University-Industry Collaboration in Biopharmaceutical Industry: The Italian Case

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Abstract

We investigate the determinants of University-Industry interactions in the biopharmaceutical in Italy, over the period 2004-2010. Because of the specificities of biopharmaceutical industry, we choose co-publishing as a proxy of University-Industry relations. By integrating different statistical sources, we construct a novel dataset of co-published articles containing measures of proximities; agglomeration; firms' and universities' characteristics. Following a consolidated methodology, we extend our dataset of effective U-I interactions, which activated a co-publication, with the set of potential U-I interactions which did not. The resulting dataset is used to estimate probabilistic models for the occurrence and intensity of University-Industry interaction. Our main findings confirm to a large extent predictions of the relevant literature. Namely: *i*) both geographical and organizational proximity increase the probability and the intensity of co-publications; *ii*) the proximity of a firm to other biopharmaceutical firms and universities attenuates the impact of geographical proximity on the probability of co-publishing; *iii*) there exists complementarity between organizational proximity and geographical proximity. A relevant and completely novel result is that firms' and Universities' size; composition of the academic staff as well as quality of academic research exert a significant impact on the intensity of co-publishing.

Keywords: University-Industry collaborations, Biopharmaceutical industry, Co-publishing

JEL codes: O310, O320, O330, R100

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1 Introduction

In the last decade, economic literature has devoted increasing attention to University-Industry (U-I, henceforth) interaction in its various modes (such as personnel mobility; informal contacts; consulting relationships; joint research projects; joint publications; co-patenting; spin off),[1] The reason being that University research produces knowledge spillovers and U-I collaborations may play an important role as innovation drivers at local level (Owen-Smith and Powell, 2004; Audia et al., 2006; Mueller, 2006). In this setting, geographical proximity (proxied by the co-location of R&D labs and Universities) is regarded as relevant for knowledge intensive sectors such as pharmaceuticals (Abramovsky and Simpson, 2009). More generally speaking, according to the common wisdom, geographical proximity may enhance U-I collaborations as it helps overcoming institutional differences, (Ponds et al., 2007) facilitating face to face interactions which can create that mutual trust essential to collaboration activities.[2]

Because of the internationalization of knowledge, enhanced by Information and Communications Technologies diffusion, recently, the prominent role of geographical proximity has been increasingly questioned by some scholars (among others, Breschi and Lissoni, 2001; Howells, 2002; Gertler, 2003; Boschma, 2005). As a consequence, non-geographical dimensions of proximity, such as organizational, institutional, social and cognitive and their impact on knowledge transfer are coming to the fore (Boschma, 2005; Ponds et al., 2007; D'Este et al., 2013).

Within this strand of literature, D'Este et al. (2013) have recently investigated complementarity and substitutability between geographical proximity and other kinds of proximity such as organizational proximity and industrial clustering.

Our paper intends to contribute to this strand of literature, investigating: *i*) the relevance of different types of proximity as well as their interactions in shaping University-Industry

[1]For a systematic analysis on the variety of channels of interactions, see D'Este and Patel (2007). Among the contributions of the last decade, see, for instance the analysis for several countries: Calvert and Patel (2003), D'Este and Patel (2007), D'Este and Iammarino (2010), Laursen et al. (2011), D'Este and Perkmann (2011), D'Este et al. (2013), Hewitt-Dundas (2013) for studies on U.K.; Balconi and Laboranti (2006), Abramo et al. (2009), Abramo et al. (2010), Abramo et al. (2011), Iacobucci and Micozzi (2013), Muscio and Pozzali (2013) for Italy; Ponds et al. (2007), Bekkers and Freitas (2008) for Netherlands; Grimpe and Fier (2010), Slavtchev (2013) for Germany; Azagra-Caro et al. (2006), Azagra-Caro (2007), Barbolla and Corredera (2009) for Spain; Boardman (2009), Boardman and Ponomariov (2009), Bozeman and Gaughan (2007) for the U.S. Recently, Perkmann et al. (2013) (page 430) highlighted in their review on U-I relations (focussing on academic engagement and commercialization) as this literature may suffer of limited comparability given the way measures are constructed. In fact, the construction of the dependent variable representing academic engagement with industry may vary considerably among contributions. Moreover, the comparability is further hampered by differences in industries and countries for which U-I collaborations are investigated.

[2]Ponds et al. (2007) stress how successful interaction is less correlated to geographical proximity when institutional proximity is high (as in the case of two universities) since the underlying structure of incentives and constraints is similar.

collaboration in the biopharmaceutical industry, a strategic sector in the Italian economy;[3] *ii*) the intensity of the relation between University and biopharmaceutical firms; *iii*) the impact of partner specific characteristics, such as firms' and universities' size; universities' quality of research, on the U-I relations. Among the different modes, our analysis focusses on co-publication as a proxy of U-I collaborations. The reason being that co-publishing is particularly appropriate when analyzing relations between University and biopharmaceutical firms. The latter is a science-based industry[4], whose growth and profitability are strictly dependent on successful research. Discovery and development of drugs require an increasing amount of human and financial resources, therefore biopharmaceutical industry has the vital need to acquire external knowledge and engages with university and public research centers to exploit public spill-overs. These factors explain the reason why biopharmaceutical companies are extensively involved in publishing activities in order to be part of the research community and interact with scientists from both industry and academia. As a result, the share of collaborative publication is more than two third of total publications (Gittelman and Kogut, 2003) and this evidence makes co-publishing a relevant proxy for U-I interactions (Calvert and Patel, 2003).

Our econometric investigation is based upon a unique database we built up which gathers data on co-publications for the 2004-2010 period. The contributions of this article to the U-I literature are twofold. First, it confirms and extends to a science based industry as biopharmaceutical and to the co-publishing mode of U-I relations, the main predictions of current recent literature and, in particular, D'Este et al. (2013). We find that both geographical and organizational proximity exert a positive impact on co-publishing and there exists substitutability between geographical proximity and individual firms' proximity to firms? clustering. Moreover, we shed some new light on the interaction between geographical and organizational proximity which, in the case of biopharmaceutical industry, result to be complements. Second, it advances our knowledge on the intensity of U-I relations, highlighting the role played by individual characteristics of firms (such as size) and universities (such as size; composition of academic staff and research quality). Such research design might open up avenues for further refinements, allowing also to outline some policy implications. In this vein, the paper provides an entirely new empirical result. We, in fact, find that the intensity of co-publishing is higher when: *i*) the firm is large (more than 249 employees); *ii*) the University level of Research quality is higher; *iii*) the larger and

[3]Biopharmaceutical industry is usually intended as a subset of pharmaceutical industry (biopharmaceuticals are biological medical products manufactured using biotechnology), however in this study we adopt a broad definition since the progression of biopharmaceutical development incorporate several industrial (NAICS, North American Industrial Classification System) sectors such as biological product manufacturing, medicinal and botanical manufacturing (on this point, see Battelle, 2013). Brusoni et al. (2005) highlighted as pharmaceutical firms increased the breath of their knowledge base and exhibit depth in knowledge integration in particular in the fields of biotechnology, biochemical research and neurosciences. Since chemical-biotech and pharmaceutical research are strictly related, and the present study focuses on joint research between university and industry, it is more appropriate to investigate these sectors as a single industry. Therefore, hereinafter, we will refer to biopharmaceutical industry as the chemical, biotech and pharmaceutical industry.

[4]According to Pavitt (1984) taxonomy.

younger is the academic staff. The remainder of the paper is organized as follows. Section 2 analyzes the main modes of interaction between biopharmaceutical firms and Universities; Section 3 reports the empirical analysis: specifically, empirical strategy is outlined in subsection 3.1, proximity measures and partner specific characteristics are illustrated in subsection 3.2, subsections 3.3 and 3.4 show the results of our empirical investigation, Section 4 concludes.

2 Why biopharmaceutical industry? Peculiarities and interaction with University

Biopharmaceutical industry is of particular interest for several social, legal and economic reasons. The discovery of new drugs requires very significant investments in research and development, and, at the same time, implies an equally high degree of uncertainty on the results (Grabowski, 2006).[5] As a consequence, this industry is characterized by high value added, high innovation propensity and high level of investments in R&D, human and physical capital (Ryan, 1998; Cockburn et al., 1999).

Therefore, biopharmaceutical industry is a science-based industry whose growth and profitability are strictly dependent on successful research. University research affects positively productivity of local firms (Jaffe, 1989; Zucker and Darby, 1997) and public spillovers are crucial in driving productivity and investments in biopharmaceutical industry (Ward and Dranove, 1995; Cockburn and Henderson, 1998; Furman et al., 2006). Rejecting the linear model of research labour division in which universities conduct basic research, while applied research is carried out by the private sector, Cockburn and Henderson (1996) and Cockburn and Henderson (1998) find reciprocal (and complex) interactions between university and the private sector. Moreover, connectedness between public and private research is crucially influenced by the science base produced by public sector and by in-house basic research conducted by private sector. Private sector's investments in basic research are, in fact, fundamental in building that "absorptive capacity" which enables them to make use of external knowledge (Cockburn and Henderson, 1998; Gambardella et al., 2000; Fabrizio, 2009). Pharmaceutical firms perform basic research on a moderate level (Cohen and Levinthal, 1989, 1990; Rosenberg, 1990; Gambardella, 1992; Cockburn and Henderson, 1996; Fabrizio, 2009) and, in order to quickly absorb externally generated knowledge and convert it into products, industrial researchers frequently work on topics similar to their colleagues in publicly funded labs (Hicks et al., 1996; Narin and Rozek, 1988). Moreover, pharmaceutical industry widely cooperates with public labs (Gambardella, 1995) or biotechnology firms (which are a frequent acquisition target), focusing on their downstream capabilities (Achilladelis and Antonakis, 2001; Gambardella, 1995; Henderson et al., 1999; Grabowski and Vernon, 1994). Frequently, external biotechnology firms serve as liaison

[5] At the end of a long and difficult process of incubation, that requires between 12 and 14 years from the initial phase to the phase of marketing of a drug composed of new chemical entities, a large part of the products cannot even cover the effective costs, with the consequence that the sector generally counts on a small number of blockbusters drugs to recover the totality of investments sustained (Grabowski, 1995).

brokers: valued-added intermediaries between Universities and downstream alliance partners (large Pharma) (Stuart et al., 2007).
Given the aforementioned need of pharmaceutical firms to acquire knowledge from external sources (in particular from universities and public research centers which perform basic research and clinical trials), the best way to achieve this goal is to be part of the research community. Therefore, unlikely other industries, pharmaceutical companies publish extensively (Koenig, 1983; Hicks, 1995; EU-Commission, 2003; Leten et al., 2010) because their papers serve as tickets to scientific networks (Hicks, 1995; Cockburn and Henderson, 1998). Cockburn and Henderson (1998) highlight the importance for these firms to be actively connected to the scientific community. When firms collaborate with universities or governmental research institutes, publication is likely (Ponds et al., 2007). Furthermore, the freedom to publish as an employee within a company attracts good scientists (Rubenstein, 1989) and is promoted by many firms (Zucker and Darby, 1997). Indeed, Sternitzke (2010) reports that each drug is shown to be accompanied by, on average, about 19 journal publications and 23 additional patents (US data) and Gittelman and Kogut (2003) document that the share of collaborative publications is about 70% of total articles published. As a result, those firms with a policy to publish are more successful than others (Henderson and Cockburn, 1994).
Given the biopharmaceutical industry publishing behavior described above, it is particularly relevant to study co-published works as proxy of knowledge transfer between university and industry. Therefore, even though not all collaborations end with a co-published article, co-publications can be taken as a good proxy for University-Industry collaborative activity (Calvert and Patel, 2003; Ponds et al., 2007). Calvert and Patel (2003) for the U.K. found that more than half of all U-I co-publications in their dataset (time horizon 1981-2000) where imputable to chemical, medical and biological sciences. This result further reinforces the evidence on the peculiarity of the industry under analysis in our work with respect to its interaction with university. In addition, co-patenting, considered also to be a good proxy for U-I collaboration in biopharmaceutical industry might be not suitable at all in the Italian case, since co-patenting, compared to other countries, is a more limited phenomenon (due to the institutional intellectual property right system) and the sample of co-patenting in this particular industry might be severely restricted and non-sufficiently informative.
Life sciences profoundly changed the processes of discovery and development of new drugs, requiring a notable increase of resources (in terms of critical mass of human capital as well as in terms of financial resources). It follows that nowadays biopharmaceutical industry, more than other industries, has to be analyzed as a system of linkages among different actors (big pharmaceutical firms, small biotech firms, universities, public research centers, national health systems, policy makers and financial institutions). This aspect has gained attention by European policy makers in the light of Horizon 2020 objectives. In this regard, the EU Commission has recently highlighted the need for EU public-private partnerships in research and innovation (EU-Commission, 2013), particularly for industries where research and innovation are high risk activities and there is no guarantee of success since this might discourage private sector to undertake investments, even if the economic

and societal returns could potentially be very large. In fact, public-private partnership may reduce uncertainty by enabling a long term approach to research and innovation and provide a legal structure to pool resources and to gather critical mass.

3 Empirical analysis

In this section, we illustrate the empirical analysis performed on the determinants of U-I co-publishing, specifically, in section 3.1 we outline the empirical strategy; section 3.2 describes the regressors included in the statistical models; sections 3.3 and 3.4 comment on the results.

3.1 Empirical strategy

The empirical analysis focuses on U-I partnerships in the specific mode of co-publications. More precisely, the phenomenon of interest consists in the publication of research articles co-authored by academic authors and scientists employed by private biopharmaceutical firms. The empirical analysis builds on an original database on co-published articles, containing measures of proximities; agglomeration; firms' and universities' characteristics.[6] We take into account the articles published in 2004-2010 period and indexed by the ISI Web of Science database.[7] Departing from the records of the database containing information on authors' affiliations, we identified a total of 827 co-publications between Italian universities and business units of biopharmaceutical companies located in Italy. The choice of the period has been dictated by the availability of specific data on universities' characteristics. In particular, for research quality we make use of data provided by the Italian National Agency for the Evaluation of Universities and Research Institutes (ANVUR), available for the time period 2004-2010. Following the same empirical strategy as in D'Este et al. (2013), we employed *real* interactions to generate all the possible couples of *potential* interactions between Italian universities[8] and biopharmaceutical firms.[9] For every *real* U-I co-authorship involving one university and one business unit, we generated 47 *artificial* observations between the remaining 47 universities and the same business unit, thus obtaining the set of all conceivable interactions, including those which did not end up in a co-authorship. This procedure has led us to a dataset of 39,696 (=827x48) U-I pairs, which constitutes the dataset used to investigate the determinants of U-I co-authorships. To this aim, we specify and estimate a probabilistic model of the logit type, whose dependent is

[6] For a detailed description of the dataset see Appendix A.

[7] We examined a total of 92,985 publications in the period 2001-2010.

[8] Our dataset included 49 universities. "Politecnico di Torino" and those universities which do not employ academic staff in the scientific areas of interests have been excluded.

[9] We consider those firms with at least one co-publication in the period 2004-2010. This approach is the same used by empirical analyses based on surveys, where the list of firms included in the survey is restricted to those which had at least one collaboration. Samples of this kind can be found in the empirical literature which, for instance, relies on data sets on collaborative research grants awarded by the UK Research Council.

a dummy variable (*Occurrence*) which takes value 1 if the generic pair enterprise i and university j experienced a co-publication, and 0 otherwise.
As the phenomenon of co-publications appears to a remarkable extent concentrated in a small number of firms, the number of co-publications can be regarded as a countable random variable. Thus, we furthermore estimate a negative binomial model, whose dependent variable is the total number of co-published articles between firm i and university j (*#Occurrence*) over years 2004-2010. With respect to a logit model, the advantage of a negative binomial choice, consists in the fact that it allows to investigate the determinants of the *intensity* of the phenomenon, that is the second focus of our empirical investigation. Descriptive statistics on the dependent variable as well as the regressors included in the analysis are reported in table 1.

3.2 Proximity measures and partner specific characteristics of firms and universities

In the econometric models proposed, some variables refer to the *(i,j)* U-I couple that published the research article, while other variables refer to characteristics specific to only one of the two actors involved in the partnership. The variables included in the analysis are the following:[10]

- *Geographical proximity*: Index of geographical proximity between enterprise i and university j. The index is computed as the inverse of the square root of the great-circle distance between the *i-th* enterprise and the *j-th* university. The great-circle distance, expressed in kilometers,[11] has been computed applying the Haversine formula to longitudes and latitudes[12] of each U-I pair.

- *Organizational proximity*: Index of organizational proximity proxied by previous co-publishing experiences of enterprise i and university j. The index is computed as the product of the scaled, square root number of co-publishing experiences of enterprise i and university j in years 2001-2003, i.e. in the three years preceding the estimation sample period. Scaled figures are computed dividing raw data by the maximum number of co-publishing experiences recorded in the pre-sample period for enterprises and universities, respectively.

- *Cluster index*: Index of proximity of enterprise i to other biotechnological firms included in the sample. The index is computed as the standardized sum of the

[10] Proximity and cluster variables have been computed as in D'Este et al. (2013). The authors are deeply grateful to Frederick Guy and Simona Iammarino for providing Stata codes for generating these variables.

[11] In the complete dataset the average distance between U-I pairs is about 420 kilometers, which reduces to about 240 kilometers in the case of *actual* U-I pairs.

[12] Latitudes and longitudes of firms and universities have been computed from their addresses. For the case of firms we referred to the address of the specific business unit (laboratory) involved in the collaboration (we do not refer to the legal address of the firm).

inverses of the square root of the great-circle distances of the *i-th* firm from the remaining business units included in the sample.

- *University cluster index*: Index of proximity of enterprise i to the universities included in the sample. The index is computed as the standardized sum of the inverses of the square root of the great-circle distances of the *i-th* enterprise from all the universities in the sample.

- *Research quality*: Index of research quality of university j. The index is computed by averaging the "R" indices of research quality of the *j-th* university in the scientific areas of chemistry and biology.[13] "R" indices are the average evaluation obtained by the university in a specific scientific area.

- *Assistant professors share*: Share of assistant professors and researchers (excluding Ph.D. students and post-doctoral fellows) on total academic staff of the university in the scientific areas of chemistry and biology.

- *Associate professors share*: Share of associate professors on total academic staff of the university in the scientific areas of chemistry and biology.

- *Full professors share*: Share of full professors on total academic staff of the university in the scientific areas of chemistry and biology.

- *Total academic staff*: Total number of academic staff of the *j-th* university in the scientific areas of chemistry and biology.

- *Company size*: Dummy variable which takes value 1 if the firm has more than 249 employees and 0 otherwise.

3.3 Proximity and the probability of collaboration between University and biopharmaceutical industry

In table 2 we report the estimation results of the logistic model on the probability of co-publishing.[14] Following Brambor et al. (2006), we include in the regressions all the constitutive terms as well as all the possible interactions among them. Moreover, in order to properly interpret the results, we compute the conditional marginal impact of covariates and their standard errors. In this context, a correct interpretation of the role played by the covariates is made difficult by the nonlinearity of the logistic model as well as by the inclusion of interacted terms. Indeed, coefficients cannot be taken as indicators for

[13] "Area 3" and "Area 5", respectively, in the classification system by the Italian Ministry of University and Research.

[14] We did not estimate a model containing simultaneously *Cluster index* and *University cluster index* due to the high level of correlation (r=0.88) among the two variables.

the marginal impact of the covariates on the probability of co-publishing, thus it is necessary to compute the marginal impact of a covariate for the range of admissible values of all the covariates. As in Brambor et al. (2006), we make this calculus on the basis of the parameters' estimates of the logit model. The results are reported in figures 1 and 2, where it is shown the direct impact of each covariate and how the covariates interact to determine the probability of co-publishing for a given U-I couple. In line with D'Este et al. (2013), our results show that *Geographical proximity* and *Organizational proximity* significantly increase the probability of co-publishing. In other words: *i*) the closer are firm *i* and university *j*, the higher the probability of co-publishing; *ii*) the higher the number of previous co-publishing experiences, the higher the actual probability of co-publishing among the two units. With regards to the other variables, it is worth it to notice that, by construction,[15] average values of the variables *Cluster index* and *University cluster index* do not vary between the groups of U-I pairs which co-published and the one of U-I pairs which did not. Therefore, the direct impact of these regressors on the probability of co-publishing cannot be significantly different from zero.[16] Notwithstanding this limitation, it is possible to investigate the hypotheses of complementarity and substitutability among these factors and other covariates. In the first panel of figure 1, the variable of interest (on the vertical axis) is the marginal effect of the variable *Geographical proximity* on the probability of co-publishing. However, given that this impact depends on the value of other covariates, it has been computed for different values of the variable *Cluster index* (on the horizontal axis) and for three different values of the variable *Organizational proximity* which generate three distinct lines. From the figure it emerges that the marginal effect of *Geographical proximity* is always positive, as the three lines are safely far from the zero-line (in red). When the *Cluster index* increases, the marginal effect of *Geographical proximity* is weakened, as the three lines are all downward sloping, meaning that the two variables are *substitutes*. Lastly, as *Organizational proximity* increases, the corresponding line shifts upward and thus the marginal effect of *Geographical proximity* is reinforced, implying that the two variables are *complements*. The panel on the right side of the figure confirms the findings by looking at the same results from a slightly different perspective, where the role of the two variables *Cluster index* and *Geographical proximity* is exchanged. Similarly, from the two panels of figure 2, we conclude that the impact of *Geographical proximity* on the probability of co-publishing is weakened by *University cluster index*, while it is reinforced by higher values of *Organizational proximity*. Therefore, we conclude that *Geographical proximity* and *University cluster index* are *substitutes* while *Geographical proximity* and *Organizational proximity* are *complements*. Our results confirm the conclusions of D'Este et al. (2013) with respect to substitutability between geographical proximity and firm clustering. With regards to the interaction between *Geographical proximity* and *Organizational*

[15] On this point see D'Este et al. (2013).

[16] The same result holds for those regressors measuring firm-specific and university-specific characteristic such as, for example, firm's size or academic staff . Therefore, these kind of variables have not been included among the regressors of the logit model. On the contrary, as firm-specific and university-specific covariates vary over the range of the "number of co-publications" variable, they are included as additional regressors in the negative binomial model.

proximity, D'Este et al. (2013) could not reach a clear-cut conclusion on the hypotheses of complementarity or substitutability relation between the two variables. Conversely, we can conclude in favour of the hypothesis that *Geographical* and *Organizational proximities* are *complements*, in accordance to hypothesis 2a in D'Este et al. (2013). In other terms, the time-persistence of the partnership[17] is higher the lower the distance among the two units involved in the partnership; *Geographical proximity* makes easier to keep in good shape a research network.

3.4 The intensity of the U-I relations: the role of proximity and partner specific characteristics

In the second part of our empirical analysis, we move from the study of the probability of the occurrence of the collaboration to the study of the frequency of the event. To this aim, we investigate the determinants of Italian universities' intensity of interaction with biopharmaceutical firms, by looking both at *Geographical* and *Organizational proximity* measures and at firms' and universities' specific characteristics. We estimate a pooled negative binomial model[18], where the dependent variable is the overall number of co-publications between a biopharmaceutical firm i and university j over the period 2004-2010.

We obtain results (tables 3 and 4) in accordance with our priors, highly statistically significant and robust to the choice of regressors included in the model. First, we observe that *Geographical proximity*, *Organizational proximity* and *Cluster index* positively affect the expected number of co-publications among firms and universities. Moreover, the the logit model results on the issues of *substitutability* and *complementarity* are confirmed to a large extent. From the left panel of figure 3, it follows that the marginal impact of *Geographical proximity* decreases as *Cluster index* increases and that an increase in *Organizational proximity* shifts the line upward. The right panel of figure 3 confirms that for low levels of *Cluster index* (the blue line in figure), *Organizational proximity* reinforces the impact of *Geographical proximity.* Similar results hold in the model where *University cluster index* is included as covariate instead of *Cluster index.* To sum up, negative binomial regressions confirm that both *Cluster index* and *University cluster index* are *substitutes* for *Geographical proximity*, while *Organizational proximity* is a complement for *Geographical proximity*, for low levels of *Cluster index* and *University cluster index.*

Going to firm-specific and university-specific characteristics, we observe that the *Company size* significantly affects the number of co-published articles. This results confirms previous findings highlighting that large companies invest more in R&D and are thus more connected with universities (see among others Link and Rees, 1990; Acs and Audretsch, 1990; Slavtchev, 2013).[19]

[17]The impact of *Organizational proximity* measures to what extent the fact of having co-published before increases the probability of co-publishing today and therefore can be taken as an indicator for persistence in the U-I partnership.

[18]The likelihood ratio test revealed that the phenomenon of co-publications is over dispersed and therefore the negative binomial model is more appropriate than the Poisson model.

[19]As outlined in section 2, this is particularly true for biopharmaceutical industry.

Consistent with previous findings (Mansfield and Lee, 1996; D'Este and Iammarino, 2010; Abramo et al., 2011; Laursen et al., 2011), we find that *Research quality* and *university size*, as proxied by *Total academic staff*[20] in the relevant field, are good predictors for the number of co-published research articles. Especially in science-based industries, high level of university research quality attracts firms willing to carry out joint research, Abramovsky et al. (2007) find evidence of co-location of research labs and highly ranked departments in the case of chemicals and pharmaceutical industries. However, the higher the quality of research, the higher the probability that a university collaborates with distant firms. Therefore, on theoretical grounds, research quality might either increase the importance of *Geographical proximity* or mitigate its role. This aspect has been also investigated by D'Este and Iammarino (2010) who find an inverted U-shaped relation between academic research quality and distance of collaborations. We could not test the hypothesis of a U-shape relationship between research quality and the number of partnerships due to the low variability of our research quality index.[21]

The composition of the academic staff significantly affects the intensity of co-publishing. The latter is positively related: to the share of assistant professors (*Assistant professors share*) and associate professors (*Associate professors share*); instead, it is negatively related to the share of full professors (*Full professors share*). In line with Giuliani et al. (2010), we detect a "juniority effect" rather than a "seniority effect". We interpret this result as a rational behavior of academic staff to the existing career incentives. The divergence of our result from previous findings (Link et al., 2007; Bozeman and Gaughan, 2007; Ponomariov, 2008; Boardman, 2008, 2009; Boardman and Corley, 2008; D'Este and Perkmann, 2011; Haeussler and Colyvas, 2011; Perkmann et al., 2013) can be explained by the fact that we take into consideration co-publishing, that is a different type of U-I collaboration. In fact, the literature which claims a "seniority effect" is mainly based upon different aspects of U-I collaborations, such as the ability to activate joint research projects. In those cases it is very likely that the coordinator (or the academic reference) of a joint project might be a "senior academic", and this will explain the "seniority effect". Full professors - given their experience, reputation and consolidated network - are more involved in coordinating, institutional and consulting activities.[22] By contrast, when, as in our case, the U-I collaboration is proxied by co-publishing, younger researchers, who need publications for upgrading in their career, will be more proactive in publishing, co-authoring with authors both from academia and the private sector.

[20]See for instance Abramo et al., 2011 for evidence on U-I collaborations in pharmacology in Italy.

[21]The research quality index is highly correlated with its squared value, thus impeding an empirical identification of the quadratic relationship.

[22]As robustness check we performed the same analysis as in tables 3 and 4 on the subsample of observations given by only *real* pairs (230 observations) and all our findings are confirmed.

4 Conclusions

The aim of this paper is to contribute to the debate on University-Industry collaboration. We delimitate the boundaries of our investigation to a specific industry and a specific mode of collaboration, respectively, the Italian biopharmaceutical industry and the co-publishing mode of U-I collaboration over the 2004-2010 period. As shown in section 2, in general, co-publishing represent the most favorite channel of collaboration between biopharmaceutical firms and University, as successful research is a key determinant of firms' growth and profitability as well as a source of financing and prestige for academics. In Italy, the biopharmaceutical industry is a strategic sector, because of its contribution to private R&D; exports; attraction of multinational investments, highly qualified employment. Being mainly concentrated in two Italian regions, Lazio and Lombardia, the biopharmaceutical firms have long enjoyed agglomeration externalities, taking advantage of the presence of high ranked Universities in both regions. Notwithstanding, Orsenigo (2001), and more recently, Giunta et al. (2014) show that U-I relations in Italy are suboptimal, well below the potential of both the industry and the universities, causing, in some case, poor biopharmaceutical firms' economic performances.

We study U-I collaboration, considering both its occurrence (the University and the firm experience a co-publication) and its intensity (how many articles the pair have published together). In our empirical investigation, we make use of a unique database we built up for the research purpose. In accordance with the main literature on U-I relations, we investigate the role played by different kinds of proximities (geographical and organizational proximity as well as firm proximity to the cluster of firms and universities) in enhancing such collaboration. We also take into consideration interactions, paying particular attention to the interaction of proximities variables with agglomeration ones, such as firms or Universities clusters. The results of our empirical exercises confirm to a large extent the main predictions of current literature: *i*) *Geographical* and *Organizational proximity* enhance both the probability and the intensity of co-publishing; *ii*) the proximity of a firm to other biopharmaceutical firms or universities attenuates the impact of *Geographical proximity* on the probability of co-publishing. New to the reference literature is the complementarity between *Organizational proximity* and *Geographical proximity.*

Our empirical investigation deems to make a step forward in the large body of empirical literature on U-I relations as it complements the established analyses taking into considerations specific characteristics of the pair involved in the co-publishing relations. The results show that the intensity of co-publishing is higher when: *i*) the firm is large (more than 249 employees); *ii*) the University Research quality level is higher; *iii*) the larger and younger is the academic staff.

In the Italian case, the results are particularly interesting as the industrial structure is peculiarly fragmented (in the manufacturing sectors, 84% are micro firms with less the 10 employees). By contrast, the biopharmaceutical sector is populated, on average, by large multinational firms. In fact, the percentage of employees in firms with staff of over 250 exceeds 72% (58.5% of which are firms with staffs of 500 or more), as against the manufacturing sector average of 22.8% (Farmindustria, 2011). Therefore, it should be a cause of concern the current migration of biopharmaceutical establishments to other European regions and the consistent reduction of employment in the industry over the last five years. As for the University side, on average the age of the Italian academic staff is quite high, thus undermining the chances of recurrent co-publishing.[23] The findings in this paper have some implications for policy. Two requirements seem to be essential and interdependent to exploit the full potential of U-I relations in Italian biopharmaceutical industry: to potentiate and enlarge the core of large biopharmaceutical firms and to attract young researchers in the Universities.

[23]In 2012 the average age of full professors in chemical and biological sciences was 56 years; that of associate professors in chemical sciences was 52 and in biological sciences was 51. The most striking result regards the average age of assistant professors: 44 in chemical sciences and 45 in biological sciences (source: http://statistica.miur.it).

Appendix A: The dataset

We consider publications indexed in the Web of Science database, in the following categories: Biochemistry molecular biology; Chemistry medicinal; Chemistry multidisciplinary; Chemistry analytical; Chemistry applied; Pharmacology pharmacy; Biology or cell biology; Biochemical research methods; Biotechnology applied microbiology; Plant sciences or chemistry organic; Microbiology or reproductive biology, for a total of 92,985 publications in the period 2001-2010.

Data on academic employees are from the Italian Ministry of University and Research (MIUR) and refer to the following sectors: Analytical, chemistry-physics (3A), Pharmaceutical, technological and alimentary (3D); Animal biology and anthropology (5B); Biochemistry (5E); Applied biology (5F); Experimental and clinical pharmacological sciences (5G); Genetics and microbiology (5I).

The statistical source of data on firms is the AIDA - Bureau van Dijk database, that has been integrated with data from the Italian High Institute for Public Health and from the Annual Report of the Regional Council of Latium (CREL) of year 2008. We have restricted the analysis to enterprises operating in the following sectors: Cultivation of healing herbs (01.28 according to the ATECO classification system); Production of chemical products (20); Production of pharmaceutical products (21); R&D in biotechnologies (72.11); Pharmacology (72.19.09).

Data on Research quality are by the Evaluation of Research Quality (VQR 2004-2010) conducted by the Italian National Agency for the Evaluation of Universities and Research Institutes (ANVUR).

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Table 1: Descriptive statistics

VARIABLES	Mean	Stand.Dev.	Minimum	Maximum	Observations
Geographical proximity	0.3052	0.3927	0.0121	1	827
Organizational Proximity	0.2417	0.2917	0	0.9682	827
Cluster index	28.8606	21.4916	2.2216	64.8132	827
University cluster index	4.2194	0.8109	0.5941	5.3874	827
Research quality	1.0203	0.1238	0.4450	1.2800	827
Assistant professor share	0.4228	0.0629	0	0.7273	827
Associate professor share	0.3026	0.0542	0	0.5714	827
Full prof. share	0.2746	0.0627	0	1	827
Total academic staff	180.8912	97.4469	2	372	827
Company size	0.7412	0.4382	0	1	827

Table 2: Co-publishing of Italian Universities with biopharma industry, pooled logit estimation (dep. var. Occur)

VARIABLES	(1) occur	(2) occur	(3) occur	(4) occur	(5) occur
Geographical proximity	3.0805***	3.1226***	3.2574***	3.3063***	3.3333***
	(0.103)	(0.103)	(0.139)	(0.141)	(0.141)
Organizational Proximity	1.3590***	1.4051***	1.7868***	1.6638***	1.6706***
	(0.143)	(0.142)	(0.186)	(0.186)	(0.185)
Cluster index	0.0517		0.1048	0.0515	
	(0.045)		(0.077)	(0.060)	
University Cluster index		−0.0091	−0.2722***		−0.0679
		(0.046)	(0.076)		(0.056)
Geographical proximity#Cluster index	−0.5908***			−0.7532***	
	(0.094)			(0.138)	
Geographical proximity# University Cluster index		−0.6480***			−0.6888***
		(0.103)			(0.139)
Geographical proximity#Organizational Proximity			−0.9286***	−0.8335**	−0.7692**
			(0.333)	(0.338)	(0.343)
Organizational Proximity#Cluster index				0.0352	
				(0.206)	
Organizational Proximity#University Cluster index					0.4144*
					(0.235)
Geographical proximity#Organizational Proximity#Cluster index				0.4832	
				(0.344)	
Geographical proximity#Organizational Proximity#University Cluster index					0.0209
					(0.399)
Constant	−4.5518***	−4.5615***	−4.6444***	−4.6141***	−4.6265***
	(0.051)	(0.051)	(0.059)	(0.058)	(0.059)
Observations	39,696	39,696	39,696	39,696	39,696
R^2	0.107	0.108	0.104	0.108	0.109

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors in parentheses.

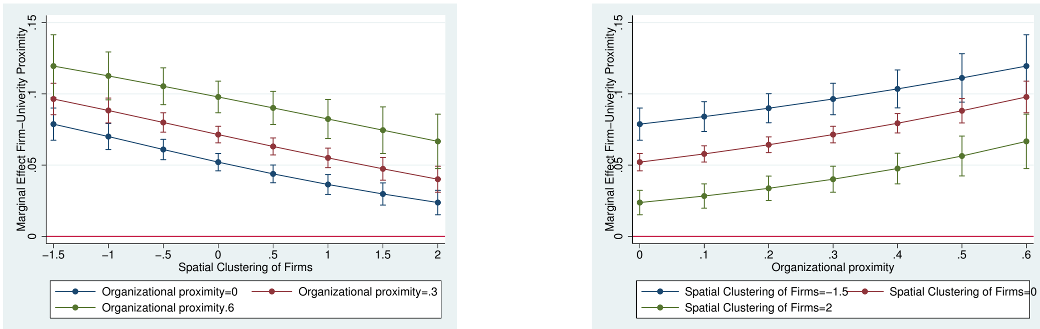

Figure 1: Marginal effect of firm-university proximity on the probability of partnership as clustering of firms varies (panel on the left) and as organizational proximity varies (panel on the right)

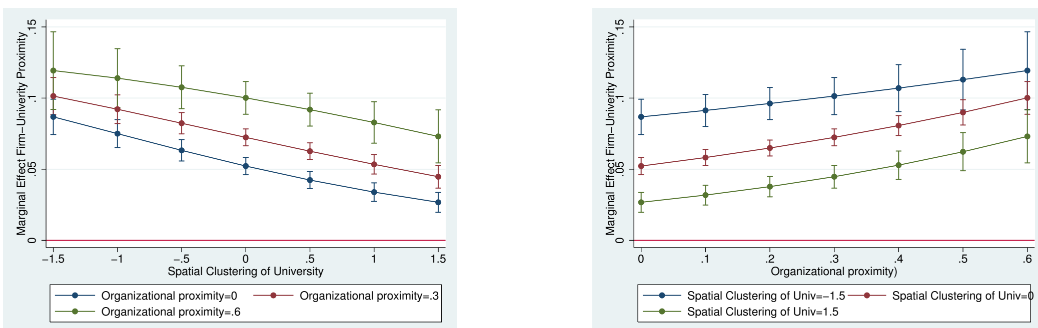

Figure 2: Marginal effect of firm-university proximity on the probability of partnership as clustering of universities varies (panel on the left) and as organizational proximity varies (panel on the right)

Table 3: Intensity of co-publishing of Italian Universities with biopharma industry, pooled negative binomial estimation (dep. var. #Occur)

VARIABLES	(1) #occur	(2) #occur	(3) #occur	(4) #occur	(5) #occur	(6) #occur
Geographical proximity	3.3519***	3.5991***	3.2845***	3.5265***	3.3475***	3.5794***
	(0.186)	(0.231)	(0.181)	(0.221)	(0.184)	(0.226)
Organizational Proximity	1.9782***	1.8020***	1.7691***	1.6186***	1.9123***	1.7493***
	(0.363)	(0.320)	(0.368)	(0.324)	(0.365)	(0.323)
Cluster index	0.1885***		0.2030***		0.1920***	
	(0.072)		(0.073)		(0.072)	
University Cluster index		0.0121		0.0228		0.0157
		(0.071)		(0.071)		(0.072)
Geographical proximity#Cluster index	−1.7709***		−1.7817***		−1.7656***	
	(0.174)		(0.176)		(0.171)	
Geographical proximity#University Cluster index		−1.9902***		−1.9808***		−1.9699***
		(0.242)		(0.239)		(0.236)
Geographical proximity#Organizational Proximity	0.0971	0.2643	0.4970	0.6690	0.2285	0.4154
	(0.426)	(0.425)	(0.434)	(0.419)	(0.429)	(0.423)
Organizational Proximity#Cluster index	1.0550***		0.9058**		0.9667**	
	(0.383)		(0.384)		(0.381)	
Organizational Proximity#University Cluster index		1.9615***		1.8274***		1.8821***
		(0.498)		(0.502)		(0.500)
Geographical proximity#Organizational Proximity#Cluster index	−0.4483		−0.4108		−0.4113	
	(0.441)		(0.442)		(0.438)	
Geographical proximity#Organizational Proximity#University Cluster index		−1.2246**		−1.2596**		−1.2308**
		(0.584)		(0.583)		(0.584)
Research quality	1.0344**	1.0174**	1.3297***	1.3253***	1.2551***	1.2564***
	(0.464)	(0.448)	(0.444)	(0.431)	(0.437)	(0.423)
Assistant prof. share	1.2258**	1.2909**				
	(0.553)	(0.548)				
Associate prof. share			2.3059***	2.3545***		
			(0.749)	(0.736)		
Full prof. share					−1.9660***	−2.0754***
					(0.707)	(0.687)
Total academic staff	0.0077***	0.0074***	0.0073***	0.0070***	0.0075***	0.0072***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Company size	0.3443***	0.3352**	0.3763***	0.3663***	0.3641***	0.3535***
	(0.133)	(0.131)	(0.131)	(0.129)	(0.131)	(0.129)
Constant	−6.4628***	−6.4540***	−6.8648***	−6.8561***	−5.6097***	−5.5607***
	(0.514)	(0.494)	(0.516)	(0.505)	(0.518)	(0.493)
Observations	39,696	39,696	39,696	39,696	39,696	39,696
R^2	0.0725	0.0724	0.0729	0.0728	0.0730	0.0730

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses.

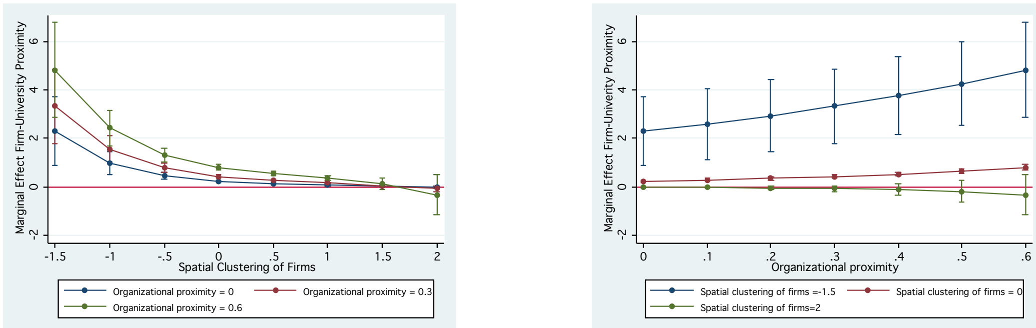

Figure 3: Marginal effect of firm-university proximity in the negative binomial model as clustering of firms varies (panel on the left) and as organizational proximity varies (panel on the right)

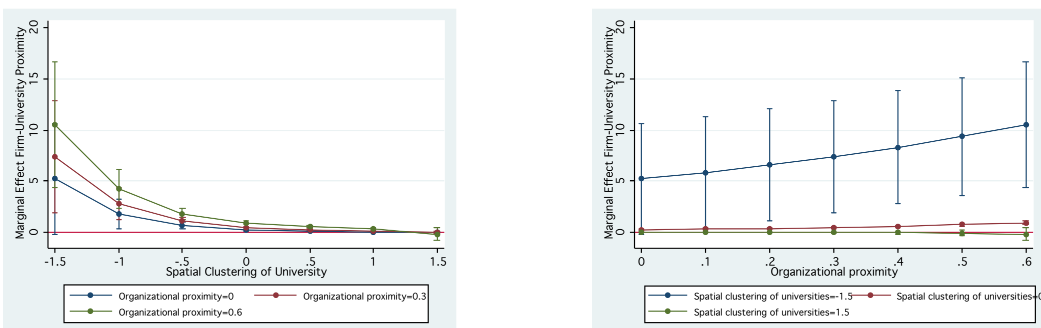

Figure 4: Marginal effect of firm-university proximity in the negative binomial model as clustering of universities varies (panel on the left) and as organizational proximity varies (panel on the right)

Table 4: Intensity of co-publishing of Italian Universities with biopharma industry, pooled negative binomial estimation (dep. var. #Occur)

VARIABLES	(1) #occur	(2) #occur	(3) #occur	(4) #occur	(5) #occur	(6) #occur
Geographical proximity	3.4806***	3.3999***	3.5362***	3.4622***	3.5297***	3.4556***
	(0.132)	(0.131)	(0.137)	(0.136)	(0.137)	(0.136)
Organizational Proximity	1.7724***	1.7677***	1.6763***	1.6668***	1.7522***	1.7454***
	(0.261)	(0.257)	(0.260)	(0.254)	(0.264)	(0.259)
Cluster index	0.1822***		0.1715***		0.1720***	
	(0.063)		(0.065)		(0.063)	
University cluster index		0.0668		0.0590		0.0616
		(0.065)		(0.066)		(0.065)
Research quality	1.0355**	0.9533*	1.3737***	1.3109***	1.2764***	1.2068***
	(0.493)	(0.491)	(0.467)	(0.467)	(0.457)	(0.456)
Assistant prof. share	1.3518**	1.3723**				
	(0.580)	(0.593)				
Associate prof. share			2.4189***	2.5889***		
			(0.767)	(0.774)		
Full prof. share					−2.1752***	−2.2853***
					(0.708)	(0.705)
Total academic staff	0.0074***	0.0072***	0.0069***	0.0067***	0.0071***	0.0069***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Company size	0.4103***	0.4419***	0.4350***	0.4657***	0.4280***	0.4582***
	(0.132)	(0.132)	(0.131)	(0.132)	(0.129)	(0.130)
Constant	−6.4922***	−6.4012***	−6.9239***	−6.8923***	−5.5516***	−5.4350***
	(0.542)	(0.537)	(0.541)	(0.546)	(0.552)	(0.546)
Observations	39,696	39,696	39,696	39,696	39,696	39,696
R^2	0.0689	0.0679	0.0692	0.0684	0.0695	0.0686

*** p<0.01, ** p<0.05, * p<0.1. Robust standard errors in parentheses.