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ORIGINAL PAPER

Innovation in peripheral regions: Do collaborations compensate for a lack of local knowledge spillovers?

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Abstract It is widely accepted that firms in peripheral regions benefit to a lesser extent from local knowledge spillovers than firms located in agglomerations or industrial clusters. This paper investigates the extent to which innovative firms in peripheral regions compensate for the lack of access to local knowledge spillovers by collaborating at other geographical scales. So far, the literature predominantly suggests that collaborations *complement* rather than *compensate for* local knowledge spillovers. Using data on the collaboration patterns of innovative firms in Sweden, this paper provides evidence that firms with low access to local knowledge spillovers tend to collaborate more. This effect, however, depends on firm size and in-house capabilities. Our findings suggest that firms with strong in-house capabilities do indeed compensate for a lack of local knowledge spillovers with collaborations while firms with weaker in-house capabilities depend more on the regional knowledge infrastructure.

JEL Classification R10 · R11 · O30 · O31 · O18 · P48

1 Introduction

Innovation is a knowledge-driven process, which relies on both internal competencies of firms and access to external knowledge sources. While external knowledge can be

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acquired on different spatial scales, there are strong theoretical arguments as to why geographical proximity is important for knowledge transfer. These arguments build on the acknowledgment of the partly tacit nature of knowledge (Malmberg and Maskell 1999, 2006; Polanyi 1958), the embeddedness of knowledge in a sociocultural and institutional context (Gertler 2003, 2004), the importance of social networks (Granovetter 1973, 2005) as well as local labor mobility (Agrawal et al. 2006; Breschi and Lissoni 2009). Empirical evidence confirms a strong spatial dimension of knowledge spillovers (Anselin et al. 1997; Audretsch and Feldman 1996; Jaffe et al. 1993). The importance of local knowledge spillovers and localized learning is therefore often used for explaining the positive effects of agglomerations and clusters (Malmberg and Maskell 1999, 2006).

Innovative firms situated in the knowledge periphery, i.e., in areas with a limited knowledge infrastructure, are less likely to experience the benefits associated with local knowledge spillovers than firms located in agglomerations or clusters with a highly developed knowledge infrastructure. In principle, firms in such peripheral regions can compensate for a lack of local knowledge spillovers by collaborations with non-local actors. Such collaborations establish an organizational framework through which interactive learning also with distanciated partners is facilitated (Lagendijk and Lorentzen 2007; Tödtling et al. 2006; Trippl et al. 2009). This paper aims to investigate whether collaborations with non-local actors can compensate for a lack of local knowledge spillovers, more specifically, to what extent innovative firms in knowledge peripheries collaborate more on different geographical scales than firms in non-peripheral regions.

This question is fundamental if we maintain the theoretical propositions that (1) innovation is essentially a collective process where firm-internal knowledge is combined with firm-external knowledge and that (2) local knowledge spillovers play an important role to access firm-external knowledge. So far, however, the literature predominantly suggests that collaborations *complement* rather than *compensate for* local knowledge spillovers (e.g., Bathelt et al. 2004; Camagni 1995; Cooke 2002). The complementary character mainly benefits firms in clusters and agglomerations where local knowledge spillovers exist and where firms arguably also have greater opportunities to collaborate. However, few studies investigate whether collaborations can also compensate for a lack in local knowledge spillovers. Notwithstanding some exceptions (Fitjar and Rodríguez-Pose 2011; Tödtling et al. 2012), there is a dearth of systematic empirical evidence on this question.

This paper is structured as follows: In Sect. 2, which covers the theoretical background, we will discuss the importance of geographical proximity for knowledge spillovers. We will elaborate on the implications for firms in peripheral regions and argue that collaborations with non-local actors can be a compensation for lacking local knowledge spillovers. In Sect. 3, we describe the empirical strategy as well as the indicators used. This paper combines data about collaborations of 2,261 innovative firms in Sweden from the 2008 Community Innovation Survey with microdata for firms and individuals provided by Statistic Sweden. This microdata allow to measure opportunities for knowledge spillovers as well as firm-internal innovation relevant knowledge. The results are presented in Sects. 4 and 5 concludes the paper.

2 Theoretical background

The opportunities and abilities of firms to identify, access, and use knowledge from outside the organization is a central theme in innovation studies. The literature distinguishes between purpose-built, formalized collaborations and knowledge spillovers (Bathelt et al. 2004). The latter emphasize non-formal knowledge flows, typically among collocated actors. In this chapter, we first elaborate on the key arguments why geography affects knowledge spillovers. Following this, we discuss the theoretical and empirical grounds for knowledge exchange with non-local actors. We, thereupon, analyze the implications of this line of reasoning for firms in peripheral regions and why firms potentially use collaborations to compensate for lacking opportunities of local knowledge spillovers.

2.1 Local knowledge spillovers

The acknowledgment of local knowledge spillovers goes back to classical works in economics. In his seminal work, Marshall (1920) highlights the importance of external economies arising from co-location, including the development of shared knowledge and trust. Still today, there is an ongoing debate, fueled partly by the rise of modern information and communication technologies, on the reasons why geographical proximity matters for innovative firms (Bathelt et al. 2004; Breschi and Lissoni 2001). According to this debate, knowledge spillovers can be explained by a variety of factors such as the tacit dimension of knowledge, the institutional embeddedness of actors, social networks, labor mobility and different dimensions of proximity.

One important theoretical foundation for local knowledge spillovers has to do with the notion of "localized learning" and the partly tacit nature of knowledge (Malmberg and Maskell 2006; Maskell and Malmberg 1999). The acknowledgment of tacit knowledge rests on Polanyi's seminal contribution (1958) that, simply put, argues that not all knowledge is codifiable and that the transfer of tacit knowledge (i.e., un-codifiable knowledge) requires learning by interacting, doing and practice. Tacit knowledge is thus more difficult to transfer over distance (Lam 2000). Furthermore, even for knowledge that is in principle possible to codify, there are costs associated with the process of codification. This implies that tacit and uncodified knowledge is not ubiquitously available and can thus be an important source for competitive advantage of firms and regions (Malmberg and Maskell 1999). Maskell and Malmberg summarize that:

> [t]he proximity argument is twofold. First, it is related to the 'time geography' of individuals. Everything else being equal, interactive collaboration will be cheaper and smoother, the shorter the distance between the participants. The second dimension is related to proximity in a social and cultural sense. To communicate tacit knowledge will normally require a high degree of mutual trust and understanding, which in turn is related not only to language but also to shared values and 'culture' (Maskell and Malmberg 1999, p. 180).

Gertler (2003, 2004) takes the second argument further and suggests that the concept of tacit knowledge has frequently been used in a too literal sense focussing

mainly on the cognitive dimension of knowledge and argues that tacit knowledge is often embedded in a social, cultural and institutional context. He provides an example of producers of advanced machinery in Germany operating under the assumption that their clients have a long-term time horizon in utilizing the equipment, retaining their workforce and providing them with a high degree of training and education. Interactive learning at the producer–user interface is appreciated leading to strong problem-solving competencies within the clients' organizations. Only when entering a market with a different institutional architecture like the US or China, German producers have become aware that the tacitly held assumptions, work routines, ways of collaborating and interactive learning depend on the social, cultural or institutional context. Taken out of the context, tacit knowledge may therefore loose significantly in value.

A related but still conceptually different argument is the role of social networks in the learning process. Information and knowledge (both tacit and codified) is exchanged more freely through social networks (Granovetter 1973, 2005). Furthermore, the costs associated with identifying and accessing knowledge and information is reduced when this is done through social networks (Gertler 2003). Social networks, and the institutional arrangements that often follow, are also important for generating trust and punishing opportunistic behavior (Bachmann and Inkpen 2011; Gulati and Sytch 2008). This in turn increases the willingness to exchange information and knowledge.

As regards the geography of social networks, Agrawal et al. (2006) offers interesting insights insofar as they suggest that co-location is important to establish social relationships; once a social relationship is established, however, it often maintains even if actors move to a different location (cf. Nilsson and Mattes 2013). Basing their analysis on co-citations of patents, they provide empirical evidence that a social relationship increases the likelihood of knowledge flows with the former location. Even more interesting, they show that co-location is more important for sharing knowledge between different scientific areas than within only one area. As it is often the combination of different types of knowledge that is the source of more radical innovations (Asheim et al. 2011; Grillitsch and Trippl 2013; Strambach and Klement 2012), this provides a further argument for the importance of geographical proximity especially for more novel innovation activities.

Another core argument for the importance of geographical proximity relates to the flow of people between different organizations. Breschi and Lissoni (2009, p. 460) argue that "[t]he fundamental reason why we observe geographical localization of patent citations is the low propensity of a special category of knowledge workers and providers of knowledge-intensive services (the inventors) to relocate in space." Similar to the study of Agrawal et al. (2006), Breschi and Lissoni find that inventors moving between different organizations are important carriers of knowledge and key facilitators of knowledge exchange between organizations. The finding that labor mobility is bounded in space also introduces a spatial bias for social networks and information exchange, and thus further supports the argument that geographical proximity to firm-external knowledge sources matters. Also recent case studies provide evidence that external knowledge sourcing in the form of recruitment predominantly occurs at the regional scale (Grillitsch et al. 2013; Plum and Hassink 2013).

2.2 Non-local knowledge transfer

There are ample arguments why geographical proximity supports interactive learning and knowledge exchange in innovative firms. However, this does not mean that interactive learning and knowledge exchange is not possible over longer distance. Boschma (2005, p. 62) argues that there are different forms of proximity and that "geographical proximity per se is neither a necessary nor a sufficient condition for learning to take place: at most, it facilitates interactive learning, most likely by strengthening the other dimensions of proximity." Hence, he argues that other forms of proximity can substitute for geographical proximity (cf. Knoben and Oerlemans 2006). Interactive learning over distance can be organized by a variety of forms such as temporary work teams, collaborations, strategic alliances, and other forms of global networks (Amin and Cohendet 2005; Powell et al. 1996). Furthermore, empirical evidence provides support for the relevance of extra-regional knowledge sources from different types of regions (Chaminade 2011; Gertler and Levitte 2005; Owen-Smith and Powell 2004; Saxenian 2006; Saxenian and Hsu 2001; Tödtling et al. 2012; Trippl et al. 2009). For instance, in an empirical study covering seven European countries and 15 case studies, it has been shown that extra-regional knowledge sources are highly relevant and that their importance depends on the regional and national innovation systems in which firms are embedded, the dominating knowledge sources of the industry as well as the type of innovation that firms engage in (Tödtling and Grillitsch 2012).

Most studies, however, consider extra-regional knowledge sourcing as complementary to local knowledge sourcing. Bathelt et al. (2004, p. 42) differentiate between local buzz and global pipelines and hypothesize that local buzz "generates opportunities for a variety of spontaneous and unanticipated situations where firms interact and form interpretative communities" while global pipelines complement local buzz by the integration of multiple environments that open "different potentialities and feed local interpretation and usage of knowledge hitherto residing elsewhere." Also, the literature on innovative milieus emphasizes the complementary nature of external knowledge links (Camagni 1995; Crevoisier 2004; Maillat 1998).

> The link-up with external energy is crucial […]. Autarchy in a cultural and technological sense and a sole reliance upon local entrepreneurial capabilities are definitely mistakes in the long run. This is due to the limited reaction capability and competitiveness of any small area in the face of massive international evolutionary processes. (Camagni 1995, p. 324).

Equally, the contributions on regional innovation systems highlight that localized learning between different actors engaged in knowledge exploration and exploitation as well as policy actors fosters innovativeness but that this is not enough. Firms frequently complement and combine knowledge available regionally with knowledge acquired from more distanciated sources (Asheim and Coenen 2006; Cooke 2002; Isaksen 2001; Tödtling et al. 2006; Trippl 2011).

2.3 Implications for firms in peripheral regions

The literature reviewed above suggests that innovation depends to a large extent on firms' abilities and opportunities to access firm-external knowledge. Also, the literature suggests that local knowledge spillovers, which refer to different mechanisms such as informal knowledge transfer or labor mobility, play an important role for accessing firm-external knowledge. Local knowledge spillovers are often complemented with knowledge from non-local actors. Several scholars have raised the argument that firms located in clusters and agglomerations with high opportunities for local knowledge spillovers should also find it easier to access knowledge from non-local actors (Bathelt et al. 2004). Following this line of argument, firms in peripheral regions face a double disadvantage of (1) lower opportunities for local knowledge spillovers and (2) higher difficulties of accessing knowledge from non-local actors.

If we maintain the theoretical proposition that firm-external knowledge is important for innovations, the crucial question for firms in peripheral regions is whether they can compensate for lacking local knowledge spillovers by entering collaborations with non-local partners. Once established, collaborations with non-local actors provide an organizational framework, i.e., create organizational proximity, which enables the exchange of knowledge and interactive learning (Lagendijk and Lorentzen 2007). While there are different ways of accessing knowledge over distance including for instance reading industry literature, attending conferences and trade fairs, etc. (Maskell 2014), collaborations allow for the highest degree of interactive learning and transfer of (also tacit) knowledge (Tödtling et al. 2006; Trippl et al. 2009). In addition to representing usually formalized conduits for knowledge transfer, collaborations are also considered as an indicator of informal networks. Informal networks facilitate the establishment of collaborations and remain after formalized collaborations have ended (Owen-Smith and Powell 2004). In line with these arguments, Johansson and Quigly (2004, p. 175) argue that:

> [w]hen co-location is infeasible, networks may substitute for agglomeration. This possibility of substitution means that small regions may survive and prosper – to the extent that networks can substitute for geographically proximate linkages, for local diversity in production and consumption, and for the spillouts of knowledge in dense regions.

In other words, peripheral regions are characterized by a weaker supply of local knowledge spillovers than core regions. Such a lack of spillovers can potentially be compensated for by entering into collaborations with distant actors. While, following the above logic, firms in peripheral regions can be expected to have a higher demand for collaborations than firms in core regions, the ability to initiate and benefit from collaborations varies between firms. Most notably, the absorptive capacity of a firm greatly influences its ability to identify, internalize and use knowledge from external sources (Cohen and Levinthal 1990). The main source of absorptive capacity is the level of similar or related competencies within the organization. Furthermore, the attractiveness of firms as collaboration partners depends on their internal competencies and reputation (Ter Wal and Boschma 2011). This implies that among the firms

located in the knowledge periphery, those with a strong absorptive capacity are more able to form collaborations and thereby compensate for a lack of local knowledge spillovers.

Conceptually, it is important to differentiate between the need of firms located in the knowledge periphery to compensate for a lack of local knowledge spillovers and the need of firms in general to compensate for a lack of internal competencies. In general, firms with less in-house competencies are expected to have a higher need to complement their in-house competencies. At the same time, such firms will also have lower abilities and possibilities to establish and draw advantage from collaborations than firms with high in-house competencies. In order to compensate for a lack of firm-internal competencies, firms can potentially use both local knowledge spillovers and collaborations. As local knowledge spillovers are less demanding and exclusive than collaborations, it can be argued that firms with low internal competencies will find it easier to compensate for lacking internal competencies through local knowledge spillovers than through collaborations. This implies that it will be more important for firms with low internal competencies to be located in knowledge-rich regions in order to access firm-external knowledge.

Empirical evidence about the possible compensation of a lack of access to local knowledge spillovers with collaboration is scarce. Tödtling et al. (2012), for instance, find that ICT firms in a peripheral region in Austria use more international knowledge sources than ICT firms located in the capital region of Vienna and the large industrial region of Upper Austria. Hence, there is some evidence that firms located in peripheral regions can—at least to some extent—compensate lacking regional knowledge sources with non-local collaborations. However, more systematic empirical analyses are required to address this paper's research question.

3 Empirical strategy

The empirical strategy of this paper aims to investigate whether innovative firms located in the knowledge periphery collaborate more on different geographical scales than firms located in non-peripheral regions. This would indicate that innovative firms in peripheral regions use collaborations to compensate for the lack of opportunities to access firm-external knowledge through local knowledge spillovers. Furthermore, the paper investigates whether there are differences between innovative firms as it can be expected that firms with higher internal capabilities are more able to engage in collaborations as a compensation for local knowledge spillovers. Innovative firms are identified with data from the Community Innovation Survey 2008 (CIS). The analysis is done for all firms engaged in innovation activities, regardless whether these activities have already led to the introduction of innovations, are still ongoing or were abandoned. These data are merged with firm-level and individual-level register data from Statistics Sweden. Information on the dependent and independent variables as well as on controls is provided below (see also descriptive statistics and correlations in "Appendix").

Table 1 Collaborating firms

Collaborations	Nr	%
Overall	1,034	46
National	980	43
Foreign	758	34
Global	443	20
Total	2,261	100

3.1 Dependent variable

The dependent variable captures collaborations between organizations in relation to innovation activities.[1] The CIS provides information on whether the surveyed firms have collaborated actively with other organizations on innovation activities during a given period (here 2006–2008). The firms are then asked to specify at what geographical scale these collaboration partners are located. The following binary dependent variables are used:

- Firms that collaborated (yes/no)
- Firms that collaborated with national partners (yes/no)
- Firms that collaborated with foreign partners (incl. outside Europe) (yes/no)
- Firms that collaborated with partners outside Europe (yes/no)

The analysis is conducted on 2,261 firms that have engaged in activities related to product or process innovations. Table 1 shows the number and share of innovative firms that have collaborated by geographical scale. Forty-six percent of the firms have collaborated. Forty-three percent collaborated at the national scale, 34 % with partners outside Sweden and 20 % with partners outside Europe.

3.2 Independent variable

The independent variable measures the access firms have to local knowledge spillovers (accessibility). This subsection first describes how relevant knowledge for product and process innovations is measured and in a second step elaborates on how accessibility is modeled.

The measure for knowledge aims at capturing knowledge relevant for generating technological innovations. This is because the questions on collaborations, i.e., the dependent variables, relate only to product and process innovations, which are described in the CIS survey predominantly as technological innovations.[2] The study

[1] The CIS formulates the following question: "During the three years 2006 to 2008, did your enterprise co-operate on any of your innovation activities with other enterprises or institutions? Innovation co-operation is active participation with other enterprises or non-commercial institutions on innovation activities. Both partners do not need to commercially benefit. Exclude pure contracting out of work with no active cooperation".

[2] Marketing, design and organisational innovations are covered in a different section in the CIS. The data on innovation collaborations only relate to product and process innovations.

draws on occupational and educational data for individuals in order to identify individuals with high technological competencies. The use of occupational data has several advantages: It refers to the type of work that individuals are actually performing (as opposed to e.g., educational data, which is often outdated). Furthermore, the occupational classifications relate to skills that are normally required to perform that type of work. The individuals can be linked to firms in the CIS survey and to Swedish municipalities. Individuals with high technological competencies are defined as follows:

- All employees registered as physical, mathematical and engineering science professionals. Individuals in this category have a skill level equivalent to at least 3–4 years of higher education and an academic degree.
- Employees registered as research and development managers.
- Employees registered as corporate managers that also have more than 2 years of university training in a technological field including science, mathematics and computing as well as engineering, manufacturing and construction.
- Employees registered as managers of small enterprises that also have more than 2 years of university training in a technological field including science, mathematics and computing as well as engineering, manufacturing and construction.

The independent variable is a proxy for local knowledge spillovers. This study captures local knowledge spillovers by applying the concept of *accessibility*, which is widely used in regional science and transport economics. Accessibility has been interpreted in different forms such as : (1) nearness, (2) proximity, (3) ease of spatial interaction, (4) potential of opportunities for interaction, and (5) potential of contacts with activities and suppliers (Weibull 1980). We follow closely the original definition of Hansen (1959, p.73) who understands accessibility as 'the *potential* of opportunities for interaction'. Accordingly, we define accessibility as the potential of opportunities for knowledge spillovers.

In several recent papers, the concept of accessibility has been applied to measure the potential for and ease of knowledge interactions (Andersson and Ejermo 2005; Andersson and Gråsjö 2009; Andersson and Karlsson 2007; Massard and Mehier 2009). Typically, accessibility is modeled by an exponential distance-decay function as follows:

$$\mathrm{ACC}_{ir} = \sum_{s=1}^{n} K_s e^{-\lambda t_{rs}} + (K_r - K_{ir}) e^{-\lambda t_{rr}}$$

ACC_{ir} is the accessibility of a firm i located in municipality r to relevant knowledge K. The first term in the formula relates to a firm's accessibility to knowledge available in other municipalities while the second refers to a firm's accessibility to knowledge in the own municipality. The access to knowledge from other municipalities $s = 1, \ldots, n$ is diminished by applying an exponential distance-decay function $e^{-\lambda t_{rs}}$. t_{rs} denotes the time-distance between two municipalities r and s as provided by the Swedish Transport Administration. The time-distance values are multiplied by λ capturing how sensitive knowledge spillovers are to time-distance. λ is set to 0.017 following an empirical analysis about time-distance sensitivity for interregional business trips (Hugosson 2001; Andersson and Ejermo 2005). The second term captures the opportunities to

access knowledge from the municipality, in which a firm is located. Hence, for a firm i located in municipality r, we deduct the relevant firm-internal knowledge K_{ir} from the relevant municipal knowledge K_r to derive the firm-external knowledge in municipality r, which is then subject to the distance-decay function as above. The term t_{rr} relates to the average time-distance between zones within a municipality and is also provided by the Swedish Transport Administration.

The accessibility measure considers not only the potential of local knowledge spillovers but knowledge spillovers from Sweden overall. However, the exponential distance-decay function models that knowledge spillovers are more likely if the knowledge source is located in proximity. Knowledge spillovers in the municipality in which the firm is located have the highest weight. However, firms can potentially also benefit from knowledge spillovers from other, and particularly neighboring municipalities. The relative weight reduces exponentially using empirically derived parameters, which implies a decay of knowledge spillovers of 50 % at a time-distance of 40 min and of 90 % at a time-distance of 2 h. Hence, accessibility measures the opportunities for knowledge spillovers for a firm in a given location, strongly favouring spillovers from nearby sources and thereby being a good proxy for local knowledge spillovers.

Figure 1 shows that the accessibility values are highest in the three Swedish urban regions Stockholm, Gothenburg and Malmö. With increasing distance from these agglomerations, the accessibility values decrease. Each firm has been assigned the accessibility value of the respective municipality in which it is located, corrected for the firm-internal technological competencies.

3.2.1 Controls

The likelihood that a firm engages in collaboration depends on several factors, not only the potential for local knowledge spillovers. As shown in Table 2, we control for the knowledge intensity of the firm measured as the share of individuals with a high level of technological competencies, firm size, foreign ownership, foreign sales, industry classification and location in a metropolitan area.

4 Results

Table 3 depicts the results of the logit regressions for all innovative firms. The regression results are presented for firms that have engaged in any type of collaboration (overall) as well as firms that have collaborated with other Swedish actors (national), with foreign partners (foreign) or with partners located outside Europe (global). Models 1–4 are without interactions, models 5–8 consider interactions between accessibility to local knowledge spillovers and technological intensity of the firms and models 9–12 include interactions between accessibility and firm size.

Models 1 and 2 provide evidence that firms have a higher likelihood to collaborate if located in the knowledge periphery. The estimates are significant for collaborations overall as well as for collaborations with Swedish partners. There is no evidence however that firms located in the knowledge periphery are more likely to

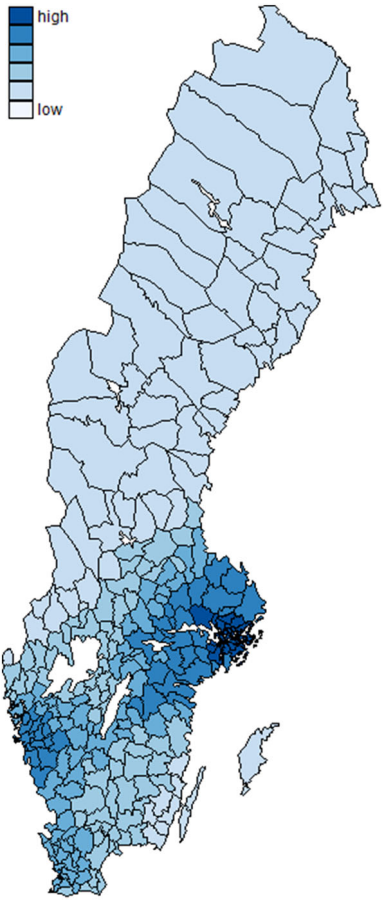

Fig. 1 Accessibility to technological competencies

collaborate with foreign or global partners (models 3 and 4). The effects of being located in the knowledge periphery differ, however, by type of firm. The results provide strong evidence that firms with high technological intensity (models 5–8) and large firms (models 9–12) have a higher tendency to engage in collaborations if located in the knowledge periphery. These results hold for all geographical scales.

Tables 4 and 5 provide analyses of the marginal effects of the interaction terms. The slope of the accessibility variable is reported at specific values of technology intensity and firm size keeping all other variables fixed at the mean. We chose values that correspond to the fifth, 25th, 50th, 75th and 95th percentiles of the measure for technology intensity and firm size. As regards the interactions with technological intensity (Table 4), we find that overall and on the national level, firms have a higher likelihood to collaborate if located in the knowledge periphery as compared to firms located in more knowledge-rich regions for all chosen values of technology intensity (see model 6). In contrast, the reported marginal effects for model 7 and 8, covering

Table 2 Control variables

Control variable	Description	Source[a]
Technological intensity	Share of individuals with a high level of technological competencies using occupational data	Longitudinal individual database and business statistics
Size of firm	Logarithm of number of employees	Business statistics
Foreign ownership	Yes/no	CIS
Foreign sales	Yes/no	CIS
Industry classification	Main NACE groups	CIS
Metropolitan area	Location of the firm in Stockholm, Gothenburg or Malmö	Firm register and business statistics

[a] All data were provided by Statistic Sweden

foreign and global collaborations, provide evidence that only firms with very high technological competencies are more likely to collaborate if located in the knowledge periphery. Firms with low technological competencies have a higher tendency to collaborate at the global scale if located in the knowledge centers. From the models including interactions with firm size (see Table 5), we find that large firms located in the knowledge periphery have a higher probability to collaborate at all geographical scales than firms in core regions. We do not find a significant effect for small firms.

The interaction terms can further be interpreted graphically. Figure 2 depicts the probability that firms collaborate depending on the accessibility to technological competencies and firm-internal knowledge. This graph refers to collaborations overall (i.e., Model 5). There are two main findings: Firms located in the knowledge periphery have a higher likelihood to collaborate. This likelihood decreases substantially for firms located in more knowledge-rich regions. Furthermore, firms with higher technology intensity tend to collaborate more than firms with lower technology intensity. Figure 3 illustrates the interaction between accessibility and firm size for collaborations overall (model 9). The slope for small firms is almost flat, while the slope turns out steeper for larger firms. Hence, there is a substantial difference in the likelihood to collaborate for big firms depending on their location in knowledge-rich or knowledge- poor regions while the difference is marginal for small firms.

As regards the control variables, there are also some interesting and conclusive findings. Firm-internal knowledge shows a positive and highly significant relationship with collaborations on all geographical scales, which holds in all models. Furthermore, all models provide evidence that large firms and firms with foreign sales have a higher likelihood to collaborate. This relates to the discussion in the theoretical section, where we argue that firms with low internal competencies have both a higher need and a lower ability to access firm-external knowledge. The results suggest that the lower ability of firms with low internal competencies to collaborate outweighs the higher need for collaborations that such firms may experience. This finding supports the literature on absorptive capacity (Cohen and Levinthal 1990). Firm-internal knowledge augments

Table 3 Logit regression results for all innovative firms and collaboration (overall), within Sweden (national), with partners outside Sweden (foreign), and with partners outside Europe (global)

Variables	(1) Overall	(2) National	(3) Foreign	(4) Global	(5) Overall	(6) National	(7) Foreign	(8) Global	(9) Overall	(10) National	(11) Foreign	(12) Global
Accessibility	0.9929*** (0.002)	0.9924*** (0.002)	0.9959 (0.003)	0.9999 (0.002)	0.9952** (0.002)	0.9941** (0.002)	0.9986 (0.003)	1.0049** (0.002)	1.0106* (0.006)	1.0097* (0.006)	1.0140* (0.007)	1.0156 (0.010)
Accessibility × technology intensity					0.9998** (0.000)	0.9999* (0.000)	0.9998** (0.000)	0.9997*** (0.000)				
Accessibility × log size									0.9956*** (0.001)	0.9958*** (0.001)	0.9958*** (0.001)	0.9965* (0.002)
Technology intensity	1.0131*** (0.002)	1.0119*** (0.002)	1.0178*** (0.003)	1.0195*** (0.003)	1.0193*** (0.005)	1.0162*** (0.004)	1.0242*** (0.005)	1.0293*** (0.006)	1.0132*** (0.002)	1.0120*** (0.002)	1.0178*** (0.003)	1.0196*** (0.003)
Log size	1.4211*** (0.075)	1.4299*** (0.081)	1.4892*** (0.071)	1.4531*** (0.090)	1.4205*** (0.075)	1.4296*** (0.081)	1.4887*** (0.071)	1.4531*** (0.090)	1.6485*** (0.092)	1.6494*** (0.095)	1.7157*** (0.097)	1.6333*** (0.135)
Foreign owner	0.9556 (0.114)	0.8775 (0.109)	1.4297** (0.217)	1.0903 (0.155)	0.9567 (0.114)	0.8784 (0.110)	1.4321** (0.215)	1.0968 (0.155)	0.9251 (0.115)	0.8499 (0.107)	1.3862** (0.224)	1.0618 (0.158)
Foreign sales	1.4356*** (0.197)	1.3324*** (0.145)	2.5388*** (0.445)	2.3967*** (0.325)	1.4340*** (0.197)	1.3311*** (0.145)	2.5392*** (0.444)	2.3963*** (0.323)	1.4038** (0.202)	1.3037** (0.150)	2.4761*** (0.453)	2.3425*** (0.334)
Metropolitan area	0.9269 (0.141)	1.0054 (0.135)	1.0133 (0.167)	0.9403 (0.159)	0.9373 (0.134)	1.0138 (0.130)	1.0296 (0.157)	0.9704 (0.148)	0.9135 (0.138)	0.9906 (0.133)	0.9984 (0.168)	0.9265 (0.162)
Constant	0.1688*** (0.055)	0.1664*** (0.052)	0.0411*** (0.015)	0.0196*** (0.008)	0.1596*** (0.050)	0.1598*** (0.048)	0.0384*** (0.013)	0.0172*** (0.007)	0.0955*** (0.022)	0.0958*** (0.023)	0.0233*** (0.006)	0.0120*** (0.005)

Table 3 continued

Variables	(1) Overall	(2) National	(3) Foreign	(4) Global	(5) Overall	(6) National	(7) Foreign	(8) Global	(9) Overall	(10) National	(11) Foreign	(12) Global
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,261	2,261	2,261	2,261	2,261	2,261	2,261	2,261	2,261	2,261	2,261	2,261
Pseudo R^2	0.067	0.065	0.123	0.122	0.068	0.065	0.124	0.124	0.07	0.067	0.125	0.124
Wald-ξ^2	714***	670***	338***	632***	1474***	895***	900***	13627***	974***	796***	588***	1432***
AIC	2,935	2,919	2,556	1,990	2,935	2,920	2,555	1,988	2,929	2,914	2,551	1,989
BIC	3,010	2,994	2,630	2,065	3,015	3,000	2,635	2,068	3,009	2,994	2,631	2,069
Log pseudolikelihood	−1,455	−1,447	−1,265	−982	−1,454	−1,446	−1,264	−980	−1,451	−1,443	−1,261	−980

Reported are odds ratios and clustered standard errors in brackets. Clustering is applied on the level of Swedish regions (län)
***, **, and * significance at the 1, 5, and 10 percent level

Table 4 Analysis of marginal effects for the interaction between accessibility and technological intensity; models 5–8

		(5) Overall	(6) National	(7) Foreign	(8) Global
Percentile	At TI (%)				
25th	0.0	−0.0012**	−0.0014**	−0.0003	0.0006**
		(0.001)	(0.001)	(0.001)	(0.000)
50th	2.9	−0.0013**	−0.0015***	−0.0004	0.0005**
		(0.001)	(0.001)	(0.001)	(0.000)
75th	10.9	−0.0017***	−0.0018***	−0.0007	0.0003
		(0.001)	(0.001)	(0.001)	(0.000)
95th	65.0	−0.0036***	−0.0033***	−0.0032***	−0.0030**
		(0.001)	(0.001)	(0.001)	(0.001)

Reported is the slope of the accessibility variable holding TI (Technological Intensity in %) fixed at the levels indicated in the table and holding all other variables fixed at their mean. Standard errors are reported in brackets

***, **, and * significance at the 1, 5, and 10 percent level

Table 5 Analysis of marginal effects for interaction between accessibility and firm size; models 9–12

		(9) Overall	(10) National	(11) Foreign	(12) Global
Percentile	At size				
5th	10	0.0002	0.0000	0.0006	0.0006
		(0.001)	(0.001)	(0.001)	(0.000)
25th	16	−0.0004	−0.0005	0.0004	0.0006
		(0.001)	(0.001)	(0.001)	(0.000)
50th	36	−0.0012**	−0.0013**	−0.0003	0.0004
		(0.001)	(0.001)	(0.001)	(0.000)
75th	140	−0.0027***	−0.0028***	−0.0017***	−0.0003
		(0.001)	(0.001)	(0.001)	(0.000)
95th	861	−0.0040***	−0.0041***	−0.0036***	−0.0019**
		(0.001)	(0.001)	(0.001)	(0.001)

Reported is the slope of the accessibility variable holding size (number of employees) fixed at the levels indicated in the table and holding all other variables fixed at their mean. Standard errors are reported in brackets

***, **, and * significance at the 1, 5, and 10 percent level

the capacity of firms to absorb knowledge from external sources. Larger firms usually have more resources at their disposal to engage in collaborations as suggested in the literature on liabilities of smallness and newness (Aldrich and Auster 1986; Freeman et al. 1983; Stinchcombe 1965). Also, strong internal competencies increase the attractiveness of firms as collaboration partners (Ter Wal and Boschma 2011). This can lead to self-reinforcing processes where firms with strong internal competen-

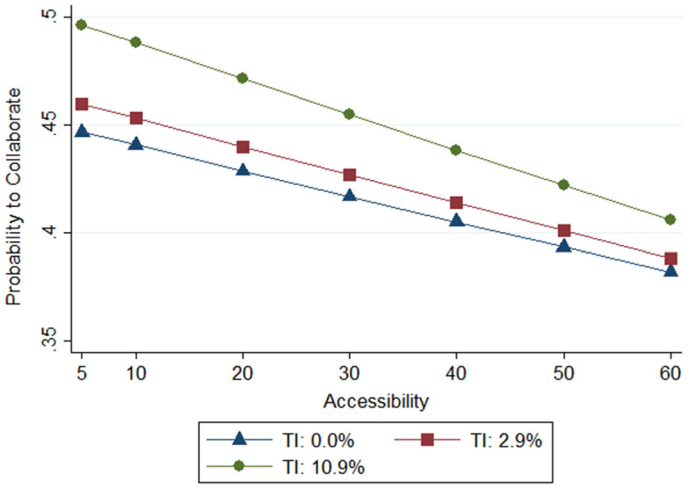

Fig. 2 Analysis of marginal effects for the interaction between accessibility and technological intensity (TI) for collaborations overall (model 5)

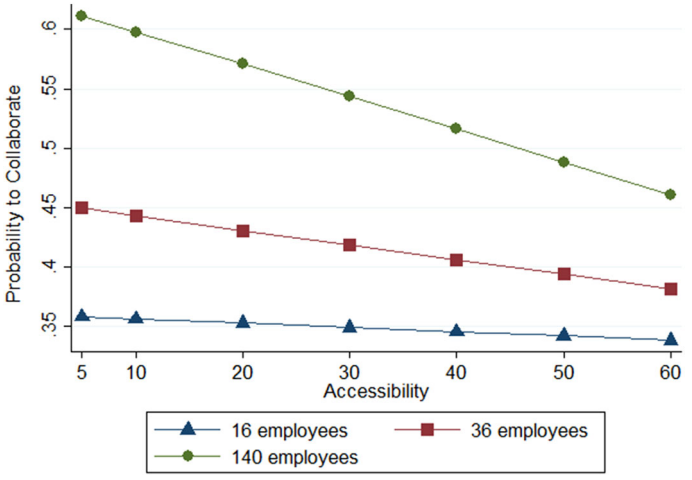

Fig. 3 Analysis of marginal effects for interaction between accessibility and firm size for collaborations overall (model 9)

cies have advantages in sourcing knowledge externally, which in consequence further strengthens their internal competencies (Grillitsch et al. 2013).

As large firms and firms with a high technological intensity are more able to engage in collaborations, they will find it easier to use collaborations as a compensation for a lack of accessibility to local knowledge spillovers. Such firms therefore collaborate more if located in the knowledge periphery than if located in knowledge centers. Firms with lower internal competencies, i.e., smaller firms and firms with a lower share of highly qualified staff, will find it more difficult to complement their internal

Table 6 Logit regression results for firms below and above median firm size

Variables	Below median firms size				Above median firms size			
	(1) Overall	(2) National	(3) Foreign	(4) Global	(5) Overall	(6) National	(7) Foreign	(8) Global
Accessibility	0.9950* (0.003)	0.9956 (0.003)	1.0011 (0.004)	1.0005 (0.006)	0.9903*** (0.003)	0.9889*** (0.002)	0.9926** (0.003)	0.9986 (0.004)
Technology intensity	1.0104*** (0.003)	1.0075** (0.004)	1.0161*** (0.003)	1.0141*** (0.002)	1.0183*** (0.003)	1.0200*** (0.004)	1.0192*** (0.004)	1.0274*** (0.006)
Foreign owner	0.9352 (0.134)	0.8261 (0.103)	1.5295 (0.430)	1.4487 (0.401)	0.9291 (0.136)	0.8618 (0.140)	1.3422** (0.199)	0.9818 (0.130)
Foreign sales	1.3543 (0.315)	1.2558 (0.245)	2.5061*** (0.673)	2.3221*** (0.596)	1.5116*** (0.164)	1.3979*** (0.149)	2.5316*** (0.344)	2.4403*** (0.386)
Log Size	1.1266 (0.280)	1.1526 (0.323)	1.1489 (0.228)	0.8863 (0.177)	1.5598*** (0.083)	1.5376*** (0.074)	1.5822*** (0.070)	1.6399*** (0.110)
Metropolitan area	1.0563 (0.199)	1.0822 (0.188)	0.9969 (0.113)	1.1485 (0.247)	0.8013 (0.116)	0.9139 (0.119)	1.0114 (0.239)	0.8128 (0.181)
Constant	0.3013 (0.250)	0.2808 (0.242)	0.0668*** (0.054)	0.0706*** (0.053)	0.1144*** (0.027)	0.1243*** (0.026)	0.0363*** (0.009)	0.0111*** (0.004)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,134	1,134	1,134	1,134	1,127	1,127	1,127	1,127
Pseudo R^2	0.025	0.021	0.081	0.108	0.070	0.068	0.100	0.120
Wald-ξ^2	208***	201***	707***	545***	640***	1292***	643***	962***
AIC	1,472	1,445	1,135	827	1,467	1,479	1,421	1,157
BIC	1,538	1,510	1,201	892	1,533	1,544	1,487	1,222
Log pseudo-likelihood	−723	−709	−555	−400	−721	−726	−698	−565

Reported are odds ratios and clustered standard errors in brackets. Clustering is applied on the level of Swedish regions (län)
***, **, and * significance at the 1, 5, and 10 percent level

competencies through collaborations and consequently also to compensate for a lack of localized knowledge spillovers. Hence, a location in knowledge-rich regions is particularly important for such firms.

In order to further qualify the above, Table 6 provides results where the sample is split in two groups based on the median firm size corresponding to approximately 35 employees. For simplicity reasons, the groups are labeled small versus large firms. For small firms, the accessibility measure is weakly significant for collaborations overall and insignificant for national, foreign and global collaborations. In contrast, large innovative firms have a significantly higher likelihood to engage in collaborations if located in the knowledge periphery. This finding holds for collaborations in general as well as for collaborations with Swedish and foreign partners, therefore supporting the arguments made above.

The odds ratios for the accessibility measure can be interpreted by taking some Swedish regions as examples. The three largest urban areas in Sweden are Stockholm, Gothenburg and Malmö. Stockholm is by far the largest agglomeration with the highest accessibility to technological competencies followed by Gothenburg and Malmö. We compare these urban regions with Karlskrona, the provincial capital of Blekinge County, which is located in the southeastern part of Sweden. The measures for accessibility are approximately 61 for Stockholm, 33 for Gothenburg, 21 for Malmö and 8 for Karlskrona. For illustration purposes, we use the model for large firms and collaborations overall (Table 6, Model 5). The odds ratio for the accessibility variable is 0.9903. This means that compared to large innovative firms in Karlskrona, the odds for engaging in collaborations decreases by 40 % for large innovative firms located in Stockholm, by 22 % if located in Gothenburg and by 12 % if located in Malmö.

5 Conclusions

This study finds evidence that innovative firms in peripheral regions tend to collaborate more than similar firms in regions with high access to local knowledge spillovers. This implies that innovative firms use collaborations to compensate for a lack of opportunities to access local knowledge spillovers. This finding is interesting because the majority of studies emphasize the complementary character between local knowledge spillovers and collaborations. Typically, in the literature, it is stressed that firms in clusters and agglomerations will find it easier to establish collaborations with both local and distant actors, i.e., it could be expected that firms located in agglomerations or clusters should collaborate more than firms located in the periphery.

However, this line of thought neglects the fact that innovative firms in peripheral regions have to compensate for lacking opportunities of local knowledge spillovers if fundamental propositions of innovation theory are upheld, namely that (1) innovation results largely from collective processes for which access to firm-external knowledge is important and that (2) local knowledge spillovers are important to access firm-external knowledge. Given these propositions, firms in peripheral regions can be innovative only to the extent to which they are able to compensate for lacking opportunities of local knowledge spillovers. Collaboration is a potential mechanism for compensation as they establish an organisational framework (organisational proximity) that allows for interactive learning processes.

Furthermore, firms differ in their capability to engage in collaborations and thus to compensate for a low access to local knowledge spillovers. Large firms and firms with high technological competencies have a higher absorptive capacity and are more attractive collaboration partners than small firms and firms with less qualified staff. Accordingly, we find that large firms and firms with a high level of technological competencies collaborate significantly more at all geographical scales if located in the knowledge periphery. Interestingly, innovative firms with a low level of technological competencies located in the knowledge periphery collaborate more nationally but less with foreign and global partners. There are no significant

results for small firms. These results lead to the conclusion that the regional knowledge infrastructure is more important for small firms and firms with low internal competencies.

This paper draws on quantitative data for Sweden. It would be interesting to investigate whether the observed patterns also hold in other spatial contexts. In particular, a study including a larger number of urban areas and regions with different degrees of access to local knowledge spillovers would unveil to what extent the reasoning and results of this study are generalizable. In addition, it is suggested to conduct qualitative research to see how exactly innovative firms in peripheral regions compensate for a lack of local knowledge spillovers. This study provides evidence that innovative firms in knowledge peripheries have a higher likelihood to collaborate. However, to create an understanding how such firms in the periphery establish collaborations, source knowledge and resources through collaborations and appropriate them internally requires qualitative approaches. Also this study draws attention to firm-specific differences largely depending on firm size and competencies. It would be interesting to see whether there are outliers, like small innovative firms in peripheral regions that collaborate, and investigate how they compensate for being located in the knowledge periphery. Such studies can be highly interesting for regional policy makers and firms located in peripheral regions. Furthermore, research along these lines would further our understanding how learning and innovation processes work in areas that lack a rich knowledge infrastructure.

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Appendix

See Table 7.

Table 7 Descriptive statistics and correlations

	Variables	Obs.	Mean	SD	Min	Max	1	2	3	4	5	6	7	8	9	10
1	Collaborations overall	2,261	0.46	0.50	0.00	1.00	1.00									
2	Collaborations national	2,261	0.43	0.50	0.00	1.00	0.95	1.00								
3	Collaborations foreign	2,261	0.34	0.47	0.00	1.00	0.77	0.71	1.00							
4	Collaborations global	2,261	0.20	0.40	0.00	1.00	0.54	0.50	0.70	1.00						
5	Technology intensity	2,261	11.65	20.21	0.00	100.00	0.10	0.08	0.13	0.18	1.00					
6	Accessibility	2,261	29.01	19.19	0.48	61.38	−0.03	−0.03	0.00	0.03	0.25	1.00				
7	Foreign owner	2,261	0.22	0.41	0.00	1.00	0.06	0.05	0.16	0.09	0.00	0.08	1.00			
8	Foreign sales	2,261	0.70	0.46	0.00	1.00	0.11	0.09	0.21	0.16	0.04	−0.11	0.11	1.00		
9	Log size	2,261	3.98	1.50	0.69	10.43	0.24	0.24	0.30	0.23	−0.03	0.07	0.30	0.12	1.00	
10	Metropolitan area	2,261	0.25	0.43	0.00	1.00	−0.01	−0.01	0.01	0.03	0.25	0.58	0.06	−0.11	0.04	1.00

Bivariate correlations and descriptive statistics, innovation active firms

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