2.5174	-0.0617*
	(2.4372)	(0.0332)
PCOMP	0.5016	-0.0596
	(4.5090)	(0.0715)
QCOMP	0.2289***	0.0010
	(0.0561)	(0.0007)
SIZE	-19.2969***	-0.0160
	(1.9462)	(0.0245)
SIZE2	1.9399***	0.0066**
	-19.2969***	-0.0160
DEMANAG	0.8559*	0.0297***
	(0.4618)	(0.0073)
YOUNG	1.2554	0.0099
	(0.9306)	(0.0142)
MEDAGE	1.3090**	0.0027
	(0.5829)	(0.0062)
FOROWN	0.2297	0.0055
	(0.6661)	(0.0118)
ABROAD	0.9642	0.0687***
	(0.8393)	(0.0060)
EXTFIN	0.4445	0.0132**
	(0.4359)	(0.0067)
RDTAX	3.7782***	0.0172*
	(0.7119)	(0.0104)
RDSUB	1.7711***	0.0309***
	(0.6526)	(0.0085)
AUT	-0.4413	-0.0085
	(0.9656)	(0.0191)
FRA	2.7666***	0.0123
	(1.0317)	(0.0180)
GER	1.8550**	-0.0115
	(0.9439)	(0.0163)
HUN	3.6074*	-0.0225
	(1.8722)	(0.0282)
ITA	0.5505	-0.0408**
	(1.1266)	(0.0168)
SPA	1.4463	-0.0432**
	(1.2902)	(0.0208)
REDSALE	-1.1418**	-0.0185**
	(0.5288)	(0.0073)
RDREG	1.1747***	–
	(0.0859)	
NBANKS	–	0.0055**
		(0.0023)
Constant	19.5943*	0.0839
	(11.3182)	(0.1462)
$\rho_{iDRDUNI}$	0.2297	0.0055
	(0.6661)	(0.0118)
$\rho_{iDRDOTH}$	-0.2583***	0.1144
	(0.0659)	(0.1453)
$\rho_{iDRDGRO}$	-0.1961	0.1703
	(0.1655)	(0.1539)

Notes: Robust standard errors, clustered at the regional level, are reported in parentheses below the estimates. All estimates are obtained using sample weights.
***, ** and * denote significance at 1, 5 and 10 percent levels, respectively.

Table A.4 – Multivariate Tobit Model with Exogenous Explanatory Variables: Marginal Effects

Explanatory Variables	(1) University cooperation	(2) Other firms cooperation	(3) Within group cooperation
RDINT	0.0047***	0.0041	-0.0018
	(0.0017)	(0.0030)	(0.0018)
APPROF	0.5062***	0.7884***	0.1036
	(0.0831)	(0.1287)	(0.0897)
APPROI	-0.2438	-1.7607*	0.9025
	(0.6617)	(0.9902)	(0.9076)
INSPEXT	2.4176***	3.1443***	-0.5333
	(0.5032)	(0.9770)	(0.4496)
INSPGRO	0.6205	-1.1259	4.3155***
	(0.8682)	(1.2765)	(0.9704)
INSPINT	-0.2161	-2.2742	-1.5539
	(0.8343)	(1.4910)	(1.0621)
COST	0.3381***	0.3989**	-0.0868
	(0.0960)	(0.1825)	(0.1296)
RISK	0.2226	0.2775	0.3606
	(0.2074)	(0.2149)	(0.2534)
COMPIN	0.7485***	-0.0287	-0.4214
	(0.2659)	(0.3678)	(0.3048)
PCOMP	0.4235	0.1878	-0.0325
	(0.4456)	(0.7448)	(0.5598)
QCOMP	-0.0124**	0.0141**	0.0058
	(0.0053)	(0.0067)	(0.0074)
SIZE (log)	0.0888**	-0.0906*	0.2222***
	(0.0364)	(0.0523)	(0.0666)
DEMANAG	0.0775*	0.0332	0.1822***
	(0.0466)	(0.0660)	(0.0631)
YOUNG	0.0359	0.0666	-0.1961
	(0.1075)	(0.1236)	(0.1513)
MEDAGE	-0.0098	-0.0300	0.1662**
	(0.0472)	(0.0676)	(0.0665)
FOROWN	-0.0017	0.0188	0.7288***
	(0.0520)	(0.1135)	(0.1227)
ABROAD	0.0789	-0.1365	-0.0987
	(0.0764)	(0.0951)	(0.1004)
EXTFIN	0.1573***	0.2392***	-0.0997
	(0.0449)	(0.0707)	(0.0799)
RDTAX	0.0607	-0.0540	0.0003
	(0.0530)	(0.0930)	(0.0751)
RDSUB	0.2636***	0.2902***	0.0278
	(0.0694)	(0.0856)	(0.0679)
AUT	0.2537**	-0.3094	-0.1914
	(0.1142)	(0.2639)	(0.2253)
FRA	-0.0860	-0.3798*	0.0415
	(0.1253)	(0.2093)	(0.1359)
GER	0.3719***	-0.1541	-0.2090
	(0.0777)	(0.1633)	(0.1375)
HUN	0.2200	-1.0038***	-0.3770
	(0.2039)	(0.3144)	(0.3003)
ITA	0.0541	-0.2809	-0.0749
	(0.1027)	(0.1754)	(0.1447)
SPA	0.1284	-0.4187**	-0.1582
	(0.1232)	(0.2085)	(0.1459)
ρ_{12}	0.4515***		
	(0.0384)		
ρ_{13}	0.0681*		
	(0.0409)		
ρ_{23}	0.0526		
	(0.0340)		
Significance of country fixed effects	40.00*** [0.0000]	13.81** [0.0319]	5.98 [0.4249]
Obs.	7545		
Log-likelihood	-311339.04		

Notes: Robust standard errors, clustered at the regional level, are reported in parentheses below the estimates. *p*-values of the joint significance of country fixed effects are reported in square brackets. All estimates are obtained using sample weights.
***, ** and * denote significance at 1, 5 and 10 percent levels, respectively.

Table A.5 – Reduced Form Equations of the Multivariate R&D Cooperation Intensity Model: Coefficient Estimates

Explanatory Variables	(1) RDINT	(2) APPROF
APPROI	9.0254	0.9825***
	(7.2490)	(0.0913)
INSPEXT	6.0015	0.0306
	(6.0100)	(0.0807)
INSPGRO	11.6842	-0.1002
	(8.2321)	(0.1231)
INSPINT	14.9863	-0.1326
	(11.2002)	(0.1277)
COST	0.3784	0.0339**
	(1.3792)	(0.0160)
RISK	2.3159	0.0227
	(1.8828)	(0.0223)
COMPIN	-2.5496	-0.0629*
	(2.4318)	(0.0334)
PCOMP	0.5735	-0.0586
	(4.5142)	(0.0714)
QCOMP	0.2282***	0.0010
	(0.0561)	(0.0007)
SIZE	-19.2058***	-0.0163
	(1.9475)	(0.0245)
SIZE2	1.9296***	0.0066**
	(0.2285)	(0.0031)
DEMANAG	0.8575*	0.0296***
	(0.4621)	(0.0073)
YOUNG	1.2607	0.0102
	(0.9264)	(0.0143)
MEDAGE	1.2935**	0.0028
	(0.5828)	(0.0062)
FOROWN	0.2202	0.0056
	(0.6652)	(0.0118)
ABROAD	0.9674	0.0685***
	(0.8392)	(0.0060)
EXTFIN	0.4372	0.0130**
	(0.4356)	(0.0066)
RDTAX	3.7935***	0.0171
	(0.7093)	(0.0104)
RDSUB	1.7329***	0.0308***
	(0.6534)	(0.0085)
AUT	-0.4136	-0.0091
	(0.9626)	(0.0190)
FRA	2.7343***	0.0118
	(1.0347)	(0.0179)
GER	1.9627**	-0.0123
	(0.9478)	(0.0161)
HUN	3.3452*	-0.0229
	(1.8276)	(0.0281)
ITA	0.5217	-0.0423***
	(1.1270)	(0.0164)
SPA	1.4442	-0.0448**
	(1.2857)	(0.0204)
REDSALE	-1.1650**	-0.0164**
	(0.5276)	(0.0078)
RDREG	1.1362***	–
	(0.0891)	
NBANKS	–	0.0060***
		(0.0019)
Constant	19.7976*	0.0820
	(11.2368)	(0.1461)
$\rho_{iPRDUNI}$	0.1518	-0.1409
	(0.1278)	(0.1058)
$\rho_{iPRDOTH}$	-0.3690***	0.1145
	(0.0814)	(0.1076)
$\rho_{iPRDGRO}$	-0.2326	0.1808
	(0.1476)	(0.2576)

Notes: Robust standard errors, clustered at the regional level, are reported in parentheses below the estimates. All estimates are obtained using sample weights.
***, ** and * denote significance at 1, 5 and 10 percent levels, respectively.