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Beyond Regional Clusters: On the Importance of Geographical Proximity for R&D Collaborations in a Global Economy—the Case of the Flemish Biotech Sector

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Research Paper

Beyond Regional Clusters: On the Importance of Geographical Proximity for R&D Collaborations in a Global Economy—the Case of the Flemish Biotech Sector

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ABSTRACT When internal knowledge bases are insufficient for developing innovations, companies tend to collaborate with external R&D partners. According to a long-standing literature on "clusters", "industrial districts", "local production systems" and "regional innovation systems", geographical proximity between innovation partners is considered a precondition for inter-organizational collaborations: proximity is said to facilitate trust, the transfer of tacit knowledge and the intensity of interactions. This article investigates the importance of geographical proximity for R&D collaborations between biotech firms and their innovation partners. Are geographically close innovation partners likely to collaborate more intensely? Studies of the Flemish biotech industry shed light on this question. Regression analyses combined with qualitative interview data reveal that geographical proximity has become less important for inter-organizational collaborations. Owing to lower communication and transportation costs, innovation partners can easily collaborate even when they are not situated close to each other. This leads us to conclude that globalization transforms inter-organizational collaborations.

KEY WORDS: Inter-organizational collaboration, research and development, globalization, geographical proximity, biotech industry

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1. Introduction: How Geographical Proximity Matters for R&D Collaborations

Amongst contributors to the competitiveness literature, there is broad agreement that innovations constitute a key factor of corporate competitiveness in a globalizing economy. This seems particularly true for developed economies, where high wages and ancillary wage costs can only be balanced by a steady increase in labour productivity resulting from process innovations, or by product innovations that offer superior value added to customers (see inter alia Porter, 1990; Lundvall, 1992; Nelson, 1993; Hall and Soskice, 2001). To remain competitive in today's global economy, firms in developed capitalist countries therefore often compete in innovation-intensive, so-called "high-tech" industries. This insight has led politicians across the Western world to acknowledge the development of high-tech industries as one of the key drivers of national competitiveness (European Commission, 2003; Deuten and Boekholt, 2009).

While innovation scholars tend to agree that there is no linear relation between the amounts invested in research and development (R&D) and the innovation output, as numerous functions play together for innovations to materialize, agreement is equally broad that innovations do not occur without R&D activities. Only when public and private organizations actively engage in R&D can innovations materialize on a broader scale. Importantly, though, innovations in high-tech industries do not often result from the R&D activities of a single actor. The complexity of sophisticated technologies typically requires the collaboration of several innovators, including public bodies, firms and academic institutes. High-tech innovations tend to prosper whenever basic scientific knowledge, often discovered by public and academic organizations, is fruitfully merged with applied knowledge, typically developed by private firms.

In order to foster competitiveness in high-tech industries, one fundamental question therefore is how to foster R&D collaborations. It is interesting to note how scholars of inter-organizational collaborations increasingly diverge in their answers to this question. In the early days, dating back to the late 1970s, there was broad agreement that geographical proximity between collaboration partners, i.e. their location within the same regionally limited production network, is a key driver of R&D collaborations. More precisely, this literature on local networks[1] highlights that actors in the same region can meet easily and, hence, more frequently due to reduced geographical distance. Regular meetings facilitate the development of trust and the transfer of complex tacit knowledge which, in turn, is both crucial for the development of sophisticated technologies and transferrable most easily through face-to-face contact. Therefore, the location within the same regional cluster increases the intensity of interaction between collaboration partners and, ultimately, the rate of high-tech innovations (Zucker and Darby, 1996; Fritsch and Schwirten, 1999; Nooteboom, 1999; Cooke, 2002).

More recently, however, several scholars have found geographical proximity to be (ever) less important for R&D collaborations. In a globalizing economy, innovation partners

1. As section 2 illustrates in more detail, this literature includes the writings on "industrial districts" (Piore and Sabel, 1984; Pyke *et al.*, 1990; Pyke and Sengenberger, 1992; Cossentino *et al.*, 1996), the "cluster" literature of Porter (1998, 2000), the studies of "regional innovation systems" (Saxenian, 1994; Cooke *et al.*, 1997, 1998), as well as the work on "local production systems" (Crouch *et al.*, 2001, 2004).

increasingly seem to collaborate across regional and, even, national boundaries (Vedovello, 1997; McKelvey *et al*., 2003; Mora-Valentin *et al*., 2004; Saxenian, 2006; Moodysson and Jonsson, 2007; Ponds *et al*., 2010). Consequently, the question arises whether geographical proximity still matters for R&D collaborations in today's global economy. *Does the location within the same regional network increase the intensity of R&D collaborations between the involved parties?*

To shed light on this question, this article analyses quantitative and qualitative data on R&D collaborations in the Flemish biotech sector. For two reasons, biotech companies provide particularly insightful cases to study. First, owing to their innovation intensity and the massive amounts of investment required for bringing new drugs to the market, biotech firms are particularly likely to cooperate with providers of basic and applied knowledge. Second, and as a corollary of the first, local networks are frequently observed phenomena in the biotech sector. Biotech firms typically cluster within one region, close to universities, hospitals and other public research organizations (PROs) with which they cooperate to develop new drugs (Meyer-Krahmer and Schmoch, 1998; Van Geenhuizen and Reyes-Gonzalez, 2007). If geographical proximity matters for the intensity of R&D collaborations, then it matters in the biotech sector. In other words, should local proximity turn out *not* to facilitate intense R&D cooperation in the biotech sector, chances are high that it is even less important for firms in other high-tech industries.

A particularly comprehensive dataset to study the importance of geographical proximity for R&D collaborations in the biotech sector is a database provided by the IWT (the Agentschap voor Innovatie door Wetenschap en Technologie), which is the Flemish Government Agency for Innovation through Science and Technology. This database includes information on all R&D collaborations between public and private organizations in Flanders that were sponsored by the government between 2003 and 2007. Quantitative regression analyses of this dataset combined with evaluations of qualitative interview data deliver striking results. Contrary to the claims in the bulk of the long-standing local networks literature, geographical proximity turns out not to influence the intensity of R&D collaborations. These findings lead us to conclude that globalization—understood here as increasing flows of goods, capital and people across national borders due to decreasing transportation and communication costs as well as decreasing barriers to trade—transforms R&D collaborations in that cooperation across, rather than within, local networks gains momentum.

To illustrate this argument, the remainder of this article is structured as follows. Based on a review of the literature on inter-organizational collaborations in general and local networks in particular, the analytical framework of this paper is developed in section 2. The data and methods used to shed light on the importance of local networks for the intensity of R&D collaborations are discussed in section 3. Section 4 presents the results, which are critically reviewed in the conclusions, section 5.

2. Literature and Analytical Framework: New Answers to a Long-Standing Research Question

Until the recession caused by the oil shocks of the 1970s, organization researchers generally considered Fordist companies as most profit-yielding: their all-inclusive in-house manufacturing was said to minimize production costs due to the optimization of individual production steps. Interestingly, though, the Fordist production giants turned out to be more

prone to failure during the oil-shock recessions than the small-scale producers located in regional networks: it was enough for one department of a Fordist company to experience a bottleneck in order to endanger the production process of the entire company.

In contrast to large Fordist companies, small firms continued to prosper during the economic crises of the 1970s. Seeking to explain this puzzle, studies of local networks gained momentum. Contributors to the literature on *industrial districts* revealed how close collaboration makes it possible to divide the production process of one good between small firms located in the same region. Geographical proximity facilitates frequent meetings, the development of trust and the transfer of tacit knowledge between these small-scale manufacturers. The specialization in individual production steps leads to increased flexibility. If one of the firms faces economic difficulties, the production process can rapidly be redesigned. And even if small-scale producers go bankrupt, they can be replaced comparatively easily (Piore and Sabel, 1984; Pyke *et al.*, 1990; Pyke and Sengenberger, 1992; Cossentino *et al.*, 1996).

Later strands of the literature on local networks, including Porter's *cluster studies* (Porter, 1998, 2000) as well as the work on regional *innovation systems* (Saxenian, 1994; Cooke *et al.*, 1997, 1998; Fritsch and Schwirten, 1999) shift focus. They no longer study the importance of local cooperation for entire production processes, but rather focus on R&D activities. Consequently, these studies explain how the frequency and types of innovations can differ between local networks, depending on the ability of the embedded actors to collaborate with each other. Studies on *local production systems* (Crouch *et al.*, 2001, 2004) reassess the arguments proposed in previous strands of the local networks literature. Does globalization alter local production processes? Does it affect the importance of geographical proximity for inter-organizational cooperation in general and for joint R&D activities in particular? Interestingly, the contributors to this literature do not find evidence that would answer these questions in the affirmative: geographical proximity remains important for the development of trust, the transfer of tacit knowledge, the exchange of ideas, the division of production steps between several small firms and, ultimately, for the rate and type of innovations made. In short, local networks are found to resist pressures for change resulting from increasing international competition.

Since the beginning of the new millennium, however, analysts of inter-organizational cooperation increasingly have provided different results, illustrating how globalization transforms inter-organizational cooperation boundaries. Researchers undertaking qualitative studies were the first to raise doubts about the importance of geographical proximity for R&D collaborations. Already towards the end of the last millennium, Vedovello (1997) found that a small distance between firms and universities facilitates informal relationships, but no formal R&D links. Similarly, Saxenian (2006) provides insightful evidence on how ICT entrepreneurs in the US cooperate intensely with small firms in Israel, Taiwan, India and China. According to Saxenian, these firms succeed only because of their close collaboration across national boundaries, which enables US companies to gain complementary knowledge from specialized niche producers abroad. More recently, Moodysson and Jonsson's study of eight biotech firms in Sweden shows that "even though [...] proximity is facilitative, global [...] collaboration is indispensable for most [biotech firms]. The convenience of local collaboration can never replace the extreme requirements of specialized knowledge, which forces [biotech firms] to seek collaborators on a global arena despite the impediments they face in these situations" (Moodysson and Jonsson, 2007: 115).

Complementing the scepticism of qualitative research regarding the importance of geographical proximity, also quantitative studies increasingly focus on identifying those conditions that facilitate university–industry cooperation and, hence, knowledge-spillover effects. Considering geographical proximity implicitly rather than explicitly, these studies reveal that university–industry collaborations depend on the scientific discipline (Meyer-Krahmer and Schmoch, 1998), on the industry (Anselin *et al.*, 2000), as well as on the R&D intensity, the firm size and the industrial environment of the collaborating partners (Laursen and Salter, 2004).

Following up on the doubts emerging from these findings, the most recent quantitative studies explicitly turn to analysing the impact of proximity on R&D collaborations and their success. Accordingly, Mora-Valentin *et al.*, (2004) find that the success of R&D collaborations depends on the commitment, previous links, definition of objectives and conflicts between the cooperating partners, but *not* on their geographical proximity. Similarly, Audretsch *et al.*, (2005) find that high-tech firms are most likely to be located close to universities in order to benefit from knowledge spillovers, while Ponds *et al.*, (2007) show that R&D collaboration partners are frequently located close to each other in order to overcome organizational differences. Ponds *et al.*, (2010), in turn, show that academic knowledge spillovers occur through geographically localized mechanisms, as well as through R&D collaborations at the *national* and *international* levels. In other words, geographical proximity is no longer found to be a *conditio sine qua non* for successful R&D collaborations.

Our article seeks to shed light on this debate. By analysing R&D collaborations between firms and universities in the biotech industry, i.e. by focusing on those innovation partners that are still said to be most likely to locate themselves close to each other, our study questions how important regional proximity is for R&D collaborations in a globalizing economy. Consequently, the first—and the key—hypothesis to be tested in this paper is:

Hypothesis H1: Firms that are geographically close to potential innovation partners collaborate more intensely on joint R&D projects than firms that are geographically distant from potential innovation partners.

Several other factors can be hypothesized to influence the intensity with which firms engage in R&D collaborations. The size of the firm seems particularly important in this respect. Small firms are typically more dependent on externally generated knowledge than large companies as the former have more limited internal knowledge bases and R&D resources (Nooteboom, 1999; Das and Teng, 2000; Laursen and Salter, 2004). Small firms may therefore be more likely to engage in R&D collaborations than large firms. Consequently, the second hypothesis to be tested in this paper is:

Hypothesis H2: Small firms collaborate more intensely on joint R&D projects with external partners than large firms.

According to Saxenian (1991), most small firms in high-tech industries are spin-offs that are located close to the organization (university or company) from which they originated. Typically, spin-offs continue to entertain intense relationships with their parent organization. Consequently, small firms can be expected to have more intense R&D collaborations with local cooperation partners than large firms (Sonn and Storper, 2008). These insights suggest that the following interaction effect between corporate size and regional proximity should be tested as a third hypothesis:

Hypothesis H3: Small firms that are geographically close to potential innovation partners collaborate more intensely on joint R&D projects than large firms that are geographically distant.

Industries differ in their innovation processes as well as in their use of internal and external knowledge respectively (Pavitt, 1984). High-tech industries are knowledge intensive, which implies that firms in these industries spend a higher share of their funds on R&D than firms in low- or medium-tech industries. To access the necessary knowledge resources, firms in high-tech industries are likely to entertain more intense R&D collaborations with innovation partners than firms in low- and medium-tech industries. In line with Freeman (1991), Powell *et al.*, (1996) and Anselin *et al.*, (2000), a fourth hypothesis should thus be tested on how the technological sophistication of industries influences the intensity of R&D interactions between innovation partners:

Hypothesis H4: Firms in high-tech industries collaborate more intensely on joint R&D projects with external partners than firms in medium- and low-tech industries.

An important advantage of regional proximity is its capacity to enable the transfer of complex tacit knowledge which, in turn, is both vital for high-tech industries and typically only transferable face to face. Organizations that are geographically close usually find it easier to exchange information face to face (Zucker and Darby, 1996; Nooteboom, 1999). Owing to the high degree of complex tacit knowledge needed in high-tech industries, it is likely that high-tech firms cooperate particularly intensely with other actors of the same regional network. Consequently, a fifth hypothesis to be tested studies the interaction effect between the technological intensity of a firm and the regional proximity to its collaboration partners:

Hypothesis H5: High-tech firms that are geographically close to potential innovation partners collaborate more intensely on joint R&D projects than low-tech firms that are geographically distant.

The various hypotheses tested in the remainder of this paper are graphically presented in Figure 1.

3. Data and Operationalizations: Measuring the Key Concepts

The biotech industry provides a particularly fruitful case from which to gain insights into the importance of regional proximity for the intensity of R&D collaborations: biotech firms are knowledge intensive, yet active in various segments of different technological intensity, and they have a strong tendency to cluster within regions (Meyer-Krahmer and Schmoch, 1998; Van Geenhuizen and Reyes-Gonzalez, 2007). Should the following analyses reveal that geographical proximity has become less important for R&D collaborations, we can thus conclude that proximity matters even less for firms in industries with lower propensities to cluster.

Consequently, and in line with the above conceptualizations, our units of analysis are R&D collaborations that biotech firms entertain with external innovation partners. A company is classified as a biotech firm whenever it is involved in "the application of science and technology to living organisms as well as parts, products, and models thereof, to alter living or nonliving materials for the production of knowledge, goods, and services" (OECD, 2006).

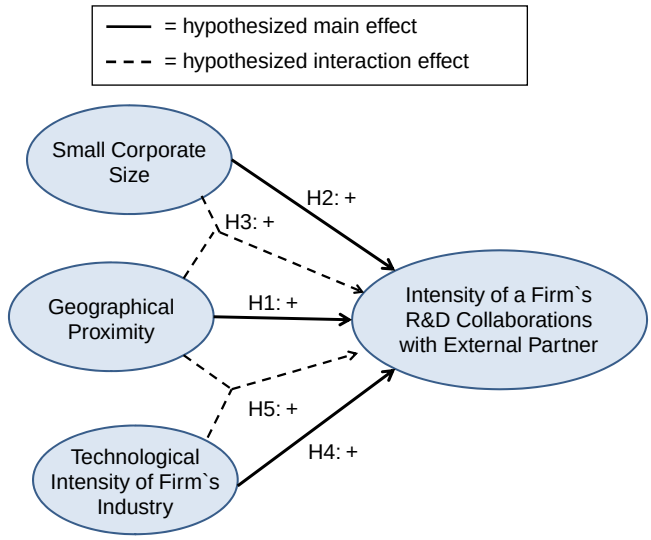

Figure 1. Visualization of hypotheses

To gain insights into the intensity of R&D collaborations of biotech firms, the IWT—the Flemish Agency for Innovation through Science and Technology[2]—offers the most comprehensive database. More precisely, the IWT database includes information on all Flemish biotech firms that have received subsidies for R&D collaborations with PROs in the period between 2003 and 2007. Throughout this observation period, there were overall 73 dedicated biotech firms active in Flanders. Of these 73 firms, 47 companies participated in subsidized R&D collaborations. Whenever more than two organizations participated in one collaboration project, we enlisted all cooperating pairs between the involved biotech firms and PROs. In doing so, we identified overall 154 R&D collaborations during the observation period, of which data was available for 144 R&D collaborations. Figure 2 depicts a map with an overview of all life sciences companies and PROs in Flanders. The 47 companies analysed below constitute a representative sample of these life sciences firms.

Before turning to the operationalization of variables, it is necessary to understand how representative the IWT data is of all R&D collaborations. While we here intend to propose general arguments on R&D collaborations, our findings can only be generalized if the 144 *subsidized* R&D collaborations constitute a major part of all R&D collaborations during the observation period. To shed light on the representativeness of the data used here, two questions need to be answered.

First, were the R&D collaborations that received subsidies funded entirely or did the subsidy awarded cover only a share, for example 50 per cent, of the entire R&D collaboration? If the amount of subsidies granted covered only parts of the R&D projects, the IWT data would not reflect the extent of collaborations appropriately. According to De Cleyn

2. As suggested by its name, the IWT is a governmental agency which aims at fostering the development of technology-intensive firms.

Figure 2. Map of life sciences firms and PROs in Flanders

(2011), an expert on public–private partnerships in Flanders, IWT never funds entire projects but only funds certain percentages thereof—depending on the project's research focus, the size of the companies involved and the involvement of international R&D partners. Importantly, though, the applicants are aware that only partial funding will be granted, which—according to De Cleyn—leads firms to over-apply for funds by indicating higher amounts than actually needed. This implies that R&D collaborations are *de facto* subsidized entirely.

A second question concerns the extent to which biotech firms in Flanders were involved in non-subsidized R&D collaborations during the observation period. If the share of non-subsidized R&D collaborations is large, the IWT data would not be representative. To begin with, IWT was the only agency in Flanders that subsidized R&D collaborations in the biotech industry during the observation period. It can therefore be assumed that biotech firms seeking subsidies for R&D collaborations only applied to, and received subsidies from, IWT. Furthermore, amongst all biotech firms that undertook R&D collaborations in Flanders during the observation period, large firms succeeded in covering the major part of their expenses through subsidies. According to De Cleyn (2011), large companies have the necessary resources in order to continuously apply for funding, so that a major share of their R&D collaborations is subsidized. While small firms have fewer resources available to this end, they often partner with large firms which, in turn, apply for funding. We therefore conclude that the subsidized R&D collaborations contained in the IWT data constitute a major and, hence, representative share of all R&D collaborations in the biotech industry during the observation period.[3]

3. It could finally be possible that non-local R&D partners may apply for subsidies more systematically than local R&D partners. Two reasons make this possibility an unlikely scenario. First, when asked about the representativeness of the sample, De Cleyn (2011) did not mention this phenomenon. Second, even if local collaboration partners applied less systematically for R&D subsidies than distant R&D partners, the share of non-subsidized collaborations seems overall rather small, so that non-subsidized R&D collaborations are likely not to have significant effects.

The IWT data makes it possible to operationalize the dependent variable—*intensity of R&D collaborations*—as the total time of R&D activities performed by a biotech firm and an external innovation partner. For each subsidized R&D collaboration between a biotech firm and a PRO, the total number of months of human work (measured in full-time equivalents) was calculated between 2003 and 2007.[4] Multiple collaborations between a biotech firm and a PRO during this time period were added up.

The independent variables were measured as follows: *regional proximity* is operationalized as the co-location of R&D collaborators within the same regional cluster. More precisely, we follow the approach of Van Geenhuizen and Reyes-Gonzales (2007). Consequently, a firm and its R&D partner need to fulfil two conditions in order to qualify as being geographically close. First, the collaboration partners need to be located within the same cluster which, in turn, is defined as an agglomeration that "contains at least one knowledge institute and 10 young entrepreneurial companies" (Van Geenhuizen and Reyes-Gonzales, 2007: 1686). The map in Figure 2 indicates that, according to this definition, four areas in Flanders qualify as clusters: Antwerp, Brussels, Ghent and Leuven.

Second, within one cluster, we consider a biotech firm to be close to a PRO if the geographical distance between the two innovation partners can be bridged by car in less than 15 minutes. "The underlying idea is that within this time–distance range several unplanned personal contacts per day can be made, allowing for a smooth transfer of tacit knowledge" (Van Geenhuizen and Reyes-Gonzales, 2007: 1686–1687). The proximity variable is thus dichotomous and assumes a value of 1 if the two collaboration partners are located within the same cluster *and* less than 15 car-minutes away from each other. Otherwise, i.e. if none or only one of these two conditions applies, the proximity variable assumes a value of 0.

In line with the OECD (2005: 46) standard definition, *a firm's size* is measured as the average number of R&D employees per year (in full-time equivalents) over the period 2003–2007. In order to scale the firm-size variable in accordance with hypotheses H1 and H3, the initial values were reversed. Hence, small numbers do not indicate small firms with few R&D employees but denote large firms with many employees. In other words, the higher the firm-size scores, the smaller the firms, i.e. the lower the number of R&D employees.

Within the biotech *industry*, several segments can be identified that vary in their technological and, hence, their R&D intensity, namely the sub-industries of red, green and white biotechnology (OECD, 2006). While red biotech firms focus on activities that seek to improve human and animal health, green biotech firms develop applications for agricultural products, whereas white biotech firms focus on environment-related devices such as industrial processing or natural resource extraction. Importantly, human and animal cells (including their DNA, RNA and proteins) are more complex than plant cells and bacteria. Accordingly, biotechnological modifications of human and animal cells (red biotechnology) are more technology intensive than modifications of plant cells (green biotechnology) and bacteria (white biotechnology). This implies that the clinical trials necessary to test active components of pharmaceutical products are more sophisticated than those needed for applications of agricultural products and environment-related devices. Consequently, red

4. Given that subsidies are granted to the overall R&D project, we cannot determine whether all involved collaboration partners benefit from the subsidies to the same extent. Consequently, we assigned the overall amount of subsidies granted (measured in terms of full-time months of human work) to each collaboration couple.

Table 1. Descriptive statistics

	N	Minimum	Maximum	Mean	Std. deviation
Intensity of R&D collaborations	144	2.79	8.63	6.1925	1.25451
Regional proximity	144	0	1	0.22	0.417
Firm size (= corporate smallness)	144	1	540	407.24	146.029
Red biotech segment	144	0	1	0.53	0.501

biotech firms are typically more R&D intensive than green and white biotech firms. Whether or not a firm is active in the red biotech segments is therefore taken as an indicator of the R&D intensity of its industry.

Table 1 provides an overview and descriptive statistics of the variables used in the following regression analyses.

It should finally be noted that we base our analyses not only on quantitative analyses of the IWT dataset, but also on qualitative data collected to assess the importance of regional proximity for knowledge diffusion. More precisely, we conducted interviews with two university researchers and five research officers of Flemish biotech firms in order to gain more in-depth insights into the causalities underlying the regression results. Information relating to these qualitative interviews is provided in the Appendix.

4. Results: Quantitative Analyses and Qualitative Explanations

We began our studies with OLS regression analyses of the IWT data. To understand whether the dataset conforms to the statistical standard assumptions underlying OLS regressions, both the dependent as well as all independent variables were checked for normal distribution of scores. Given that the distribution of scores turned out to be skewed for the dependent variable (*intensity of R&D collaborations*), the scores of this variable were transformed into logistic numbers.

To test hypotheses H1 to H5, we conducted five sets of OLS regression analyses. While the first set (models 1a–c) tests the individual impact of all main effects—*geographical proximity*, *corporate size* and *industry* (independent variables)—on the *intensity of R&D collaborations* (dependent variable), models 2a–c assess the joint impact of any combination of two main effects. The joint importance of the three main effects (model 3a), as well as the impact of *geographical proximity* and *corporate size* together with their *interaction effect* (model 3b), and also the influence of *geographical proximity*, *industry* together with their *interaction effect* (model 3c), are respectively tested in the third set of models. Models 4a and 4b assess how the three main effects together with one of the two interaction effects influence the *intensity of R&D collaborations* respectively. Model 5, the most complete model, finally assesses the relative influence of all five predictors on the dependent variable. Consequently, the OLS regression equation for model 5 can be written as follows:

$$\ln Y_i = \beta_0 + \beta_1{}^* x_1 + \beta_2{}^* x_2 + \beta_3{}^* x_3 + \beta_4{}^* x_4 + \beta_5{}^* x_5 + \epsilon$$

where:

Y_i = intensity of R&D collaborations
β_0 = constant
x_1 = geographical proximity
x_2 = corporate size
$x_3 = x_1 * x_2$
x_4 = industry
$x_5 = x_1 * x_4$
ϵ = residual

The results of these analyses are presented in Table 2.

The results of the OLS regressions show that the three main effects—geographical proximity, corporate size and industry—have a significant and additive impact on the intensity of R&D collaborations. When controlled for each other in model 3a, the explanatory power of the model is notably higher ($R^2_{Model3a} = 0.217$) than when each main effect is regressed individually (see R^2 of models 1a–c), or together with another main effect (see R^2 of models 2a–c), on the intensity of R&D collaborations. It is furthermore noteworthy that the inclusion of the interaction effect testing hypothesis H3 (*geographical proximity * corporate size*) leads to multicollinearity problems in model 3b (average $VIF_{Model3b} = 7.478$), model 4a (average $VIF_{Model4a} = 5.960$) and model 5 (average $VIF_{Model5} = 5.420$). Consequently, we retain model 4b as the most parsimonious model and reject hypothesis H3.

At first sight, model 4b seems to confirm hypotheses H1, H2 and H4 because all main effects come out as significant predictors of the R&D collaborations' intensity, whereas the interaction between geographical proximity and an industry's technological intensity is not significant. Interestingly, though, the relationship between *geographical proximity* and R&D intensity (H1) is not only strong and statistically significant but negative. In other words, innovation partners that are close to each other collaborate less intensely in joint R&D activities than innovation partners which are more distant. Whenever a biotech firm is as close as a 15-minutes drive to its innovation partner, the log likelihood of an intense R&D collaboration decreases by 0.271 points. Intense R&D collaborations seem more likely between innovation partners that are geographically distant rather than close. This finding falsifies hypothesis H1.

The falsification of hypothesis H1 is corroborated by qualitative interviews with two university researchers and five research officers working for five Flemish biotech firms (see the Appendix). These interviewees explained that their search for R&D partners is mostly driven by the intention to gain access to complementary, high-quality knowledge resources. Biotech firms search for "key scientists" in the field who have the required expertise. Whether or not these scientists are geographically close to the firm is of little importance. The research officers furthermore explained that their firms were university spin-offs which conduct more technologically advanced research than the parent universities from which companies had spun off. The chances of finding complementary knowledge are better at PROs that are not located in the same cluster. While the interviewees indicated that face-to-face interactions and trust are important in order to identify partners for joint R&D collaborations, they also highlighted that meetings at conferences and workshops are sufficient for the development of trust-based relations. In sum, due to ever better and cheaper opportunities to communicate and travel to distant locations, geographical

Table 2. Predictors of the intensity of R&D collaborations (results of OLS regressions: standardized B)

Independent variables	Models 1a–c (individual impact of 1 predictor)			Models 2a–c (joint impact of 2 predictors)			Models 3a–c (joint impact of 3 predictors)			Models 4a–b (joint impact of 4 predictors)		Model 5
H1: Geographical proximity	−0.196**			−0.183**	−0.175**		−0.164**	~~0.015~~	−0.282**	~~0.031~~	**−0.271****	~~0.086~~
H2: Corporate size		−0.282***		−0.274***		−0.270***	−0.263***	~~−0.243***~~		~~−0.232***~~	**−0.263*****	~~-0.234***~~
H3: Interaction effect: proximity × corporate size								~~-0.212~~		~~-0.208~~		~~-0.195~~
H4: Industry			0.343***		0.332***	0.333***	0.323***		0.273***	~~0.323***~~	**0.264*****	~~0.265***~~
H5: Interaction effect: proximity × industry									0.162		**0.162**	0.159
N	144	144	144	144	144	144	144	144	144	144	**144**	144
R^2	0.038	0.079	0.118	0.113	0.148	0.190	0.217	0.117	0.160	0.221	**0.229**	0.223

Note: Significance levels: * < 0.10; ** < 0.05; *** < 0.01. Constant not reported in table.

Crossed-out numbers indicate distorted coefficients due to multicollinearity problems: Average $VIF_{Model3b} = 7.478$; Average $VIF_{Model4a} = 5.960$; Average $VIF_{Model5} = 5.420$.

proximity seems ever less important for the development of trust and, consequently, for the intensity of collaborations between innovation partners.

Model 4b furthermore reveals that the influence of a *firm's size* is statistically significant, yet negative. An increase in corporate smallness—i.e. a decrease in firm size—by one employee decreases the log likelihood of a more intense R&D collaboration by 0.263 points. Interestingly, this finding refutes hypothesis H2 which suggested the opposite relationship. This result was both confirmed and explained by the university researchers interviewed (see the Appendix). According to these experts, small firms are perceived as less reliable and attractive collaboration partners because small companies have less financial and knowledge resources to offer. These more limited knowledge bases can imply that potential collaboration partners encounter difficulties when trying to understand each other, which, in turn, hinders an efficient knowledge transfer. The interviewed researchers furthermore mentioned that large firms tend to "know their way" to the PROs, whereas small firms often have difficulties in recognizing new knowledge opportunities and adequate collaboration partners.

With regard to the *knowledge intensity of an industry*, the OLS results of model 4b show support for hypothesis H4. Firms active in the red biotech industry are more likely to contribute to knowledge diffusion than firms that are active in green or white biotech industries (standardized B = 0.264). According to the research officers interviewed at red biotech firms (see the Appendix), this result is explained precisely by the reasoning that led us to formulate hypothesis H4. The technological complexity of new drugs implies that firms cannot deliver the necessary expertise on their own. They need to complement their internal knowledge base with adequate external know-how. Red biotech firms are, for example, partly dependent on the expertise of hospitals in order to conduct clinical trials. In a similar vein, the interviewed university researchers described how their PROs were dependent upon both the expertise of small red biotech firms as well as the up-scaling technologies of large red biotech firms. The research officers interviewed at green and white biotech firms, in turn, confirmed that their firms do not necessarily need to access complementary knowledge resources and are therefore less dependent on R&D collaborations with external knowledge providers.

We furthermore learn from models 3c and 4b that the interaction effect hypothesized by hypothesis H5 has a positive but statistically insignificant impact on the outcome: in line with our rejection of hypothesis H1, we find that *red biotech firms located close to their cooperation partners* are not likely to collaborate more intensely (standardized B = 0.162). This leads us to reject hypothesis H5.

5. Discussion and Conclusions: Why Geographical Proximity Matters Less for R&D Collaborations in a Globalizing Economy

This paper has endeavoured to shed new light on a long-standing research question: how does geographical proximity influence the intensity of inter-organizational R&D collaborations? Until the beginning of this millennium, the literature on inter-organizational collaborations provided a strikingly unanimous answer: proximity matters! It matters because it enables frequent meetings between innovation partners, the development of trust, the transfer of tacit knowledge and, thus, intense R&D collaborations (Pyke *et al.*, 1990; Pyke and Sengenberger, 1992; Saxenian, 1994; Zucker and Darby, 1996; Porter,

1998; Fritsch and Schwirten, 1999; Crouch *et al.*, 2001; Cooke, 2002). Over the past few years, however, researchers have started to provide new answers: geographical proximity seems to become less important for intense R&D collaborations. With decreasing transportation and communication costs—that is, with increasing globalization—meetings between innovation partners become less expensive and, hence, more frequent. Whether or not the innovation partners of a company are located close to its own premises seems to become ever less important for entertaining intense R&D collaborations—even across national boundaries (Vedovello, 1997; McKelvey *et al.*, 2003; Mora-Valentin *et al.*, 2004; Saxenian, 2006; Moodysson and Jonsson, 2007; Ponds *et al.*, 2010).

Our studies of R&D collaborations between Flemish biotech firms and PROs support the latter view. While our quantitative analyses of 144 R&D collaborations highlighted that Flemish biotech firms cooperate more closely with PROs that are not located within the same cluster, qualitative interviews with university and corporate researchers shed light on the causal mechanisms: to be innovative, firms require expert knowledge that often exceeds their own, internal knowledge resources. Consequently, firms look for external innovation partners, whereby trust is an important precondition for successful R&D collaborations. Yet geographical proximity no longer seems to be vital for enabling the development of trust-based relations. Meetings at conferences and workshops seem sufficient for researchers to get to know each other and decide whether or not they want to engage in joint innovation projects. Low transportation and communication costs facilitate intense interactions irrespective of whether the company and its innovation partners are located close to each other. These insights lead us to conclude that globalization transforms the nature of inter-organizational R&D collaborations: geographical proximity no longer matters.

It is important to understand that the limited importance of *geographical* proximity does *not* mean that *relational* proximity, i.e. the knowledge compatibility of R&D partners (see Moodysson and Jonsson, 2007), would no longer matter. Given that R&D partners seek access to complementary knowledge, it could well be the case that (inter-)national collaborations follow geographic patterns. As long as know-how on specific R&D topics is locally concentrated, firms and PROs are more likely to collaborate with partners in some rather than in other locations. For example, the top R&D centres in Boston and San Francisco are likely to have more connections than centres in Boston and New York. Hence, *relational* proximity matters, whereas *geographical* proximity is not necessary for developing strong research ties.

In short, our results allow us to make two fundamental contributions. First, we show that geographical proximity no longer matters even for those R&D partners that have traditionally been found to be most susceptible to co-location: industry–university collaborators in the biotech industry. We therefore conclude that geographical proximity is possibly even less important for R&D collaborations in other industries. Second, the qualitative evidence collected allows us to explain the causalities underlying the regression results. Geographical proximity has become less important because ever lower transportation and communication costs, as well as ever better online communication tools, enable R&D collaborations also over long distances.

One particularly noteworthy question results from our finding: if close location of R&D partners has become less important, even for biotech companies' collaboration with PROs, why do firms and PROs nevertheless show a tendency to locate themselves within regional clusters? Our answer to this question can only be speculative as we have not explored the

reasons for corporate location in this paper. However, we think that easy access to infrastructure and information motivates firms to locate themselves within clusters rather than in the countryside—irrespective of whether or not their R&D partners are located within the same cluster.

As is the case with virtually all research, our findings also have limitations. First, we focus on *subsidized* R&D collaborations. While industry experts suggest that our data is representative of non-subsidized collaborations as well (De Cleyn, 2011), we have no concrete figures on the data's representativeness. Second, university–industry collaborations may not be representative of R&D collaborations between private organizations. Given that public–private partnerships have been found to be particularly susceptible to the co-location of R&D partners, we assume that regional proximity is also of little importance for purely private R&D cooperation. However, our data does not allow us to test this assumption. We therefore suggest that our findings are considered with a grain of salt.

Our findings have several implications. The first one concerns the question of how [?] fruitful innovation policies could look like. The decreasing importance of geographical proximity for inter-organizational R&D collaborations raises doubts about generic policies that seek to foster innovation through the development of local clusters. Such measures only seem adequate for technology-intensive firms in the red biotech industry, which strongly rely on external collaboration partners in order to complement their internal knowledge base. Less technology-intensive companies do not seem to benefit from being located within the same cluster as their innovation partners. Rather than aiming at generic cluster developments, innovation policies would seem more successful if they were targeted at helping firms to identify the most suitable collaboration partners—irrespective of whether the latter are located inside or outside the same cluster. Given that large firms seem better able to identify suitable collaboration partners than small firms, specific policy programmes for SMEs might be more successful than generic programmes that are not tailored to the lower cooperation capacities of small companies.

A further, and particularly noteworthy, implication of the decreasing importance of proximity for inter-organizational R&D collaborations is that globalization offers more opportunities than commonly assumed. In the media, globalization is often perceived as a threat to corporate competitiveness. Decreasing communication and transportation costs provide consumers with more and better information and access to products around the globe. This increasing transparency implies that firms producing exportable goods need to compete globally. Globalization puts firms under increasing competitive pressure. At the same time, though, globalization also opens up new opportunities for inter-organizational collaborations. Innovation partners no longer need to be geographically close. As demonstrated so impressively by the contribution of Saxenian (2006), even international collaborations between extremely diverse innovation partners are not only feasible but highly beneficial for both sides. "Globalization [...] thus seems to be at least as much an opportunity as a threat" (Herrmann, 2008: 170).

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Appendix. Interviews with Experts of the Flemish Biotech Industry

Experts at PROs

1) Professor at Ghent University
   Biotechnology segment: white biotechnology
   Geographical location: cluster Ghent
   Date interview: 26 March 2009
   Location interviewer: Ghent University (on site)

2) Professor at The Katholieke Universiteit van Leuven (KU Leuven)
   Biotechnology segment: red biotechnology
   Geographical location: cluster Leuven
   Date interview: 14 April 2009
   Location interviewer: Amsterdam (telephone conference)

Experts at Biotechnology Firms

3) Director of R&D Agro-Food Department
Size of firm: medium-sized
Biotechnology segment: green biotechnology (agro-food)
Geographical location: science park Ghent
Date interview: 26 March 2009
Location interviewer: Ghent (on site)

4) Chief Executive Officer
Size of firm: medium-sized
Biotechnology segment: red biotechnology (human health)
Geographical location: science park Ghent
Date interview: 1 April 2009
Location interviewer: Amsterdam (telephone conference)

5) Chief Scientific Officer
Size of firm: large-sized
Biotechnology segment: red biotechnology (human health)
Geographical location: science park Ghent
Date interview: 2 April 2009
Location interviewer: Amsterdam (telephone conference)

6) Chief Financial Officer
Size of firm: small-sized
Biotechnology segment: white biotechnology (environmental sustainability)
Geographical location: science park Ghent
Date interview: 16 April 2009
Location interviewer: Utrecht (telephone conference)

7) Chief Executive Officer
Size of firm: small-sized
Biotechnology segment: red biotechnology (human health)
Geographical location: science park Ghent
Date interview: 22 April 2009
Location interviewer: Utrecht (telephone conference)