The Journal of Technology Transfer (2021) 46:1196–1231
https://doi.org/10.1007/s10961-019-09740-1

Commercializing academic research: a social network approach exploring the role of regions and distance

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Published online: 14 June 2019

Abstract

Relationships between firms and universities have been centre stage for some time. However, empirical studies on firms contracting research to universities remains limited. The likelihood of engaging in contract research depends on the characteristics of the firm and the university. Because existing literature further suggests that location is a key facilitator for knowledge transfer activities, the paper investigates the role played by regions and geographical distance between firms and universities when engaging in contract research. Hence, the analysis combines characteristics from both organisations and adds relationship-specific features with respect to the distance between them and the region they are located in. It also looks at the role played by cognitive distance. The paper contributes to the understanding of how academic research, commissioned by firms, is influenced by locational features: the ability to engage in contract research and the regional context, the regional embeddedness of research contract partners, and the geographical distance between these partners. It builds on an original dataset with information on contract research at firm. Based on a panel of three consecutive waves of R&D surveys in Belgium conducted in 2006, 2008 and 2010, the linkages of universities with R&D active firms are examined by linking a database on universities with one on firm R&D investments. Using the most recent insights in the social network approach, highlights the variables that impact the likelihood of firms engaging in research contracted to a university. Descriptive measurements are calculated from social network analysis to capture the basic structure of the firm-university network and construct an Exponential Random Graph model to predict firm-university relationships based on network characteristics and node attributes. Four main conclusions are drawn. First, more innovative regions do not show a higher likelihood of firms to engage in contract research with universities. Second, the likelihood for contract research is higher, if firms and universities are located in the same region. Third, geographical distance shows a negative relation to the likelihood of contract research suggesting cluster formation. Fourth, in the case of contract research cognitive distance complements geographic distance.

Keywords Firm-university relationships · Contract research · Geographical distance · Cognitive distance · Regional embeddedness · Social network analysis

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JEL Classifications I23 · L24 · O32 · O33 · R12

1 Introduction

Universities are traditionally considered to provide valuable knowledge for firms (Caniëls and van den Bosch 2011). Since innovative activities continuously become more complex, firms are increasingly seeking additional knowledge and technology from outside sources (Markman et al. 2008; Spithoven et al. 2013). Accordingly, firms maintain therefore various relationships with external organisations, among which universities are cited as an important partner (Godin and Gingras 2000; Charles 2006; Uyarra 2010). There are many possible relationships between firms and universities (D'Este and Patel 2007; Bekkers and Bodas Freitas 2008; Ramos-Vielba and Fernández-Esquinas 2012) and different channels of knowledge exchange between them have been studied (Schartinger et al. 2002; Perkmann et al. 2013; Marzucchi et al. 2015).

There is now a large body of empirical research on firm-university relationships, based on large surveys, patent analyses, bibliometric research and case study material (Fontana et al. 2006). Cohen et al. (2002) show that firms do not use all channels of academic research equally. Contract research, consulting and co-operative ventures are preferred over patenting, licensing and academic entrepreneurship (Ramos-Vielba and Fernández-Esquinas 2012; Perkmann et al. 2013, Scandura 2016). Contract research is identified as one of many channels of knowledge transfer between firms and universities (D'Este and Patel 2007). Schartinger et al. (2002, p. 313) find that the most used types of knowledge interaction are contract research and academic consulting (22%), notably higher than collaborative research (15%) and other types. In spite of this, R&D collaboration appears much more studied than contract research. Notwithstanding the substantial attention paid to firm-university knowledge transfer in empirical studies, the practice of contract research to universities remains understudied as a specific source of knowledge. Markman et al. (2008) state that contract research is neglected, mainly because it is difficult to measure. The current paper aims therefore to carry out further research into this aspect of firm-university relationship, as suggested by D'Este and Patel (2007).

A second shortcoming in the recent debate on firm-university interactions is that the impact of geographical distance of firms with respect to universities remains unclear. On the one hand, Malmberg and Power (2005) demonstrate that formalised firm-university relationships are not limited to a regional scale, because they are targeted at necessary complementary competences and knowledge. Hence, the activity of contract research is expected to occur over larger distances, entailing the internationalisation of firm-university networks where global pipelines to source the knowledge are needed (Bathelt et al. 2004). Spithoven and Teirlinck (2015) draw on the resource-based view to stress that firms source their required knowledge through R&D outsourcing, irrespective of geographical distance. On the other hand, interactions with universities are especially beneficial at a more local level. Laursen et al. (2011) argue that contract research, assuming consistent quality of academic research, is preferably outsourced to nearby located universities. The main reason for this geographical boundary is the importance of tacit knowledge (Cowan et al. 2000), which is more easily exchanged in face-to-face situations (Bathelt et al. 2004; Storper and Venables 2004; Marzucchi et al. 2015).

Contract research captures formalised market relationships (Trippl et al. 2009; Mowery and Ziedonis 2015), inducing monetary flows. Firms pay to get access to academic research, to use their equipment, to solve a practical technical problem, etc. R&D collaborations are less likely to entail comparable monetary flows as universities are likely to benefit from these interactions as well (Bodas Freitas and Verspagen 2017).

The paper investigates, empirically, the role played by regions and geographical distance between firms and universities when engaging in contract research. The likelihood of engaging in contract research depends on the characteristics of both the firm (e.g. age, size, sector, R&D intensity, regional funding) and the university (e.g. size and scientific specialisation). Our analysis combines characteristics from both organisations and adds relationship-specific features (e.g. distance). Because existing literature suggests that location, and therefore geographical distance, is a key facilitator for knowledge transfer activities (Arundel and Geuna 2004; Döring and Schnellenbach 2006; Laursen et al. 2011; Casper 2013), it is considered extensively in this paper in the context of contract research.

The contributions of the research lie, first and foremost, in the advancement of our understanding of how academic research, commissioned by firms, is influenced by locational features: the ability to engage in contract research and the regional context, the regional embeddedness of research contract partners, and the geographical distance between these partners. Second, we build on an original dataset with information on contract research at firm level (as in e.g. Laursen et al. 2011), whereas many studies start from data gathered at university level (see e.g. Muscio et al. 2015), which risks missing out research projects carried out by academics but are unknown to their respective departments and universities. Third, by using the most recent insights in the social network approach, we aim to highlight the variables that impact the likelihood of firms engaging in research contracted to a university (see e.g. Cantner and Graf (2006) for an early use of social network analysis).

The paper is organised as follows. Section 2 outlines the background literature to sketch the context and rationale of the role of regions and distance in contract research. Data, variables and analytical method are reviewed in Sect. 3. The Sect. 4 reports the analytical findings, and Sect. 5 offers a discussion of them in relation to the role of regions and distance. The final section summarises the findings, notes the limitations and expands on future research topics.

2 The role of regions and distance in contract research

2.1 The relational context of contract research between firms and universities

Contract research involves many activities ranging from simple troubleshooting and ad hoc problems, over the use of infrastructural facilities and equipment to academic research input in technical complex issues (Perkmann and Walsh 2007). In this paper contract research and consulting refer to paid-for R&D activities commissioned by external firms performed by academics (Bekkers and Bodas Freitas 2008). In the case of contract research the firm commissions the academic researcher to explore specific, previously un-researched aspects of a problem; while consulting exploits existing expertise (Perkmann and Walsh 2007). Consultancy is, according to D'Este and Patel (2007), university research that is commissioned by firms but does not require any original research.

Contract research has comparatively low entry costs, requires low levels of absorption capacity and is among the few types of interaction that spatially cluster (Schartinger et al. 2002). Compared to research collaboration and joint partnerships, contract research is more asymmetric because firms determine the objectives and deliverables of the R&D activity the academic researcher has to perform—expertise, service, prototype development, etc.—unilaterally and against payment (Perkmann and Walsh 2007). Contract research, therefore, is said to reduce academic freedom in comparison to joint research projects. However, research contracts are far more open to changes than stated by Perkmann and Walsh (2007). Buying academic research by firms create relation-specific investments as envisaged by transaction cost economics (Klein Woolthuis et al. 2005).

This section reviews the relational context of contract research between firms and universities by highlighting the need for inter-organisational trust. Both small geographic distances and regional embeddedness are inductive to trust. Scholars demonstrated the necessity for trust in inter-organizational relations if a transaction is to succeed (Zaheer et al. 1998; Schepker et al. 2014). Even in the case of formal research contracts between universities and firms trust as a facilitator remains important (Jensen et al. 2015). Etzkowitz (1998) points to the need for setting the ground rules on the structure of the relationship and the division of benefits from the research in the early stages of relationships between firms and universities. Klein Woolthuis et al. (2005) state that trust is needed prior to a contract, and is also relevant during and after the execution of the commissioned research. Researchers in highly innovative firms or well renowned academic departments are more likely to engage in contract research (Poppo and Zenger 2002). A university's output, such as publications and R&D performances, gives rise to the reputational or competence trust firms need to contract out research (Zaheer et al. 1998). Inter-organizational trust further enhances the confidence in the academic researchers' capacity for meeting deadlines and producing the deliverables on time (Santoro and Gopalakrishnan 2001).

Scholars stipulate that research contracts in inter-organizational linkages serve two functions: control (based on transaction cost economics) and coordination (based on the resource-based view (Mellewigt et al. 2007; Schepker et al. 2014). Exerting control and monitoring are both more difficult at large geographic distances or when legal systems differ between regions. The control function is needed to counter opportunistic behaviour, because the firm has to open up some of its technology to university researchers in order to be effective in its acquisition even in the context of contract research (Santoro and Gopalakrishnan 2001). Hence, the firm will have to unclose (part of the) knowledge to the academic researchers to allow them to get acquainted with the (new) technology and provide adequate solutions (Bruneel et al. 2017). Scholars argue that inter-organizational trust is especially needed in the case of interactions involving technological complex knowledge which might be exchanged between firms and universities (Jensen et al. 2015; Bruneel et al. 2017). Universities are bound to learn from the technological contexts and problems within the firm and might also be informed about previous research results obtained by the firm (Perkmann and Walsh 2007). Etzkowitz (1998) already states that firms consider universities as potential competitors notably by their potential to create academic spin-offs.

Inter-organizational trust is important before the contract is closed because it facilitates the negotiations between the two partners with respect to the appropriation of the research results (Hagedoorn and Zobel 2015). Academic researchers and departments might use this knowledge shared and commissioned by firms for their own purposes; while firms might not have the resources to craft, monitor, and enforce contracts (Subramani and Venkatraman 2003). High monitoring costs and diseconomies of scale increases the firm's vulnerability to potential opportunism as academic partners see room to pursue their self-interest (Holcomb and Hitt 2007). But the knowledge or device, developed at the university and bought by the firm, is not necessarily commercially ready or a finalised product/service. Many research projects require further development to be implemented by the acquiring firm. In this respect, there is a qualitative difference with patents or scientific publications, as contract research is predominantly tailor-made to meet firm' needs and, moreover, the knowledge involved might be unproven or unstable. Again the service after delivery is easier in cases where firm and university are closely located. Zaheer et al. (1998) see inter-organizational trust as a safeguard that partners will not voluntarily take advantage of each other should the opportunity arise. The developed technology at the university on behalf of the firm might be sold to a competitor or used to start an academic spinoff. Trust is the mechanism behind averting opportunistic behaviour by following social norms and values (Klein Woolthuis et al. 2005) which are embedded in regions.

The monitoring function of the contract is required because once signed, firms and universities are expected to develop higher degrees of involvement (Etzkowitz 1998). The bounded rationality assumption in transaction cost economics stresses the limitation of firm' managers to foresee all possible contingencies in the contract (Klein Woolthuis et al. 2005). Hence, contract research might be troubled with potential contractual hazards such as imperfect property rights, unobservable quality issues, incomplete contracts, etc. (Lerner and Malmendier 2010). Klein Woolthuis et al. (2005) expect contracts on knowledge transfer with uncertain outcomes or on technical complex research to have clauses on intellectual property rights (e.g. patents, licences, …) on spillovers (e.g. pledge to secrecy, limitations to work for other partners, …), and clauses on the management of the research project (e.g. duration, responsibilities, deliverables, …). Monitoring and enforcing these clauses are facilitated by small geographic distances stimulating personal contacts. McDonald and Gieser (1987) argue on the basis of case studies that geographical proximity in setting up university-industry R&D projects is a clear advantage in contract negotiations.

2.2 Contract research in different innovative regions

Administrative regions are often used when studying knowledge exchange (Grillitsch and Trippl 2014); spillovers (Paci and Usai 2009; Marrocu et al. 2013) or networking (Varga et al. 2014).

The main theoretical framework justifying administrative regions, is that of the regional innovation system that stresses the importance of interactions between various actors in the system (Cooke et al. 1997) and offers a conductive environment for collective learning, innovation and entrepreneurial activities (Trippl et al. 2017). The idea that firms and universities do not operate in isolation, and that innovation processes gain from the diffusion of knowledge between these two actors lies at the heart of the concept of regional innovation systems. Literature on regional innovation systems details diverse interacting actors pursuing each their own interests, formal organisations and (re)acting according to institutional arrangements (Caniëls and van den Bosch 2011). Regional innovation systems enhance the capacity for localised learning and facilitates the flow of (tacit) knowledge exchange (Asheim and Isaksen 2002). A drawback of the literature on regional innovation systems is that it often remains descriptive and does not explain the processes of forging inter-organizational linkages.

Recently, Trippl et al. (2009) introduced the concept of institutional 'thickness' (or 'thinness') to differentiate between regions. Thickness points to an interlocking pattern of supportive informal connections and formal institutions that is conductive to forging inter-organisational linkages. Institutional thickness in regional innovation systems facilitate the creation of a shared framework in which resources can be obtained since firms and universities share approaches and policies maximising understanding thus driving contract research (Keeble et al. 1999; Trippl et al. 2017). Tödtling et al. (2011) posit that the structure and size of regional innovation systems imply a different institutional thickness, which impacts the nature and geography of knowledge sourcing. Institutional thickness varies across regions, which is reflected in differences in contract research possibilities.

Balland and Rigby (2017) attribute regional differences to the cumulativeness of inventions and the difficulty to replicate region-specific developed knowledge in other regions. Contract research is also characterised by the difficulty to replicate across regions due to the cost of acquisition, the cost of absorption, the tacit component of contract research, and the complexity (Balland and Rigby 2017).

Emphasising regional differences is fully in line with scholars observing an increased role of regions in the knowledge economy (Storper 1995). This also applies to science and innovation policy for at least four reasons (Fritsch and Stephan 2005). First, R&D activities are unequally distributed across space (Teirlinck and Spithoven 2005). Second, regional innovation systems function differently across regions (Tödtling and Trippl 2005). Third, regional science and innovation policy is focused on regional development and might be counterproductive toward national (and European) objectives warranting coordination (OECD 2013). Fourth, studying regional policy facilitates benchmarking and comparison in order for policy makers to learn from each other (Fritsch and Stephan 2005).

Regions are thus politically structured systems aiming to advance their economic development. Hence, the design and implementation of science and innovation policy is often executed by regional authorities. This is especially important for federal states such as Germany, Switzerland, Spain and Belgium but also occurs in unitary states such as France, Sweden and the Netherlands (Sanz-Menéndez and Cruz-Castro 2005).

Scholars remain often silent about the regional demarcation (see Audretsch and Lehmann 2005) or use arbitrary levels without policy relevance, such as the provincial (NUTS 2) level in Belgium (Greunz 2005). Regional innovation systems, however, refer to spatial entities with at least some degree of autonomous political power (Cooke et al. 1997; Uyarra 2010). This is why the regional (NUTS 1) level in Belgium is instructive. Regions in Belgium enjoy a high degree of autonomy when it comes to science (firms) and educational (universities) policy, budgetary capabilities and political agenda setting. Also the incentive structure for academic and private sector collaborations with firms through contract research differs across regions, as discussed in Sect. 2.1.

Although a thorough discussion of regional typologies is beyond the scope of this paper, it must be acknowledged that regions differ from each other from an innovation perspective (European Commission 2017). All three regions in Belgium are responsible for implementing their own innovation policy, including the regulation on university-industry relations (Ponds et al. 2007).

Belgium consists of three administrative regions—the Brussels-Capital Region, the Flemish Region in the North, and the Walloon Region in the South—which differ in many aspects (Belgian Science Policy Office 2010). The systems allocating regional resources to stimulate R&D activities differ across regions in Belgium, although the overall objectives on employment and innovation are similar for most European regions. Regional authorities impact firm-university relationships directly through regional funding (i.e. subsidies). The possibility for firms to acquire university research also depends on university regulation (Muscio et al. 2015) which is a regional responsibility in Belgium. Belgium is, therefore, a relevant case to study the linkages at regional level between firms and universities with respect to contract research.

The Regional Innovation Scoreboard (European Commission 2017) is an on-going effort to identify the strengths and weaknesses of regional innovation systems using many indicators to cluster regions with similar characteristics. Based on a cluster analysis, Navarro and Gibaja (2009) also differentiate between the regions in Belgium, as do Marsan and Maguire (2011). The most recent version of the Scoreboard characterised the three regions in Belgium differently. European regions are grouped into four innovation performance groups according to their performance on the Regional Innovation Index relative to that of the EU: innovation leaders, strong innovators, moderate innovators and modest innovators (European Commission 2017). Innovation leaders show a performance more than 20% above the EU average and strong innovators a performance between 50 and 90% of the EU average. The most recent Regional Innovation Scoreboard introduces three subgroups within each performance group to allow for more diversity at the regional level: the top one-third regions (+), the middle one-third regions and the bottom one-third regions (−). The Flemish Region is an innovation leader (−); the Brussels-Capital Region is a strong innovator (+) and the Walloon Region is a strong innovator.

The Flemish Region benefits from an above-average economic level and an average technological development (Navarro and Gibaja 2009) and concentrates—compared to other European regions—on medium-tech sectors (Marsan and Maguire 2011). Because the Flemish Region has high R&D expenditure in the public and private sector they demonstrate increasing levels of technological capacity. According to the Regional Innovation Scoreboard, the Flemish Region is the most advanced because of its strong scores on innovative SMEs collaborating with other partners; on introducing product and process innovators; on international scientific co-publications that are often cited; and on large R&D expenditures in the business sector (European Commission 2017). The Flemish Region hosts four universities which differ considerably in size.

Navarro and Gibaja (2009) chracterise the Brussels-Capital region as an innovative capital region, hosting knowledge intensive services and public research infrastructures. With a surface of 161 km^2 the small Brussels-Capital Region hosts three universities; the medical division of a French-speaking university; and several campuses of Dutch-speaking universities. Marsan and Maguire (2011) also differentiate between the Brussels-Capital Region and other regions by stressing its function as a knowledge intensive capital or knowledge hub with a high share of tertiary educated labour force. The region is further characterised by its small size and commuting flows, a high GDP per capital and a high unemployment rate (Marsan and Maguire 2011). The Brussels-Capital Region is a densely populated region (Navarro and Gibaja 2009). The region is specialised in high value added activities. The Regional Innovation Scoreboard (European Commission 2017) characterises the Brussels-Capital Region as strong on innovative and collaborative SMEs; on the development of product and process innovations, and on the high public–private co-publications and international scientific co-publications. But there are some notable weaknesses as well: relatively weak sales generated by innovative firms and relatively weak performances in terms of R&D expenditures in the business sector and in terms of patent applications.

The industrial Walloon Region, on the other hand, is portrayed as a central region with a small technological lag, necessitating the region to focus on developing its absorptive capacity and knowledge creating capabilities. Especially enhancing the quality and quantity of the interactions among the innovative agents, such as universities and R&D active firms, is recommended (Navarro and Gibaja 2009). Although still highly ranked in the European context, the Walloon Region is the weakest one in Belgium, especially where innovative sales, R&D expenditure in the public sector; and lifelong learning are concerned (European Commission 2017).

Overall the Flemish Region is the most innovative region with an institutional thickness permitting the formation of university-industry linkages, followed by the Brussels-Capital

Region and then the Walloon Region. The innovative context of regions is bound to have implications on the forging of university-industry linkages and, therefore, the likelihood for firms to find universities to assist them in their research endeavours will be higher in the most innovative regions when compared to the less advanced regions.

Consequently, different regional innovation systems will produce differences in the likelihood of firms and universities engaging in contract research.

Hypothesis 1 More innovative regions have a higher likelihood for firms to have contract research with universities than less innovative regions.

2.3 The role of regional embeddedness in contract research

In their account of the Austrian automotive sector, Grillitsch and Trippl (2014) posit that contract research between firms and universities occur mostly at regional level provided that there are universities within the region. Co-location in administrative regions also captures the idea of the regional embeddedness of firms and universities (Laursen et al. 2011; Casper 2013). The idea of regional embeddedness refers to a shared institutional context, with similar values, norms, language, rules and regulations, facilitating knowledge exchange (Marrocu et al. 2013). Even with similar structural characteristics, regional administrations can set different strategies and goals (Niosi 2002).

Following Gertler (1995) the relations between firms and universities can be characterised as a coherent structure of organising routines linking tacit knowledge, embedded by the labour force, in the context of procedures and regulations. Isaksen and Karlsen (2013) add that specific types of knowledge is sticky and only regionally available. Markman et al. (2008) refer to differences in incentive structures of universities within and across regions, that may impede contract research by university 'tax' to cover overheads.

Regional embeddedness points towards a mutual understanding, trust and intimacy at the regional level (Sternberg and Litzenberger 2004). Dahl and Sorenson (2012) attribute this to actions of individuals who possess idiosyncratic historical, cultural and other knowledge about the region. This regional embeddedness results in enhanced opportunity identification and resource mobilisation.

Being co-located in the same administrative region could be interpreted as an indicator for institutional proximity (Davids and Frenken 2018). Ponds et al. (2007) stress the importance of university-firm linkages in joint research and the same academic incentive structure in the same administrative region as elements of institutional proximity. Caniëls et al. (2014) argue that "institutional proximity emerges from formal rules providing closeness between administrative geographical entities, for example a country, a region or a city" (Caniëls et al. 2014: 226). Institutional proximity is deemed conductive to the development of mutual trust (Broekel and Boschma 2012). However, the notion of institutional proximity in this sense is more vague than in the literature on regional innovation systems, which also looks into the interactions between actors in the institutional setting (Doloreux and Parto 2005). Doloreux and Parto (2005, 141) summarize, "all regions have some kind of regional innovation system, including not only regions with strong preconditions to innovation, but also old industrial regions (…), peripheral regions (…), rural regions (….) and regions in transition (…)". Isaksen and Karlsen (2013) demonstrate that even small regions, such as the Brussels-Capital Region, can exert regional advantages.

When regional innovation systems are characterised by institutional thickness they provide a context promoting trust relations, reducing the danger of opportunism and uncertainty. Dense informal networks are connected to the development of trust relations between organisations engaging in contract research (Uzzi and Gillespie 2002). An important aspect of institutional thickness is that it increases information flows on the presence at universities of particular expertise, knowledge, research equipment and resources. Borgatti and Cross (2003) argue that knowledge exchange, such as contract research, is influenced by the awareness of resources as valuable or relevant knowledge or skills. Contract research can be seen as an inter-organisational boundary spanning practice, enabling knowledge exchange and resource efficiency (Cumbers et al. 2003; Malmberg and Power 2005). In short, contract research presupposes that the partners are acquainted with each other and that those informal personal relations initiate formal linkages (Azagra-Caro et al. 2006).

Spatial concentrations bring a shared knowledge base in their wake (Manning 2013). This revived an interest of economies of agglomeration—especially with respect to the ease of knowledge exchange within a particular spatial scale (Waxel and Malmberg 2007). The idea is that technology clusters are characterised by regional concentration of R&D expertise (spin-offs, R&D departments in large firms,…) and highly skilled labour, but also the presence of universities performing relevant research and open to sharing this with the business environment (Manning 2013).

Consequently, organisations clustered in a region share a common local culture that facilitates knowledge spillovers by means of social and cultural norms, and its functioning is driven by the interaction among differentiated types of actors localised in the same region. Regional embeddedness could, therefore, be interpreted as a proxy for institutional proximity in as far as regions share the same laws and regulations, cultural norms and common values. In a country with strong regionalised (science) policy such as Belgium, this type of proximity might play a significant role. However, the term of regional embeddedness is preferred over 'institutional' proximity because it is much better documented.

Casper (2013) investigates the arguments in favour of the effect of regional embeddedness on the knowledge exchange between firms and universities. According to him, the creation of qualitatively strong research environments is highly conductive to such exchange. This argument is also the justification behind pan-European research initiatives such as Horizon 2020 (Miguélez and Moreno 2015). A similar position on regional embeddedness, with respect to inventor mobility and collaborative networks, is taken by Miguélez and Moreno (2015) who show that the existence of regional absorptive capacity also contributes to the efficiency of knowledge exchange mechanisms.

Regional embeddedness points to the existence of 'sticky' knowledge and intangible assets that are hard to capture and absorb for firms located outside the region (Kramer and Revilla-Diez 2012). The embeddedness of relationships is rooted in positive externalities from regional and local integration by tapping into knowledge repositories, expertise and skills (Malecki 2010; Bathelt et al. 2004) that is difficult to reproduce in other regions (Asheim and Isaksen 2002). We expand on these research lines by focusing on the effects of regional embeddedness of partners at the level of firm-university relationships. When firms and universities are located in the same region, the level of inter-organisational trust and possibilities for interactions are deemed higher, increasing the likelihood of engaging in contract research. Therefore, the following hypothesis is formulated.

Hypothesis 2 When firms and universities are located in the same administrative region, the likelihood of contracting research to universities will be higher.

2.4 The role of geographical distance in contract research

Geographical distance and regional embeddedness point to two analytical different concepts. Hansen (2015) found no evidence of substitution between geographic distance and being located in the same administrative region (institutional proximity). Especially in smaller regions a lot of actors—universities and firms alike—are quite often located near regional borders. Quite some literature on innovation stresses the fact that innovation capabilities are sustained through the use of localised resources such as the presence of customers, local learning processes and spillover effects, traditions for cooperative and entrepreneurial attitudes, labour marker characteristics, subcontractor and supplier linkages, and supporting organisations (Doloreux and Parto 2005). Hence, for actors located near regional borders, a small geographic distance implies geographic concentration in clusters using localised resources might still cross administrative regional borders.

De Fuentes and Dutrénit (2016) argue that interactions between universities and firms benefit from geographic proximity: firms are more willing to fund R&D executed by universities located in the vicinity. However, when firms look for unique or complex knowledge they might turn to universities that are located further away (Spithoven and Teirlinck 2015). But although geographical distance is acknowledged to play a key role in innovation, the exact role of distance remains ambiguous (Broström 2010). On the one hand there are scholars announcing the 'death' of distance (Ohmae 1995; Cairncross 2001); while others argue the 'persistence' of distance (Nachum and Zaheer 2005). One reason for this ambiguous treatment of distance is that scholars do not differentiate between 'information' which can be diffused increasingly smoothly across distances and borders due to the advances made in information and communication technology (ICT), and 'knowledge' which requires an understanding of the information that is being diffused (Morgan 2004). Another reason for this discrepancy lies in the different empirical approaches: some scholars focus on firm level (e.g. Monjon and Waelbroeck 2003), whereas others concentrate on the level of the individual such as R&D managers in firms (Broström 2010), or academics in universities (D'Este and Perkmann 2011).

Much theoretical and empirical work has tackled the geographical dimension of knowledge transfers between firms and universities. The unspoken, tacit nature of knowledge is a recurring aspect in explaining the geographically-bounded nature of spillovers (Cowan et al. 2000; Arundel and Geuna 2004; Mowery and Ziedonis 2015). When knowledge is difficult to transfer, the need to engage through frequent interactions necessitates limited geographical distances between organisations (Storper and Venables 2004; Laursen et al. 2011). Breschi and Lissoni (2001), however, attenuate this claim by arguing that knowledge might also be specific to a community, making tacit knowledge less relevant and stressing the cognitive dimension.

Porter (1998) claims that local knowledge relationships are different from distant relationships (see also Storper and Venables 2004). A decade later, Isaksen (2008) emphasises that useful knowledge is mostly local and unique. Woodward et al. (2006) argue that firms usually opt for locations close to universities. However, Bathelt et al. (2004), Trippl et al. (2009) and Malecki (2010) stress the relevance of the interplay between local networks and global 'pipelines'.

According to the resource-based view, firms are found to seek knowledge and technical resources wherever these are available to them (Spithoven and Teirlinck 2015). In this case, location is less central in knowledge sourcing. Even in small countries, universities can have a relatively heterogeneous research output in terms of scientific disciplines. Yet, if proximity prevails over the weight attached to the required resources, then firms will be more inclined to choose nearby universities. Paraphrasing Laursen et al. (2011), firms must choose between geographical proximity and the availability of relevant university research results.

Geographical distance between firms and universities becomes a key factor for firms to benefit from university research results. Part of the explanation for this lies in the tacit nature of knowledge spillovers (Cowan et al. 2000). Since not all knowledge can be codified and transmitted, the need for personal contact remains important, stimulating firms to buy complementary research results from (nearby) universities (Döring and Schnellenbach 2006; Laursen et al. 2011). Moreover, the cost of codification also plays a role (Cowan et al. 2000). Arundel and Geuna (2004) empirically confirm that the relationship between firms and public research organisations (including universities) is significantly affected by geographical distance. Paci and Usai (2009) demonstrate, based on patents, that knowledge transactions decline when geographic distance increases.

The literature reveals two frequently-used strategies to deal with distance in order to capture knowledge exchange by market-mediated knowledge channels such as contract research. The first strategy is in terms of geographical distance, in kilometres. Geographical distance can also be analysed by taking the centres of two places and the distance between them (as in Marrocu et al. 2013). It is posited that the likelihood for firms to engage in research contracted to a university is higher when the geographical distance is smaller (Broström 2010; Laursen et al. 2011).

Based on these insights, it is expected that the likelihood of engaging in contract research with distant universities will be lower as the distance increases. Our third hypothesis, accordingly, considers the geographical reach for contract research.

Hypothesis 3 The smaller the geographical distance between firms and universities, the higher the likelihood of contracting research to universities will be.

2.5 The effects of cognitive distance on contract research

This is not the place to expand upon the various characteristics and categories found in the 'proximity' literature, which is characterised by confusion and overlap (see Knoben and Oerlemans 2006). Without restarting the entire, well-known discussion on the various dimensions of proximity, one particular dimension—apart from geographic proximity—deserves attention in the context of inter-organisational knowledge exchange. In the context of contract research the major drivers are (1) the geographical distance between the focal R&D active firm and the knowledge producing university; and (2) the cognitive distance that ensures a potential opportunity to exchange complementary (tacit) knowledge (Torre and Rallet 2005).

Cognitive proximity captures the degree to which two different organisations or contractual partners share a common knowledge base (Broekel and Boschma 2012). However, as various scholars point out, the knowledge base must not be too similar because of the decreased learning possibilities this would entail (Nooteboom et al. 2007). However, interactive learning is hindered by too large a cognitive distances since firms need to understand, absorb and implement external knowledge when dealing with universities (Knoben and Oerlemans 2006). Especially in the case of cognitive distance an optimal level is therefore required: too little overlap of the respective knowledge bases impedes the recognition and transferability of knowledge; while too much overlap reduces the need for external academic knowledge by the firm (Nooteboom et al. 2007).

In essence, the existence of small cognitive distances is expected to compensate for the geographic distance between universities and firms (Davids and Frenken 2018; Capello and Caragliu 2018). Hansen (2015) empirically demonstrated the existence of compensation; whereas Huber (2012) did not find a substitution between geographic and cognitive distance. One reason for this divergence is, among other, the way cognitive distance is operationalized by the various authors. Hansen (2015) focused on the educational backgrounds of project partners; whereas Huber (2012) considered four different work-related dimensions. Another common practice, as illustrated by Nooteboom et al. (2007), uses patent data to capture cognitive distance. In other words, the research design and operationalization often steer the relation between geographic and cognitive distance.

In the context of university-industry relations an alternative approach is needed to capture common knowledge bases, since firms operate in economic sectors which refer to clusters of related activities—i.e. services and manufacturing sector—while universities are organised using scientific disciplines producing different types of knowledge—i.e. exact and social sciences (or 'hard' and 'soft' sciences). Two decades ago Etzkowitz (1998) acknowledged that all scientific disciplines, whether in the exact or social sciences, develop insights that are useful for different economic sectors. As an example he cited the links linguists maintain with the computer and software industry. A decade ago, Bekkers and Bodas Freitas (2008) highlighted the absence of a one-to-one relation between the knowledge in an economic sector and scientific disciplines. Moreover, the knowledge characteristics themselves vary across, and even within, economic sectors (De Fuentes and Dutrénit 2016). Schartinger et al. (2002) are one rare example of an attempt to look at the interactions between scientific disciplines and economic sectors, but they have aggregated nine university-industry channels (including contract research). Other authors use correspondence analyses to screen for positive and negative associations between scientific disciplines of the 'exact' sciences and a selection of industrial sectors (Garcia et al. 2018). We follow the practice of Capello and Caragliu (2018) to capture cognitive distance by calculating the specialisation of scientific disciplines and economic sectors.

The considerations above hinder the formulation of a priori expectations on the most common combinations of scientific specialisations and industrial sectors. However, the impact of geographical distance should at least be examined by controlling for cognitive distance, and from the literature cited above the idea is that cognitive distance complements geographic distance. The fourth hypothesis follows:

Hypothesis 4 Geographic distance will be complemented by cognitive distance in its effect on the likelihood of firms to contract research to universities.

3 Data, method and variables

3.1 Data

The social network analysis builds on two separate, but related, databases. First, the firm R&D survey targets the population of R&D active firms operating in Belgium. On three occasions, between 2004 and 2009, this survey contained a question on contract research on behalf of the firms, including the name of the university contracted out to revealing its exact location. Second, a similar R&D survey targets the R&D expenditures and their sources of funding of all non-profit organisations—public research centres and higher education institutes—among which all universities in Belgium. Both R&D surveys, organised at regional level, are based on an EU regulation and follow the guidelines of the OECD Frascati Manual to ensure that definitions are the same across regions, countries and participants (OECD 2015). The surveys are organised bi-annually, and the three waves of the R&D survey are pooled in the analysis because each firm is able to contract research out to universities in each separate wave.

Firms are defined at the level of the smallest legal entity, i.e. entities having a VAT number, that perform R&D on a permanent or quasi-permanent base. All firms that are known to perform R&D are included. An update is made each time a new survey is launched, taking into account both firms known from the past to be R&D active and a monitoring of firms declaring to be R&D active, e.g. by means of press releases or because they apply for R&D grants. An R&D active firm is any firm which declared in the survey: (1) to have at least one full time equivalent R&D employee in at least 1 year during the period 2004–2009; and (2) to have internal R&D expenditures larger or equal to 30.000 euro in at least one year during the same period.

During the period 2004–2009 firms merged, were (partially) acquired by other firms or experienced other changes with an important impact on the evolution of R&D and other enterprise variables. Therefore, information on changes with an impact larger than 10% (negative or positive) in terms of overall employment or in terms of turnover was asked for in each of the surveys. In case of mergers, acquisitions or partly sale, information is collected on other firms involved in the operation and the different firms involved were taken together as one entity for the entire period. This way firm-level data have been constructed to guarantee comparability over time, resulting in a database with 4555 firms as a starting point for the analysis.

The empirical analysis is limited exclusively to contract research to universities located in Belgium, although a minority firms have (also) contracted research to foreign universities. The reason for their exclusion is due to the impossibility to include comparable data on foreign universities. Each of the regions in Belgium hosts universities. The Flemish Region and Walloon Region each host four universities which all perform contract research on behalf of firms. Although three universities are located in the Brussels-Capital Region, only two of them perform contract research with firms.

The combined dataset allows us to construct an undirected bipartite network of firms and universities. A bipartite, also called two-mode, network comprises two sets of nodes where each set is a different social entity (Wasserman and Faust 1994). In this case, the first set of nodes represents the firms and the second set the universities. Ties are only present between nodes from a different entity, that is, between firms and universities. In our case, we dichotomised the ties between firms and universities: when a link is present, it represents a contract between a firm and a university. We end up with a

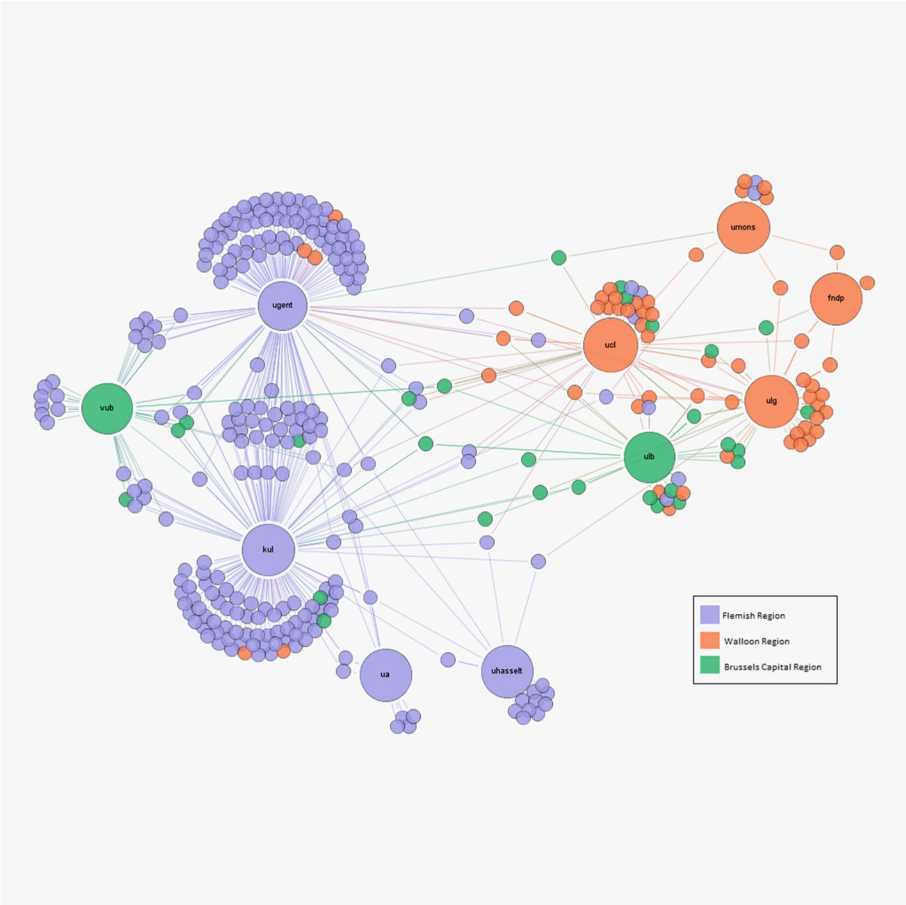


Fig. 1 Fruchterman Reingold plot of the two-mode network with isolates excluded

4555×10 matrix, which thus includes 4555 firms and 10 universities and has 582 ties present in the network. The density of the network, excluding forbidden ties in the two-mode network, is 0.013. In the first mode, 4239 firms are isolated with a degree of 0. In the second mode, the minimum degree is 7 and the maximum 183. Figure 1 is a Fruchterman Reingold plot of the two-mode network. Universities are plotted as the larger nodes and firms as the smaller nodes. Isolates are excluded and the nodes are coloured according to their region.

3.2 Method

The firm-university network allows to apply an Exponential Random Graph Model (ERGM) for bipartite networks. ERGM is a technique developed in social network analysis, which allows to estimate the effects of factors at the node, dyad and structural network level simultaneously.

Exponential random graph models are originally introduced by Frank and Strauss (1986) and Wasserman and Pattison (1996), and are extended for bipartite networks by Skvoretz and Faust (1999). Since then, several authors have contributed to the development of ERGMs for bipartite networks by proposing new parameter estimates and estimation methods (see e.g. Agneessens et al. 2004; Wang et al. 2009, 2013). The general aim of an ERGM is to identify variables that influence the probability of a simulated network emerging with similar properties to the observed one. It also allows calculation of the log-odds of forming a tie between two nodes, conditioning the structure of the network and factors at the nodal and the dyad level. Estimation of the models is preferably carried out using a Markov Chain Monte Carlo Maximum Likelihood Estimation procedure (MCMCMLE) (Snijders 2002; Snijders et al. 2006; Wang et al. 2009). MCMCMLE first generates a distribution of random graphs by stochastic simulation of a set of starting values, and second, refines those starting values by comparing the obtained random graphs with the observed network. The process is repeated until the parameters stabilise, otherwise the model fails to converge. The crucial final step in an ERGM analysis is to evaluate the goodness of fit of a model by comparing the structure of the simulated networks with the structure of the observed network. By comparing the properties of both networks, it is possible to evaluate the accurateness of the ERGM parameters in question. We included those GOF statistics in "Appendix". All the calculations were carried out in 'R', using the statnet software package (Handcock et al. 2003).

There are three reasons why two-mode ERGMs are particularly suitable for testing our hypotheses. First, firm-university networks are clearly two-mode networks where the relationships (i.e. contracts) occur between the two separate sets of nodes (firms and universities). Previously, these two-mode networks were typically projected into one-mode networks (see e.g. Cantner and Graf 2006). However, a one-mode projection implies losing information on the characteristics of the node set that is projected into the new network. Analysing the two-mode networks means retaining all the available information in the two modes of the network, in our case, university and business characteristics. Second, an ERGM analysis allows us to estimate the effects of characteristics of the two sets of nodes, dyad level information (i.e. distance) and the general network structure simultaneously on the dependent variable. Instead of analysing only descriptive network measurements (see e.g. Balconi, et al. 2004), it is an inductive technique that allows for a multivariate analysis on the dependent variable. Clearly, this is necessary for testing our hypotheses. Finally, because the data and hypotheses are inherently relational, the assumption of independence of errors is violated. Therefore, a more traditional regression analysis using network indicators as independent variables is not suitable for the research problem at hand.

3.3 Variables: node, dyad and network

Based on the background information, we constructed variables at the node, dyad and network levels to test our hypotheses. In this section we discuss the operationalisation of the different variables, structured according to their level. One important limitation for the analysis is the fact that the method currently does not contain node-level continuous variable parameters. Therefore, all these variables have to be categorised. Descriptive statistics for these variables are reported in Table 1.

Table 1 Frequency distributions of node level variables

Variable names	Frequency	Percentage
Node level: company		
Age (relative to 2009)		
< 6 years	379	8.3
≥ 6 years °	4173	91.6
Missing values	3	0.1
Size		
Micro °	1032	22.7
Small	1791	39.3
Medium	1160	25.5
Large	470	10.3
Missing	102	2.2
Sector		
Manufacturing °	2803	61.5
Service	1752	38.5
Missing	0	0.00
R&D intensity		
Low °	3589	78.8
High	254	5.6
Missing	712	15.7
Regional funding		
Low °	4070	89.3
Medium	43	0.9
High	442	9.7
Missing	0	0.0
Region		
Brussels Capital Region °	459	10.1
Flemish Region	3003	65.9
Walloon Region	1093	24.0
Missing	0	
Node level: university		
Bibliometric output		
Low °	4	40.0
Mid	3	30.0
High	3	30.0
Missing	0	0.0
R&D expenditures		
Low °	5	50.0
Mid	3	30.0
High	2	20.0
Missing	0	0.0
Region		
Brussels Capital Region °	2	20.0
Flemish Region	4	40.0
Walloon Region	4	40.0

Table 1 (continued)

Variable names	Frequency	Percentage
Missing	0	0.0
Dyad level (N = 4555 × 10)	Average	St. deviation
Distance (km)	86.2	43.0
Dyad level (N = 582 observed ties)	No. of ties	Percentage
Cognitive distance based on bibliometric specialisation		
Firm in services and universities in social sciences and humanities °	104	17.9
Firm in manufacturing and universities in social sciences and humanities	229	35.3
Firm in services and universities in exact sciences	153	26.3
Firm in manufacturing and universities in exact sciences	96	16.5
Cognitive distance based on R&D specialisation		
Firm in services and universities in social sciences and humanities °	156	26.8
Firm in manufacturing and universities in social sciences and humanities	157	27.0
Firm in services and universities in exact sciences	158	27.2
Firm in manufacturing and universities in exact sciences	111	19.0

The symbol ° indicates that this category is taken as reference in the analyses

3.3.1 Node level

3.3.1.1 The firm The age of a firm is divided into two classes, based on the official definition of young innovative companies or YICs (Czarnitzki and Delanote 2013). Firms less than 6 years old are considered as 'young', from 6 years and above, they are categorised as 'mature'. The size of a company is based on the number of employees. Four classes are constructed according to the EU definition. 'Micro' firms have fewer than ten employees, 'small' firms have more than 10 but fewer than 50, 'medium' firms more than 50 but fewer than 250, and 'large' firms have 250 or more employees (Spithoven et al. 2013). To control for the sector activity firms are categorised into service versus manufacturing firms. This categorization starts from the original dataset using the sector classification made by Marsili and Verspagen (2002) using eight different groups of sectors: firms active in industries relying on continuous processes; fundamental processes; product engineering; science based insights; other manufacturing sectors; knowledge intensive services; and other services. The classification of sectors of Marsili and Verspagen (2002) is also used in the study on knowledge transfer channels by Bekkers and Bodas Freitas (2008).

Firm R&D intensity is measured as the amount of R&D expenditures by firms divided by the turnover in the same period. R&D intensity is vital to understand university research and is often used as a proxy for absorptive capacity (Spithoven and Teirlinck 2015). The R&D intensity of a business is coded into three categories, partly based on the official YIC definition. Firms with an R&D intensity lower than 5% are considered as low R&D firms, firms with an R&D intensity between 5% and 15% as medium R&D intensive, and those with 15% or higher are defined as high R&D intensive (Czarnitzki and Delanote 2013).

To promote the interactions between firms and universities, regional authorities might offer funding to enforce or stimulate partnerships (Perkmann and Schildt 2015). This is the case for all regional authorities in Belgium, although the modalities differ across regions. As such this variable captures part of the institutional thickness of the region. The variable is constructed using the relative percentage of regional funding of the R&D expenditure of firms and ordered into three classes based on the 33rd percentile.

To include the regional dimension use is made of administrative regions to capture regional innovation systems (Döring and Schnellenbach 2006; Caniëls and van den Bosch 2011). The regional location of a firm (at NUTS1 level) is used as an indicator of the regional innovation system. There are three regions: the Brussels-Capital Region, the Flemish Region and the Walloon Region. The administrative region can be entered in addition to geographical distance, as they are not mutually exclusive.

3.3.1.2 The university With regard to the node level characteristics of universities, three variables are included. It is demonstrated that university characteristics matter for contract research (Bodas Freitas and Verspagen 2017). The size of universities is captured using their level of average R&D expenditure over the years 2000–2009 to avoid annual fluctuations. Three categories capture university size: 'small' for expenditure of less than 10 million euro, 'medium' for expenditure between 10 and 20 million euro and 'large' for expenditure over 20 million euro. Second, a control variable for the research output of a university is created by taking into account their average bibliometric output between 2006 and 2013. The 'average' is calculated to have one measure per university. Since this varies from year to year, the bibliometric output had to be averaged to look into its effect on the likelihood of contract research. Recent empirical studies indicate that firms look for university research based on a combination of geographic distance and research quality as measured by bibliometric output (Laursen et al. 2011; Balland and Rigby 2017). Again three categories, based on the 33rd percentile, were constructed. Lastly, the regional location of a university is also included. The three possible regions are again the Brussels-Capital Region, Flemish Region and Walloon Region

3.3.2 Dyad level

At the dyad level, a variable is calculated that measures the distance, in kilometres, between the firm and a university, based on results from route planning software (Bing maps). These physical distances are included as a linear effect. We tested for a quadratic effect but did not obtain any significant results or improvement of the model. This finding might be attributable to the fact that distances between firms and universities are relatively small. This depends on the small size of Belgium on the one hand, but also on the poly-nucleated structure of the economy to be found in many countries, making agglomeration externalities omnipresent throughout the country (Teirlinck and Spithoven 2005).

We draw on the practice of Capello and Caragliu (2018) which capture cognitive distance by calculating the specialisation of scientific disciplines and economic sectors. Obviously, cognitive distance is the reverse of these items. To operationalise the cognitive distance between firms and universities—also a dyad level variable—we used the firm node level variable 'sector' and two university node level variables that categorises universities into predominantly specialised into the 'exact sciences' versus the 'social sciences and humanities' based on their bibliometric output by scientific discipline and R&D expenditures by scientific discipline respectively. More specific, for each university we calculated the ratio of bibliometric output or R&D expenditures in the 'exact sciences' as natural sciences, technology and engineering, medical sciences, and agricultural sciences versus their bibliometric output or R&D expenditures in the 'social sciences and humanities'. The resulting ratio is dichotomised using the 50% quantile. This procedure allows us to combine the firm- level variable for service sector and the university level variables for exact versus social sciences to calculate two categorical measurements of cognitive distance: one based on bibliometric output and one on R&D expenditures. Logically, these two variables have four categories accounting for each possible combination of the business sector (service or manufacturing) and the university's discipline specialisation (exact vs. social).

3.3.3 Network level

At the network level, we included two coefficients in the final models: edges and gwb-1degree. Edges represent the number of links present in the network and thus control for its general density. The gwb1degree parameter is the geometrically weighted degree statistics of the first mode, and helps to calculate the degree distribution of our model. This parameter can also be seen as an equivalent to the more traditional k-star statistic (Hunter 2007). The gwbdegree parameter has to be interpreted in relation to the degree parameter. It models a preferential attachment process; a positive coefficient refers to the presence of preferential attachment, and a negative indicates the opposite. The decay parameter was chosen based on the best fitting and stable model. We also tested for a gwbdegree effect in the second mode, but did not find a converging model. The same is true for a weighted dyad shared partner parameter in both modes.

4 Analytical results

Table 2 presents the results. Model 1 is the base model with control variables on the network, node and dyad levels. Model 2 includes the geographical distance, regional embeddedness and concurrent effects and Models 3a and 3b controls for cognitive distance effects. This stepwise procedure allows us to see the effects of each additional parameter on the primary effects. All models are stable and have appropriate goodness of fit statistics (see "Appendix").

In Model 1, the negative coefficient of edges indicates the tendency of the network to be less dense than an exponential random network, it captures the selectiveness of ties in the firm-university network and is an important control variable for the general structure of the network. The significant negative gwb1degree effect points to an anti-preferential attachment of firms. In general, there is no tendency in the network for well-connected firms to have additional contracts.

Further in Model 1, the node-level effects of the control variables are examined for firms. The age of a firm has no effect on its log-odds of engaging in research contracted to a university. This non-significant effect remains stable over all models. For firm size, we find no significant difference between small and micro-sizes firms to engage in contract research with a university. Medium-sized and large firms are more likely than micro firms to engage in contract research, and the estimates for large firms are twice as large (and have higher levels of significance) than those of medium sized firms. In other words, there is a U-shaped effect of firm size on the log-odds of contracting with a university. With regard to the nodal effect of the sector, the negative significant effect of the dummy for service sector indicates that firms in this sector are less likely to have a contract with a university compared with firms active in the manufacturing sector. Further, there is an expected significant and positive effect of higher levels of R&D intensity, which shows that more R&D

Table 2 Firm engagement in university contract research

Variable	Model 1 Estimated coefficient (s.e.) sign.	Model 2 Estimated coefficient (s.e.) sign.	Model 3a Estimated coefficient (s.e.) sign.	Model 3b Estimated coefficient (s.e.) sign.
Network level				
Edges	−4.286 (0.235)***	−2.475 (0.444)***	−4.668 (0.683)***	−3.307 (0.475)***
gwb1degree	−2.416 (0.183)***	−2.391 (0.251)***	−2.409 (0.246)***	−2.395 (0.227)***
Node level: firm				
Age (relative to 2009)—reference category is '6 years and older'				
< 6 years	−0.032 (0.148)	−0.105 (0.159)	−0.114 (0.164)	−0.107 (0.159)
Size—reference category is 'Micro'				
Small	−0.146 (0.136)	−0.140 (0.139)	−0.132 (0.143)	−0.102 (0.136)
Medium	0.332 (0.144)*	0.383 (0.144)**	0.377 (0.144)**	0.418 (0.136)**
Large	0.794 (0.145)***	0.824 (0.151)***	0.824 (0.150)***	0.875 (0.150)***
Sector—reference category is 'Manufacturing'				
Service	−0.608 (0.120)***	−0.763 (0.115)***		
R&D intensity—reference category is 'Low'				
Medium	0.431 (0.121)***	0.441 (0.135)*	0.449 (0.127)***	0.465 (0.128)***
High	0.629 (0.137)***	0.638 (0.154)***	0.620 (0.137)***	0.605 (0.140)***
Regional funding—reference category is 'Low'				
Medium	1.412 (0.121)***	1.537 (0.200)***	1.494 (0.212)***	1.571 (0.207)***

Table 2 (continued)

Variable	Model 1 Estimated coefficient (s.e.) sign.	Model 2 Estimated coefficient (s.e.) sign.	Model 3a Estimated coefficient (s.e.) sign.	Model 3b Estimated coefficient (s.e.) sign.
High	1.363 (0.100)***	1.432 (0.112)***	1.437 (0.103)***	1.429 (0.105)***
Region—reference category is 'Brussels-Capital Region'				
Flemish Region		− 1.406 (0.357)***	− 1.391 (0.357)***	− 1.394 (0.345)***
Walloon Region		− 1.021 (0.406)*	− 1.102 (0.198)*	− 0.996 (0.392)*
Concurrent				
Brussels Capital Region		1.807 (0.585)**	1.791 (0.566)***	1.763 (0.581)**
Flemish Region		0.309 (0.273)	0.267 (0.270)	0.298 (0.259)
Walloon Region		0.334 (0.487)	0.397 (0.475)	0.323 (0.461)
Node level: university				
Bibliometric output—reference category is 'Low'				
Medium	− 0.494 (0.349)	− 0.879 (0.414)*	0.580 (0.656)	− 0.808 (0.433)
High	− 0.094 (0.415)	− 0.492 (0.464)	2.402 (1.097)*	− 0.429 (0.505)
R&D expenditures—reference category is 'Low'				
Medium	1.202 (0.353)***	1.633 (0.464)***	0.123 (0.722)	1.529 (0.470)**
High	2.602 (0.404)***	2.835 (0.425)***	1.436 (0.630)*	2.816 (0.440)***
Region—reference category is 'Brussels-Capital Region'				

Table 2 (continued)

Variable	Model 1 Estimated coefficient (s.e.) sign.	Model 2 Estimated coefficient (s.e.) sign.	Model 3a Estimated coefficient (s.e.) sign.	Model 3b Estimated coefficient (s.e.) sign.
Flemish Region		−2.209 (0.456)***	−2.334 (0.437)***	−2.258 (0.435)***
Walloon Region		−0.943 (0.312)**	−0.707 (0.307)*	−0.931 (0.340)**
Dyad level: distance				
Distance (km)		−0.011 (0.002)***	−0.011 (0.002)***	−0.011 (0.002)***
Dyad level: regional embeddedness				
Brussels Capital Region		−0.755 (0.430)	−0.805 (0.411)	−0.762 (0.421)
Flemish Region		2.972 (0.355)***	2.979 (0.344)***	2.987 (0.346)***
Walloon Region		1.822 (0.385)***	1.849 (0.358)***	1.832 (0.354)***
Dyad level: Cognitive distance (CD) in terms of bibliometric output				
CD—reference category is ‘Firm in services and university in social sciences’				
Firm in manufacturing and university in social sciences		0.880 (0.148)***		
Firm in manufacturing and university in exact sciences		2.339 (0.526)***		
Firm in services and university in exact sciences		1.800 (0.560)**		
Dyad level: cognitive distance (CD) in terms of R&D expenditures				
CD—reference category is ‘Firm in services and university in social sciences’				
Firm in manufacturing and university in social sciences			0.794 (0.181)***	

Table 2 (continued)

Variable	Model 1 Estimated coefficient (s.e.) sign.	Model 2 Estimated coefficient (s.e.) sign.	Model 3a Estimated coefficient (s.e.) sign.	Model 3b Estimated coefficient (s.e.) sign.
Firm in manufacturing and university in exact sciences			0.783 (0.204)***	
Firm in services and university in exact sciences			0.092 (0.255)	
Deviance statistics				
AIC	3821	3507	3494	3509
BIC	3960	3742	3747	3762
Null deviance	63,146 (df = 45,550)	63,146 (df = 45,550)	63,146 (df = 45,550)	63,146 (df = 45,550)
Residual deviance	3789 (df = 45,534)	3453 (df = 45,523)	3436 (df = 45,521)	3451 (df = 45,521)

*Significant at 5%; **significant at 1%; ***significant at 0,1%

intensive firms are significantly more likely to engage in contracting research to a university compared to low R&D intensive firms (Spithoven and Teirlinck 2015). This significance is, again, robust over all models. Finally, firms receiving more regional funding are significantly more likely to engage in contract research with universities.

With regard to the node-level effects for universities, the bibliometric output of the university has no effect on the likelihood of firms contracting research to universities. However, the size of universities in terms of their average annual R&D expenditure does exert an effect. The higher this expenditure, the more likely a university is to have a research contract with a firm, because larger universities have greater repositories of (saleable) knowledge.

Model 2 adds three parameters: the administrative region, the regional embeddedness effect, and the physical distance in kilometres. Model 2 shows that, at the node firm level, firms located in the Flemish Region are significantly less engaged in contract research with universities compared with firms in the Brussels-Capital Region. From a policy viewpoint, the regional institutional thickness in the Flemish Region differs from that in the Brussels-Capital Region. Policy in the latter region is only responsible for the business sector, due to the state structure of Belgium in which the universities pertain to either the Flemish or French-speaking communities. Accordingly, the Brussels-Capital Region has a government R&D budget of only 1.3% of the Belgian total (Belgian Science Policy Office 2016). Cooke et al. (1997) explicitly refer to these budgets as leverages in mobilising innovative resources. As discussed in Sect. 2.2, the regional innovation system in Brussels differs considerably from that of the other regions. First, the share of overall R&D expenditure in the Brussels-Capital Region is 11.4%, compared with 60.7% in the Flemish Region and 27.9% in the Walloon Region. Second, the ratio of business R&D to non-business R&D is the lowest in the Brussels-Capital Region (1.01, which implies that business R&D and non-business R&D are equally important), whereas the other regions are more business oriented. The ratio in the Flemish Region amounts to 2.49 and is 4.56 in the Walloon Region (Belgian Science Policy Office 2016). It is against this background of the regional innovation system that the empirical findings of Model 2 must be seen. Contract research in the Flemish Region, controlling for all other variables in Model 2, is less likely to occur than in the Brussels-Capital Region because of the presence of alternative knowledge exchange channels that are publicly supported. A similar argument exists for the significant negative estimated coefficients when the node level is the university. In this case, universities in the Walloon Region are also less likely to develop contract research relationships with firms compared with the Brussels-Capital Region. Therefore, hypothesis 1 is rejected, and more innovative regions do not necessarily have a higher likelihood of firms to have contract research with universities than less innovative regions.

Second, again in Model 2, the dyad level effect of regional embeddedness captures the fact that firms and universities develop contract relationships in the same region. The positive significant regional embeddedness effect for the Flemish Region indicates that firms located there are significantly more likely to engage in contract research with a university in that same region, and the same is true for the Walloon region although the odds are somewhat lower. Hence, hypothesis 2 is supported for the Flemish Region and Walloon Region, but not for the Brussels-Capital Region. Brussels is smaller in terms of R&D expenditures and less developed when it comes to policy instruments as proxied by the government R&D budget. Even though the Brussels-Capital Region—which is quite limited in size (i.e. 161 km^2)—has three universities, these are not the largest ones in Belgium and one of them had no contract research. This might explain why firms located in Brussels do not exclusively direct their contract research to these universities and often delegate it to extra-regional universities. In this regard, the Brussels-Capital Region can, therefore, be characterised as a 'fragmented metropolitan region' (Tödtling and Trippl 2005).

Finally, Model 2 also includes concurrent effect parameters for the variable ‘region’. These parameters capture the likelihood of a firm having two or more contracts with a university, by the regional location of the firm. The positive significant concurrent effect of the Brussels-Capital Region, therefore, indicates that a firm located in this region is more likely than expected in an Exponential Random Graph Network to have two or more contracts with a university. This means that, in the Brussels Capital Region, a firm that has a contract with a university has a strong tendency to have more than one contract. This finding reflects the particular institutional thickness of the metropolitan Brussels-Capital Region (Tödtling et al. 2011). Again, this corroborates earlier findings and points to the need for firms in the Brussels-Capital Region to look for additional relevant knowledge. There are no significant concurrent effects for the other two regions.

Third, the dyad-level variable measuring the physical distance between firms and universities has a negative significant estimate, which indicates that controlling for all other variables in the model, the further away a firm is located from a university, the less likely it is for that firm to engage in contract research with that university. Therefore, hypothesis 3 is supported.

To expand the analysis, we constructed a third model that includes the effect of cognitive distance between firms and universities. Cognitive distances are expected to compensate for the geographic distances between universities and firms (Davids and Frenken 2018; Capello and Caragliu 2018). The model includes all the variables discussed above, except the main node level effect for the firm sector. Because the main sector-level effect and the cognitive distance effects are two highly related things, including both at the same time leads to multicollinearity problems and, consequently, a non-converging model. Therefore, Model 3a and Model 3b tests for cognitive distance based on bibliometric output specialisation and R&D expenditures specialisation of the university separately. Again, because these two different cognitive distance measurements are highly related, multicollinearity issues prevents their joint inclusion in one model.

Results of Model 3a and Model 3b show how cognitive distance significantly influences the likelihood of having a contract between firm and university. Model 3a looks at the cognitive distance in terms of bibliometric specialisation. Using the reference category of firms active in the service sector combined with universities that focus on disciplines in the social sciences and humanities, firms active in manufacturing in combination with universities specialised in social sciences are less likely to engage in contract research. Manufacturing firms in combination with universities specialised in the exact sciences are more likely to engage in contract research in comparison to the reference category. The same goes for firms active in the service sector when combined with universities in specialised in the exact sciences. However, the impact on geographical distance on the likelihood of firms to engage in contract research with universities does not change. Model 3b serves as a robustness check, and uses the specialisation in terms of their R&D expenditures. Manufacturing firms, irrespective of the specialisation of universities, are less likely to be engaged in contract research when compared to the reference category of firms in the services combined with universities specialised in the social sciences and humanities. These results show that cognitive distance plays a role in the probability of firms to engage in contract research with universities. The results in both models show no change in the impact of geographic distance and regional impacts. We therefore accept hypothesis 4 and conclude that, in the case of contract research between firms and universities, cognitive distance complements geographic distance.

5 Conclusions and recommendations

University-business relationships come in many shapes and forms. This research focuses on contracts by firms to acquire university research results, use university equipment, or get punctual assistance on technical solutions. It has been demonstrated in existing empirical literature that contract research is often used by firms (Schartinger et al. 2002; Perkmann et al. 2013), but the key determinants of engaging in this have been investigated to a much lesser extent. This paper looks at the impact of geographical distance and regional characteristics to gain insights on the likelihood of firms to contract research out to universities.

The empirical analysis started from a unique database created through a micro-linking exercise based on the R&D survey for firms and a similar one for universities. This unique database contains detailed information on many potential aspects influencing the likelihood of engaging in contract research and academic counselling by firms with universities.

Based on the literature grounded in economic geography, technology transfer and knowledge exchange, four distinct hypotheses are examined. First, the analysis in terms of administrative regions shows that the likelihood of engaging in contract research by firms with universities differs across regions, but it is not the most innovative region that shows the highest likelihood. This is because regions are endowed with varying institutional thickness that offers a framework in which contract research linkages are formed. Therefore, the analysis finds that firm-university contracts in the Flemish Region and Walloon Region are less likely when compared to the multi-lingual Brussels-Capital Region. Also, the firms located in this last region maintain more than one contract with universities, which are not necessarily located in its own region. This might be related to the fact that regions, using different support schemes in line with their budgetary capacities (Tödtling and Trippl 2005), also support firm-university linkages through regional funding, which proved to have a positive impact on the likelihood to engage in contract research.

Second, the analysis using the dyad level of regional embeddedness showed that firms located in the same region as universities have a greater likelihood to engage in contract research. This is not the case for the Brussels-Capital Region notwithstanding the fact that it hosts three universities in its small region. Geographical distance alone is, therefore, only part of the explanation, and firms are looking for relevant knowledge wherever it can be found, which is in line with Broström (2010) or Spithoven and Teirlinck (2015), but not too far away either.

Third, the continuous geographical distance between firms and universities shows that the increasingly questioned idea that limited distances between these organisations result in a higher likelihood to engage in contract research.

The literature stressed that geographical distance must be jointly considered with cognitive distance (Capello and Caragliu 2018; Davids and Frenken 2018). Therefore, the analyses used two different operationalisations based on firm-sector and university-specialisation, and found that, although the two measures have different impacts on the likelihood to engage in contract research, they do not alter the previous findings on geographical distance and regional impacts which prove robust.

Popular policy discourses predominantly rest on the positive impact of university research for regional development (OECD 2007). In academic literature, estimations of this impact often depend on the knowledge exchange mechanism involved. Here, the commercialisation of university research becomes a key issue (Rothaermel et al. 2007). Further, knowledge exchange often evolves around some notion of 'stickiness' of knowledge due to the tacit content (Asheim and Isaksen 2002; Power and Malmberg 2008). However, some recommendations for policy can be formulated.

First, most policy agents in regional innovation systems have developed instruments to facilitate knowledge flows. However, the uptake of these measures by economic actors differs across the systems (Tödtling and Trippl 2005). Because regions are studied through the lens of innovation systems, the system failure argument is increasingly used in framing adapted policy recommendations (McCann and Ortega-Argilés 2013). Regional policy could support measures targeting knowledge exchange and networking possibilities in general. Facilitating the exchange of university research results to firms might enhance the ability to redefine their technological structure or reduce the risk of regions running into lock-in problems. Policy should pay increased attention to aligning agencies and incentive structures to spur all forms of knowledge exchange, including contract research. It would be equally relevant to focus on the technological strengths of regions by investigating the benefits of smart specialisation strategies. The emphasis lies on funding academic excellence with critical mass (Power and Malmberg 2008). The results presented in this paper therefore induce some critical view on policies that are overly directed at their region. This is especially the case for the small-sized, less endowed and institutionally-thinner regional innovation systems as exemplified by the Brussels-Capital Region.

Second, policy actions might be undertaken to spur on R&D activities in firms. Even though the regional funding of firms is treated only as a control variable in the analysis, it cannot be neglected that higher percentages have a positive impact on the likelihood of firms to engage in contract research. Policymakers are aware of the multiple paths through which university research fulfils business needs, and contract research is only one of these.

Inevitably, the research has some limitations. First, we remain silent on the importance of contract research in terms of the budgets involved. Taking this into account might yield other results, because extra-regional or international relationships with universities might be less likely to occur, but might involve larger contract amounts and be of more value to the firms. Second, the two-mode ERGM analysis currently does not allow for the use of continuous independent variables. The decisions made on categorising the continuous variables might have an impact on the results, as different cut-off points can lead to different effect sized. Ideally, in future, continuous variables should be used to estimate linear relations. However, we explored different cut-off options for all the categorical variables, and the effects are robust. And, on the other side, the use of dummy variables also allows to detect non-linear effects. Which, in our case, is true for business size, a u-shaped effect we were able to detect thanks to the categorical independent variable.

Based on our findings and the limitations of our research, several avenues for further research inevitably open up. The paper focuses on contract research between firms and universities. There is ample scope for study here, because first, many other relationships between these two actors in the regional innovation system exist, such as R&D co-operation, informal networking relationships and student exchanges, which might also interfere with the likelihood of firms contracting research to universities. Second, firms preferring to engage in contract research might also envisage other knowledge-intensive players in the innovation system, such as public research organisations targeting their research efforts on one specific domain (e.g. biotechnology or health services), and therefore have a greater critical mass of knowledge and research results available to firms. Third, our focus at the national level through three regional innovation systems blurs our understanding of the extra-regional linkages, which might be relatively important in small, open economies (Grillitsch and Trippl 2014). Fourth, the paper complemented geographical distance with institutional and cognitive distance, but did not consider the cultural aspects that might be relevant in cases of multi-linguistic countries. Also the other dimensions in the proximity literature might be added to compose a more complete picture. Finally, our analytical results would be further strengthened by including the concordance between the scientific disciplines that universities are specialized in and the economic sectors of the firms engaging in contract research. This could be done by including the citation frequencies between the technology classes present in patent data and scientific disciplines classifications present in publication data.

Appendix: examining model fit

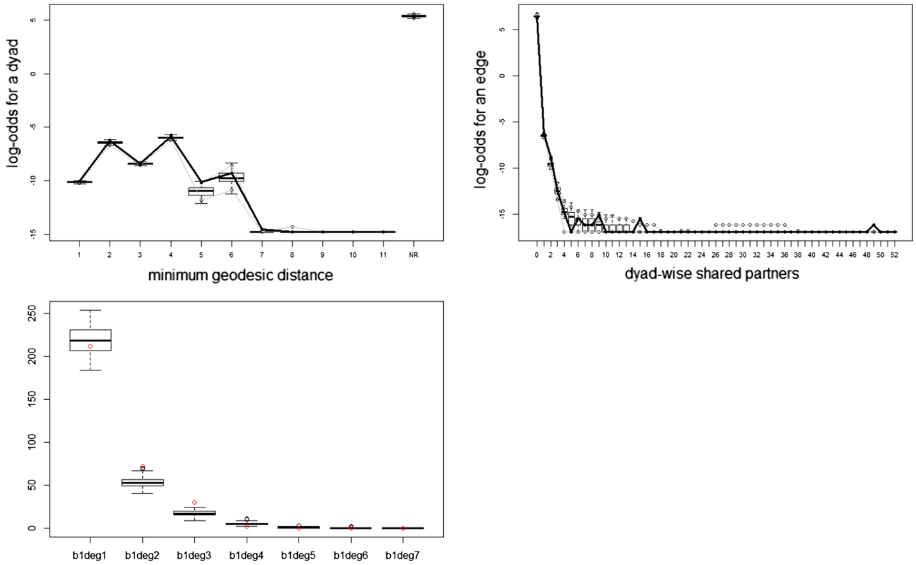
As a first goodness-of-fit check, we compare the statistics of simulated networks of the model against the observed network in below table. Note that *p* values closer to one are better (Goodreau et al. 2008; Lusher et al. 2013).

Variable	Model 1 *p* value	Model 2 *p* value	Model 3a *p* value	Model 3b *p* value
Network level				
Edges	0.90	0.88	0.74	0.90
gwb1degree	0.88	0.84	0.78	0.88
Node level: business				
Age (relative to 2009)				
< 6 years	0.98	0.76	1.00	0.88
≥ 6 years (ref)				
Size				
Micro (ref)				
Small	1.00	0.94	0.96	0.92
Medium	1.00	0.88	0.74	0.78
Large	1.00	0.96	0.82	0.86
Sector				
No service (ref.)				
Service	1.00	0.80		
R&D intensity				
Low (ref.)				
Mid	0.78	0.82	0.86	0.88
High	0.78	0.94	0.92	0.93
Subsidized				
Low (ref.)				
Mid	1.00	0.86	0.98	0.74
High	0.64	0.70	0.58	0.78
Regio (nuts1)				
Brussels Capital Region (ref.)				
Flemish Region		0.76	0.94	0.88
Walloon Region		1.00	0.86	0.98
Concurrent				
Brussels Capital Region		1.00	0.76	1.00
Flemish Region		0.72	0.80	0.84
Walloon Region		1.00	0.90	1.00

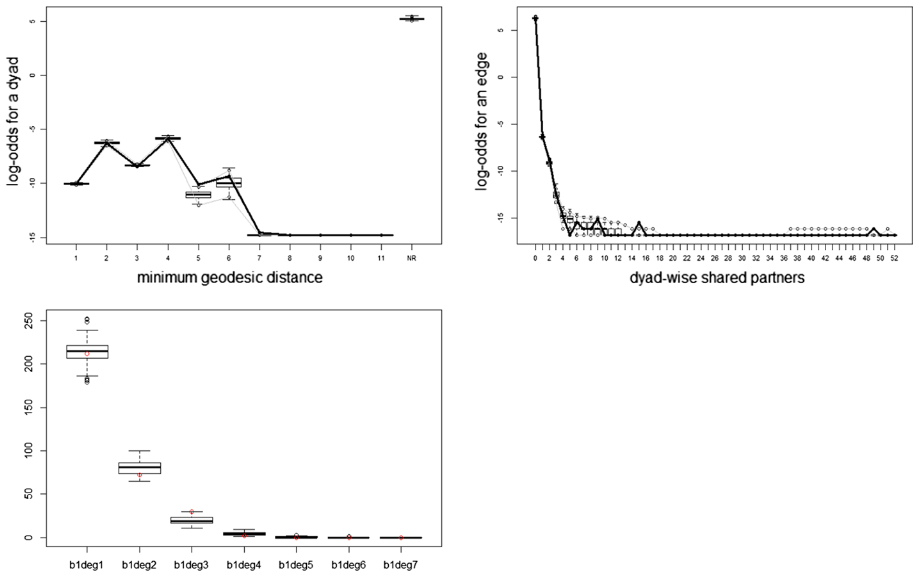
Variable	Model 1 *p* value	Model 2 *p* value	Model 3a *p* value	Model 3b *p* value
Node level: university				
Bibliometric quality				
Low (ref.)				
Mid	1.00	0.96	0.98	1.00
High	0.90	0.86	0.84	0.94
R&D expenditures				
Low (ref.)				
Mid	0.96	1.00	0.94	1.00
High	0.74	0.82	0.82	0.96
Regio (nuts1)				
Brussels Capital Region (ref.)				
Flemish Region		0.80	0.92	0.98
Walloon Region		1.00	0.82	0.98
Dyad level				
Regional embeddedness				
Brussels Capital Region		0.90	0.86	0.90
Flemish Region		0.96	0.96	0.92
Walloon Region		0.72	0.96	0.96
Distance (km)	0.88	0.82	0.96	
Cognitive distance based on bibliometric specialization				
0 Firm in services—University in social sciences (ref.)				
1 Firm in manufacturing—University in social sciences			0.70	
2 Firm in manufacturing—University in exact sciences			0.76	
3 Firm in services—University in exact sciences			0.96	
Cognitive distance based on R&D specialization				
0 Firm in services—University in social sciences (ref.)				
1 Firm in manufacturing—University in social sciences				0.92
2 Firm in manufacturing—University in exact sciences				0.96
3 Firm in services—University in exact sciences				1.00

A second typical GOF check for ERGMs is comparing a selection of network statistics of the simulated networks with the observed network. The network statistics do not necessarily have to present a predictor in the model itself. Below we plot the distribution of minimum geodesic distance, dyad-wise shared partners on the log-odds scale and degree for mode 1 (Morris et al. 2008). All plots show that the GOF of our models is at least reasonable.

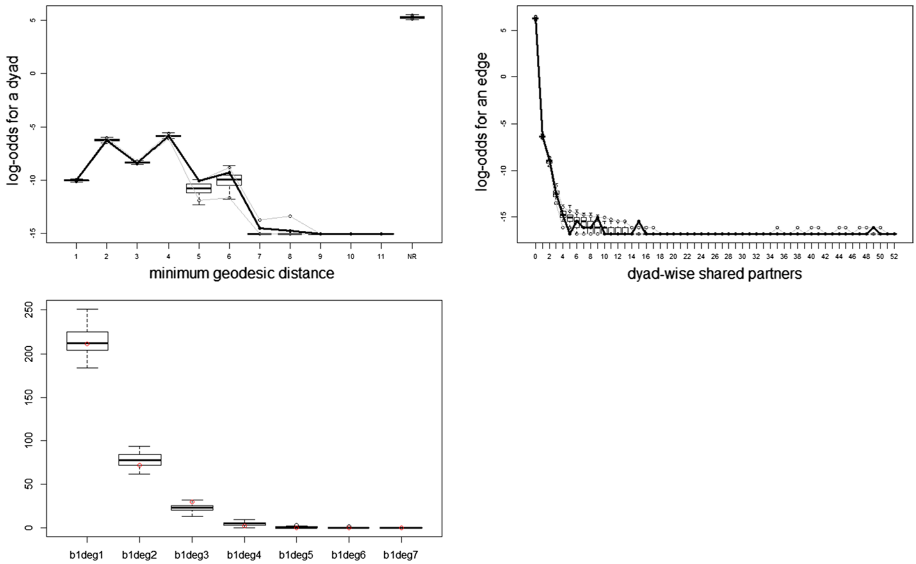
Model 1 GOF plots



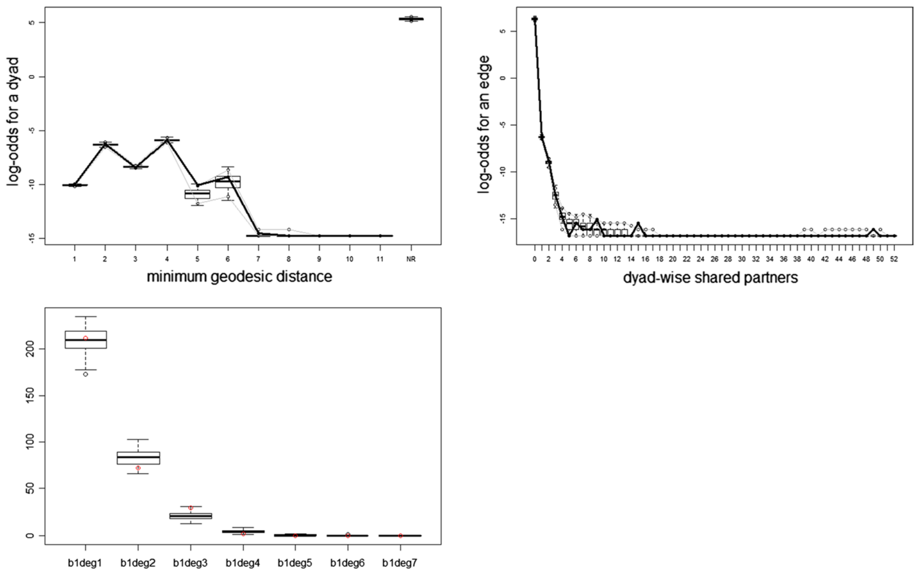
Model 2 GOF plots



Model 3a GOF plots



Model 3b GOF plots



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