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## **REMOTE COLLABORATION, ABSORPTIVE CAPACITY, AND THE INNOVATIVE OUTPUT OF HIGH-TECH SMALL FIRMS**

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### **Abstract**

It is generally recognized that firms' innovative performance can be enhanced by collaborating with remote partners. However, remote collaborations are not without challenges, as geographical distance may frustrate tacit knowledge transfer and inter-organizational learning. We investigate the moderating role of absorptive capacity by proposing that the higher firms' R&D intensity, the stronger the relationship between remote collaboration and their share of new product revenues. Drawing on survey data of 250 Dutch high-tech small firms, it is confirmed that remote collaboration is associated with innovative performance, but at low values of R&D intensity this relationship disappears.

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## *Abstract*

It is generally recognized that firms' innovative performance can be enhanced by collaborating with remote partners. However, remote collaborations are not without challenges, as geographical distance may frustrate tacit knowledge transfer and inter-organizational learning. We investigate the moderating role of absorptive capacity by proposing that the higher firms' R&D intensity, the stronger the relationship between remote collaboration and their share of new product revenues. Drawing on survey data of 250 Dutch high-tech small firms, it is confirmed that remote collaboration is associated with innovative performance, but at low values of R&D intensity this relationship disappears.

## INTRODUCTION

One of the more prominent findings in innovation research is that firms' innovative performance can be enhanced by external collaboration. Both the likelihood of innovating and the intensity or novelty of innovation increase when external partners are involved (Tomlinson, 2010). Innovation collaboration also has a well-documented spatial dimension (e.g., Oerlemans and Meeus, 2005; Huggins and Johnston, 2010). Here, it has been found that geographically distant partners are more likely to be the source of heterogeneous and diverse knowledge which can further enhance innovation performance (e.g., Grotz and Braun, 1997; Freel, 2003). However, a complication associated with geographical distance is that it may retard the tacit knowledge transfer and inter-firm learning (Malmberg and Maskell, 2006). Past work suggests that such problems in particular arise when partners are hundreds of kilometers away (e.g., Botazzi and Peri, 2003; Greunz, 2005), so that meeting face-to-face would require an overnight trip.

Recent work has begun to go beyond simple geographical distance by considering the multidimensionality of proximity. For instance, Boschma (2005) suggests that "although geographical proximity facilitates interaction and cooperation...it is neither a prerequisite nor a sufficient condition for interactive learning to take place". Rather he proposes that "some, but not too much, cognitive proximity (i.e. an absorptive capacity open to new ideas) is a prerequisite for interactive learning processes to take place"

(p.71). Crucially, he suggests that cognitive proximity, which is enhanced by investments in the development of absorptive capacity, may compensate for lack of geographical proximity between partners – including the potential pitfalls related to tacit knowledge exchange. This is consistent with Torr 's (2008) observation that between-cluster linkages are most likely amongst firms with higher absorptive capacities. To date, however, there has been limited empirical investigation of the potential moderating role of absorptive capacity on the effectiveness of innovation collaboration at greater distances. Where the issue has been studied (e.g., Drejer and Vinding, 2007; de Jong and Freel, 2010) the focus was on firms' propensity to engage in remote collaborations, rather than their innovative performance.

In this paper we take this next step by empirically exploring the extent to which absorptive capacity moderates the relationship between remote collaboration and innovative performance. The importance of these issues is underscored by growing evidence that innovation networks, particularly in technology-intensive sectors, are spatially dispersed (e.g., Whittington, Owen-Smith and Powell, 2009). Remote collaborations are here defined as innovation collaborations with those partners that cannot be traveled to back and forth in a day. We first discuss the theory underpinning the development of our hypothesis on the moderating role of absorptive capacity. Next, we present and analyze our data of 250 Dutch high-tech small firms. Their absorptive capacity (indicated by R&D-intensity) appears to be a necessary condition to benefit from remote innovation collaboration. In general remote collaboration has a positive impact on innovation performance, but in case of low R&D-intensity, the relationship is negligible.

## **THEORY AND HYPOTHESIS**

This paper is concerned with the potential moderating role of absorptive capacity on the relationship between remote collaboration and firms' innovative performance. We first explain why collaboration at greater geographical distance is expected to correlate with innovative performance. Next, we discuss the concept of absorptive capacity and how it is expected to be associated with the aforementioned relationship.

### *Remote collaboration*

The last decades have witnessed growing evidence that the organizational boundaries of innovation are shifting from “a situation where firms perform R&D activities mainly internally...to a reality where corporate partnering, collaboration and external sourcing in R&D are widespread” (de Faria, Lima and Santos, 2010). There has, in fact, been a remarkable growth in R&D partnerships during the closing decades of the last century (Hagedoorn and Van Kranenburg, 2003). In more general terms technological development and innovation are increasingly viewed as distributed activities with few firms able to go alone (Tether, 2002). This belief is captured in Chesbrough’s (2003) Open Innovation model, which counsels organizations that many of the resources required to innovate reside outside of their firm and that accessing these resources is an important step in successfully innovating (e.g., Laursen and Salter, 2006; Spithoven, Clarysse and Knockaert, 2010)<sup>1</sup>. Moreover, to the extent that the required external innovation resources are frequently embodied in (groups of) individuals and characterized by some degree of tacitness, simple market transactions are unlikely to be sufficient. Rather, ‘openness’ is likely to rest on relationships. This, in turn, underpins the conception of innovation as an iterative, cumulative and cooperative phenomenon, in which “interactive learning and collective entrepreneurship are fundamental” (Lundvall, 2010: p.5). And indeed, the body of empirical work testifying to the importance of innovation collaboration is substantial, particularly in technology-intensive industries (e.g., Bayona, Garcia-Marca and Huerta, 2001; Miotti and Sachwald, 2003).

Past work strongly suggests that the relationship between collaboration and innovation performance also applies when partnerships at greater distances are involved. Whenever partners are geographically close, they are more likely to occupy the same locale and to be cognitively proximate on the basis of shared experiences and understandings. Excessive cognitive resemblance limits innovation opportunities, since there is little left to learn (Boschma, 2005; Nooteboom, 1999; Nooteboom, Vanhaverbeke, Duijsters, Gilsing and van Oord, 2007). Rather, to access the cognitive diversity required for innovation, firms may have to search further afield. In this vein, empirical evidence confirms that collaboration at greater distance is associated with

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<sup>1</sup> In addition, Open Innovation is also concerned with the notion that there may be other ways to commercialize innovations beyond firms taking them to market themselves. This may be thought of as ‘purposive outflows’ of knowledge, rather than the ‘purposive inflows’ that is primarily our interest.

better innovative performance. In their study of German mechanical engineering SMEs, Grotz and Braun (1997) noted that “local sub-contractors mainly perform low-level production operations”, while the “more crucial and innovation-oriented ties are very often national or international in character” (p.549). Freel (2003) recorded for Scottish manufacturing SMEs that novel innovators were more likely to have distant partners than firms with only incremental innovations. Tödting, Lehner and Trippel (2006) noted that high-technology firms were both more likely to be engaged in international collaborations and to have pursued “new to the market” innovations.

Similar to Granovetter’s (1973) weak ties, more distant partners are arguably “more likely to move in circles different from our own and will have access to information different from we receive” (p.1371). Collaborations at greater distance, we propose, are then generally characterized by greater diversity of the involved knowledge sources, and this would enhance innovation performance. In this vein Laursen and Salter (2006) found a positive impact on innovation of firms’ searching for diverse knowledge sources. Likewise, Nieto and Santamaria (2007) found a positive relationship between the diversity of partners (measured in dichotomous form) and novelty of product innovation. In sum, partners at greater geographical distance are more likely to be sources of complementary, but non-redundant, knowledge, capabilities, and so on. Regarding our sample of high-tech small firms, this leads us to anticipate that

*In high-tech small firms, there will be a positive relationship between their share of remote collaboration partners and innovative performance.*

#### *Absorptive capacity*

Absorptive capacity captures the quality of human capital investments and other expenses that may enhance firms’ ability to recognize, adopt and apply external knowledge (Cohen and Levinthal, 1990). It enables the firm to import externally created knowledge and transform it into innovative products and gain a competitive advantage (Zahra and George, 2002). In our empirical analysis (see later) absorptive capacity is indicated by R&D intensity, which was central to Cohen and Levinthal’s (1989; 1990) early conceptualization of the concept.

In connection with innovation performance, we anticipate a positive and significant correlation with R&D intensity – since this is a usual suspect in many analyses of firm-level innovation. Whilst the linear model of innovation (along the lines of “more R&D in, more innovation out”) has become something of a straw man (Balconi, Brusoni and Orsenigo, 2010), empirical studies nevertheless typically find significant and positive correlations between R&D and innovation (e.g., Raymond and St-Pierre, 2010). This also applies to small firms (e.g., Nieto and Santamaria, 2010) and to technology-based small firms in particular (e.g., Kirner, Kinkel and Jaeger, 2009). Given the abundant evidence, we do not explicitly formulate a hypothesis regarding this direct relationship, but rather go beyond by exploring whether R&D intensity moderates the relationship between remote collaboration and innovation performance. In doing so, we apply the early work of Cohen and Levinthal (1989; 1990) to the context of remote collaboration, suggesting that R&D intensity is not only directly related to firms’ innovation performance, but also indirectly through its influence on firms’ ability to learn from (in this research) remote partners.

Although remote partners are expected to associate with improved innovation performance, we recognize that such collaboration also involves potential difficulties. Whilst the technology mediated transfer of *information* is possible both at low cost and over great distances, the effective transfer of *knowledge* typically relies upon face-to-face interactions. Accordingly, geographical distance would limit inter-organizational knowledge transfer (Malmberg and Maskell, 2006). In similar vein, Howells (1999: p.83) talks in terms of a “distance decay function in communication”, such that the rate of contact between partners falls approximately with the square of the separating distance. In European studies knowledge spillover reach has been concluded to work up till 300 kilometers (Botazzi and Peri, 2003) or 400 kilometers (Greunz, 2005)<sup>2</sup>. Whilst the difference in absolute distances is likely to reflect, amongst other things, differences in transport infrastructures, population densities, and travel norms, a key issue is that they seem all intended to represent the distance that people can and/or want to travel back and forth in a day.

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<sup>2</sup> Equivalent to 187.5 and 250 miles, respectively.

We here build on previous conceptual work suggesting that geographical distance should always be assessed in relation to other forms of proximity. Boschma (2005) argued that the potential problems arising from a lack of geographical proximity can be compensated by cognitive, organizational, social and institutional proximities. Moreover, he suggests that whilst geographic, social, organization and institutional proximities increase the likelihood of partners coming together, “cognitive proximity determines whether or not interactive learning processes may take place” (Boschma, 2005: p. 71). Echoing Nooteboom (1999), he defines cognitive proximity to be a function of the similarity between organizations’ knowledge bases. Organizations are cognitively proximate where they possess similar market and technological competences. And, building on shared experiences and understandings, cognitive proximity facilitates effective communication and collaboration<sup>3</sup>. In sum, Boschma (2005) recognizes a tension between geographical and cognitive proximity. In the case of remote collaborations, there is likely to be a stronger prior need for cognitive proximity, as a lack of such proximity cannot be easily resolved through face-to-face interactions. Remote partnerships accordingly require some other means to bridge cognitive gaps.

Recent observations in the literature suggest that increasing absorptive capacity may play this role. Both concepts revolve around the proposition that organizational search processes are constrained by existing knowledge. In this way, learning is seen to be cumulative, self-reinforcing and path dependent, such that it is easier to recognize and evaluate knowledge (and the returns to learning are higher) in areas of prior familiarity (Levinthal, 1996). Nooteboom and colleagues (2007) empirically demonstrated that in innovation collaborations, the negative effect of increased cognitive distance (measured via partners’ dissimilarities in technological patent profiles) is reduced by absorptive capacity – especially in the case of explorative learning.

Crucially, for our present purposes, absorptive capacity is neither homogenous across firms nor fixed within a given firm. Rather, firms may have more or less absorptive capacity and management may directly influence the level of absorptive

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<sup>3</sup> Simultaneously however, some degree of cognitive distance is also required as cognitively identical partners are not supposed to learn from each other. Indeed, the relationship between cognitive proximity and innovation has been shown to be an inverted U-shape (Nooteboom, Vanhaverbeke, Duijsters, Gilsing and van den Oord, 2007).

capacity through, for instance, investments in R&D. Investments in absorptive capacity increase their ‘zone of reasonable comprehension’ by decreasing the cognitive gaps with geographically remote partners. In this vein, Torr  (2008) observed that “...firms with higher absorptive capacities within a cluster are those that are most likely to establish linkages with external sources of knowledge. This is explained on the basis of cognitive distances between firms and extra cluster knowledge, so that firms with high absorptive capacities are considered more cognitively proximate to extra cluster knowledge than firms with lower absorptive capacity” (p.874).

This observation is supported by recent empirical work on the propensity to engage in innovation-related collaborations with more distant partners (Drejer and Vinding, 2007; de Jong and Freel, 2010). The general conclusion of these studies is that firms with a high level of absorptive capacity are more likely to collaborate with more distant partners. Given these arguments, we reason that high absorptive capacity diminishes the cognitive distance to collaboration partners (implying a greater ‘bandwidth’ for tacit knowledge transfer). This is especially important in benefitting from remote innovation partnerships (where face-to-face meetings are less practicable as a means to cross cognitive gaps). Accordingly, our central hypothesis is

*The higher the absorptive capacity of high-tech small firms, the stronger the relationship between their share of remote collaboration partners and innovative performance, and vice versa.*

## **DATA**

We use data from an existing survey of high-tech small firms in the Netherlands. This survey was commissioned by the Dutch ministry of economic affairs and conducted in the spring of 2006. While high-tech small firms are the target group of most Dutch innovation policies, their characteristics were poorly recorded in the official statistics at the time. The survey contained a long list indicators related to the innovation characteristics of high-tech firms, including detailed questions on firms’ innovation collaboration partners. We use these data for our present purposes.

All participants were members of a panel of high-tech small firms that was created for systematic data collection. Building the panel involved a considerable

screening effort. To qualify firms were not allowed to have more than 100 employees. They also had to actively engage in R&D, as defined by the Frascati manual (OECD, 2002), and to have developed new technology-based products in the past three years (Grinstein and Goldman, 2006). In the Netherlands, high-tech small firms are mostly found among manufacturers of chemicals, rubbers and plastic products, manufacturers of machines and equipment, technical wholesale traders, IT and telecom firms, engineering and commercial R&D firms (EIM, 2006).

The survey was sent out to the full panel of 675 high-tech small firms, who were invited to take a web-based survey. Altogether 379 firms participated, a response rate of 56%. Respondents were all small business owners or general managers with a good overview of their business. In comparison with the sampled firms,  $\chi^2$ -tests indicated that respondents and non-respondents were similar in terms of industry types ( $p=.97$ ) and size classes ( $p=.89$ ). For the current paper, we selected 250 firms that had reported innovation collaborations with other organizations in the past three years, and who had provided us with detailed information on their R&D intensity and innovative performance (two key variables in the models presented hereafter). Again, compared to the full panel  $\chi^2$ -tests suggested no selection bias in terms of industry types ( $p=.79$ ) and size classes ( $p=.78$ ).

### *Variables*

The dependent variable in our analysis is the innovative performance of high-tech small firms. As an indicator, we use the share of revenues obtained from new products. Given our sample of high-tech small firms, for whom technology-based new product introduction is the primary focus of competitive strategy and a major source of income, this measure is most relevant. It directly measures the success of new technology-based products in the market. Moreover, it is a frequently used indicator to empirically analyze innovative performance (e.g., Cassiman and Veugelers, 2006; Escribano, Fosfuri and Tribo, 2009; Laursen and Salter, 2006; Tsai, 2009; Tsai and Wang, 2009) and it overlaps considerably with alternative performance indicators (like patent registrations), especially in the context of high-technology firm (Hagedoorn and Cloudt, 2003). In the survey, respondents had reported their share of past year's revenues obtained with new products

– where ‘new’ was defined as a product that was no more than 3 years old. On average, respondents reported that 32% of their revenues were from new products.

To measure remote collaboration we computed the share of distant collaboration partners in the total number of innovation partners, as reported by respondents. In the internet survey, respondents provided detailed data regarding their innovation collaboration partners over the past three years. This included a full list of their partners and their locations (city, country). While incumbent public surveys (like the Community Innovation Surveys) at best record geographical distances in terms of thresholds for partner types (e.g., ‘Is your collaboration partner located at more than X kilometers away?’) or draw on nominal scales (e.g., ‘Are your partners generally in your region, country, or abroad?’), we have access to much more precise data

On average respondents had reported details of 4.5 partners, with a minimum of one and a maximum of 13. For our present purposes, a remote partner was defined as any collaborator not settled in the Netherlands or its neighboring countries; Belgium and Germany. Dutch people can typically travel to these countries by car or public transport back and forth in a day - note that most German economic activity is in the ‘Ruhrgebiet’ and close to the Dutch border. To visit other countries, it is generally necessary to fly out and stay overnight to meet face-to-face. The average share of remote innovation collaborators was 12%, indicating that most partners were in fact closely located. Eighty percent of the reported partners were from the Netherlands, while 6% were from Germany and 2% from Belgium. More distant partners were located in the United States (2%), United Kingdom (2%) and 32 other countries including Australia, Canada, China, France, Japan and Russia. Acknowledging that our definition of remote partners is somewhat arbitrary, we also computed alternative indicators drawing on the geographical distance of innovation collaborators, and used these for some sensitivity checks – these are further discussed in the results section.

To measure absorptive capacity we used firms’ R&D intensity as an indicator, i.e. R&D expenditures as a percentage of firms’ sales revenues over the past year. Following Cohen and Levinthal (1989; 1990), R&D measures have been most frequently applied to proxy the concept. It is, of course, recognized that other measures may usefully proxy more specific capabilities that also comprise absorptive capacity, but Zahra and

George (2002) argue that R&D intensity is an appropriate measure for the knowledge acquisition capabilities necessary for collaborative innovation. We are also aware that R&D may be a poor measure in broad samples of small firms, as these tend not to engage in R&D (Muscio, 2007). However, in our sample of high-tech firms respondents are R&D-performers by definition, so such there is little reason for concern. The average R&D intensity in the sample was 26% in 2006.

Finally, we include a variety of control variables that may influence the innovative performance of high-tech small firms: the volume of innovation collaboration, firm size and industry dummies. First, we control for collaboration volume, i.e. the number of external innovation partners that respondents had reported. Past empirical work on innovation and networks typically shows that such volume matters for innovation performance (e.g., Oerlemans, Meeus and Boekema, 1998; Tether, 2002). Moreover, assuming that firms initially search for partners locally, and are likely to search in remote places only when local resources are not available or already exploited (Feldman, 1994), we reasoned that remote partners are more likely to be reported by those with many external partnerships (and indeed we found a positive correlation – reported later).

The second control variable is firm size, indicated by the number of employees in fulltime equivalents. Size is a well-known determinant of the innovativeness of firms; for example, by influencing the ability to finance innovation-related investments, to spread risks, and to organize for innovation (Cohen, 1995; Nooteboom, 1994). Given that all respondents in the sample are innovative firms, we anticipate a negative relationship between size and the share of new product revenues. Whilst a little counter-intuitive, it follows empirical evidence that, though small firms are less likely to innovate, when they do innovate it is generally with greater intensity (Nooteboom, 1994). The average firm size in our sample was 19.6 fulltime equivalents.

Finally, we control for industry effects by including six dummy variables in our estimations. Industry effects are also important in explaining variance in innovative activity (Cohen, 1995; Scott, 1984). It has been demonstrated that the geographical clustering of business networks differs across industries (Bottazzi, 2001) as does the relative emphasis on tacit or codified knowledge (Marsili, 2002). Moreover, some

industries are marked by greater environmental dynamism which directly affects the share of new product revenues (e.g., young and fast-growing industries versus established ones). Our data distinguished seven industry types, including manufacturers of chemicals, rubbers and plastics (NACE codes 23-25, 9% of the sample), machinery and equipment (NACE 29-33, 21% of the sample) and other manufacturers (NACE 15-22 and 26-28 and 34-37; 8% of the sample). The sample also included services firms: technical wholesale traders (NACE 51.8, 9% of the sample), IT and telecom firms (NACE 64.2 and 72, 21% of the sample), engineering and commercial R&D services firms (NACE 74.2 and 73, 25% of the sample) and other services firms (NACE 50-74 excluding the previously mentioned codes, 7% of the sample). Manufacturers of machinery and equipment were treated as the reference group.

#### *Descriptive statistics*

Table 1 gives the descriptive statistics for the firms in our sample. We observe significant correlations between the share of new product revenues and the share of remote partners. Correlations with R&D intensity were also significant, as were firm size (with its expected negative sign) and several of the industry dummies.

**Table 1. Descriptive statistics (n=250)**

Variable	M	SD	Correlation coefficients												
			(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)		
(1) Log share of new product revenues	3.4	1.0													
(2) Share of remote partners	.12	.19	.17*												
(3) R&D intensity	.26	.27	.26**	.08											
(4) Collaboration volume	4.5	2.4	.10	.15^	.17*										
(5) Firm size	19.6	23.1	-.24**	-.04	-.33**	.12									
(6) Manufacturing of chemicals, rubbers and plastics	.09	.29	-.02	.03	-.07	.12	.15^								
(7) Manufacturing of machinery and equipment	.21	.41	.01	-.02	-.02	.02	.03	-.17*							
(8) Other manufacturing	.08	.27	-.18*	-.03	-.19*	-.08	.14^	-.10	-.15^						
(9) Technical wholesale trade	.09	.29	.10	.07	-.03	-.13^	-.01	-.10	-.15^	-.09					
(10) IT and telecom services	.21	.41	.15^	-.11	.00	-.23**	-.10	-.18*	-.28**	-.16^	-.16^				
(11) Engineering and commercial R&D services	.25	.43	-.02	.03	.20*	.24**	-.10	-.20*	-.30**	-.17*	-.17*	-.32**			
(12) Other services	.07	.26	-.14^	.08	.01	.01	-.04	-.08	-.12	-.07	-.07	-.12	-.13^		

\*\* p<.001; \* p<.01; ^ p<.05.

Moreover, some of the independent variables are correlated, the largest single correlation being between firm size and R&D intensity ( $r=-.33$ ). The reported correlations do not indicate serious concerns for multicollinearity. As a rule-of-thumb, multicollinearity problems are most likely when correlations exceed absolute values of 0.80 (Hair, Anderson, Tatham and Black, 1998).

## RESULTS

We conducted Tobit regression analyses, a form of regression used when the dependent variable is censored to the left and/or right. Such analyses are warranted when the dependent variable has clear boundaries – in our data three firms reported a minimum share of new product revenues, while 36 firms reported that 100% of their revenues were from newly introduced products. When such boundary conditions exist, Tobit regression is the recommended estimation method (Gujarati, 1995). Following previous research (e.g., Laursen and Salter, 2006), the dependent variable is used in its logarithmic form to reduce the problem of non-normality of the residuals (Greene, 2003). For the independent variables, we centered the share of remote partners and R&D intensity around their means, and computed their interaction term by multiplying these centered values (cf. Aiken and West, 1991). Thereafter, we estimated various specifications of the model to test our hypothesis.

Table 2 presents our findings. The overall goodness-of-fit of each model is assessed by comparing the difference in the transformed loglikelihood value ( $-2*LL$ ) with a baseline (empty) model. The difference is tested against the  $\chi^2$ -distribution, with the degrees of freedom equal to the number of independent variables. Moreover, the improvement in goodness-of-fit in each step is assessed by comparing the transformed loglikelihood value with the previous (nested) model and tested against the  $\chi^2$ -distribution with one degree of freedom.

**Table 2. Tobit regression models of new product revenue share (n=250)**

	I	II	III
<i>Effect parameters:</i>			
Constant	3.195** (.223)	3.136** (.220)	3.448** (.213)
Collaboration volume	.071^ (.031)	.059 (.031)	.066^ (.031)
Firm size	-.010* (.003)	-.010* (.003)	-.010* (.003)
Manufacturing of chemicals, rubbers and plastics	-.060 (.264)	-.090 (.260)	-.016 (.260)
Other manufacturing	-.406 (.287)	-.420 (.282)	-.363 (.281)
Technical wholesale trade	.551 (.296)	.474 (.293)	.536 (.292)
IT and telecom services	.260 (.213)	.280 (.209)	.324 (.209)
Engineering and commercial R&D services	-.314 (.206)	-.321 (.203)	-.290 (.203)
Other services	-.832^ (.346)	-.919* (.342)	-.771^ (.345)
R&D intensity	1.053* (.314)	1.027* (.310)	1.037* (.312)
Share of remote partners (SORP)		1.077* (.366)	1.089* (.377)
R&D intensity*SORP			3.747^ (-1.718)
<i>Model fit:</i>			
Left-censored observations	3	3	3
Right-censored observations	36	36	36
Pseudo R <sup>2</sup>	.071	.083	.090
Δ -2*LL (baseline model)	53.8**	62.4**	67.8**
Δ -2*LL (previous model)		8.6*	5.4^

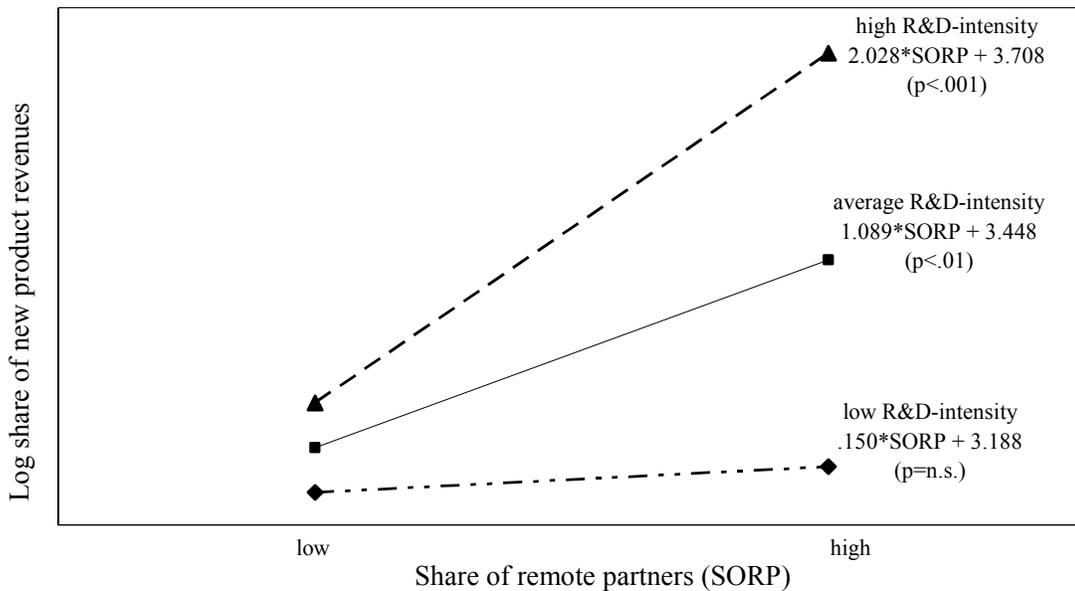
\*\* p<.001; \* p<.01; ^ p<.05. Standard errors in parentheses.

The first model includes R&D intensity and the control variables of collaboration volume, firm size and six dummies representing industry types. Echoing previous empirical work, the effect parameter of R&D intensity is positive and significant (b=1.053, p<.01), implying that high-tech small firms spending a larger part of their revenues on R&D are marked by higher shares of new product revenues. It is also confirmed that high-tech small firms reporting a larger number of external innovation partners do better in terms of innovative output (p<.05) and that, as expected, firm size is negatively associated with the share of new product revenues (p<.01). For industry types, we find that services providers (other than those in IT and telecom, engineering and commercial R&D) are less likely to report a high share of new product revenues (p<.05).

The second model adds the share of remote partners, i.e. the share of innovation partners not from the Netherlands and its neighboring countries. This model tests our presupposition that more intense remote partnering is associated with generally better innovation performance. As model fit improved significantly ( $\Delta -2*LL=8.6$ ,  $p<.01$ ), and the effect parameter of the share of remote partners was positive and significant ( $p<.01$ ), this presupposition is confirmed.

The third model then tests our main hypothesis on the moderating role of absorptive capacity. Compared to the previous model, goodness-of-fit improved significantly at the 5% level and the effect parameter was significant ( $p<.05$ ). To evaluate the significant interaction effect, we rearranged the regression equation in simple regressions of the share of new product revenues, with the share of the remote partners as the focal independent variable, and at conditional values of R&D intensity. Following Aiken and West (1991), we evaluated these simple regressions at high scores for the moderating variable (one standard deviation above the mean of R&D-intensity), at its average score, and at low scores (one standard deviation below the mean). Figure 1 shows the simple equations.

**Figure 1. Simple tobit regression models of the share of new product revenues (n=250)**



At average R&D intensity, figure 1 clearly displays that the share of remote partners is positively associated with the new product revenue share. At high values the relationship becomes more pronounced, i.e. remote collaboration is even stronger related with innovative performance ( $b=2.028$ ,  $p<.001$ ). In contrast, at low values of R&D intensity the relationship disappears ( $b=.150$ ,  $p=.74$ ). These findings imply that the higher the R&D intensity (absorptive capacity) of high-tech small firms, the more they are able to benefit from remote collaboration. Our hypothesis is supported. Moreover, R&D intensity can be regarded as a necessary condition to benefit from remote collaboration – since at low levels of R&D intensity, remote collaboration is not related with higher shares of new product revenues.

#### *Sensitivity checks*

From here, we explored the robustness of our findings (output available on request). In the first instance, we were concerned to know if our findings were sensitive to alternative formulations of the dependent variable. Without log transformation of the share of new product revenues our findings were maintained. We also computed the log-odds ratio for the dependent variable – defined as  $\log(\text{share newprod}/(1 - \text{share newprod}))$  – to obtain an alternative dependent variable which was continuous, normally distributed, and not censored. We then repeated all analyses drawing on OLS regression models, and found nearly identical results.

Second, we investigated to what extent our results were sensitive to the operationalization of the share of remote innovation partners. In the web survey respondents had provided the places of settlement (city, country) of their innovation partners. Drawing on route planning software, we computed the approximate geographical distance to each collaboration partner. If collaboration partners were settled in the same town, the geographical distance was assumed to be one kilometer. We then applied alternative definitions by computing the share of remote partners at various spatial levels, imposing thresholds of 250, 500, 750 and 1 000 kilometers, and repeated all analyses drawing on these alternative indicators. When the thresholds of 750 and 1 000 kilometers were used, all our findings were confirmed (including the significant interaction effect). In case the threshold was at 250 or 500 kilometers, only the main

effects were identical, but the interaction term was not significant anymore. Note however that these lower distances can be traveled back and forth in a day, while at the greater distances visiting collaboration partners nearly always implies staying at least one night and taking an airplane. In conclusion, these findings suggest that absorptive capacity matters to benefit from remote collaboration – but they also suggest that absorptive capacity is less crucial when relatively small distances are concerned.

## **DISCUSSION**

It is broadly accepted that external collaboration generally enhances the innovative performance of firms. Moreover, the literature suggests that collaborating with more distant partners may be particularly beneficial by increasing the likelihood of accessing novel, non-redundant knowledge and resources (Greunz, 2005). Simultaneously however, geographical distance may frustrate the benefits of collaboration, by complicating the transfer of tacit knowledge in the absence of easy and frequent face-to-face meetings (Botazzi and Peri, 2003). Drawing on the notion of cognitive proximity (Nooteboom, 1999; Boschma, 2005), we hypothesized that firms' absorptive capacity (indicated by the percentage of R&D revenue share) moderates the relationship between remote collaboration and the innovative performance of firms. In brief, we reasoned that investment in absorptive capacity facilitates tacit knowledge transfer with remote partners, so that meeting (frequently) face-to-face becomes less critical.

Our research confirms that remote collaboration generally enhances innovative performance; at least as far as high-tech small firms are concerned. More importantly, absorptive capacity indeed moderates the relationship between remote collaboration and innovation performance (measured as the share of new product revenues). Indeed, we found that in a context of high R&D intensity, the relationship between remote collaboration and innovation was more positive and more strongly significant. Conversely, in the case of low R&D intensity the relationship disappeared. This implies that absorptive capacity can be regarded as a necessary condition for successful innovation collaboration at greater distances.

These findings are in line with, and are another empirical demonstration of, Cohen and Levinthal's (1989; 1990) original conceptualization of the indirect value of

R&D. In other words, beyond a direct association with innovation performance, R&D also advances organizational learning. Moreover, we found empirical support for Boschma's (2005) proposition that geographical proximity is neither a sufficient nor a necessary condition for effective innovation collaboration, but indirectly our findings suggest that it is cognitive proximity which matters for knowledge transfer and inter-firm learning – and business do not necessarily have to be geographically close for this.

Of course, geographical proximity would still ease the effectiveness of collaborative efforts. Our descriptive statistics indeed revealed that most partners were located 'fairly' close. Only 12 percent of the reported collaboration partners were not from the Netherlands or its adjacent countries. This makes it reasonable to conclude that high-tech small firms will prefer and search for local partners in most cases. Moodysson and Jonsson (2007) noted similar behavior for Danish and Swedish biotechnology firms. However, 'when it comes to the need for highly specialized, qualified and sophisticated services, costs of overcoming distance play only a modest role, and quality, not proximity, is the decisive factor' (Drejer and Vinding, 2005: p. 893). Whilst earlier findings (Drejer and Vinding, 2007; de Jong and Freel, 2010) demonstrated that absorptive capacity enables firm to effectively search for and reach collaboration partners at greater distance, we find here that it also helps overcome the barriers to knowledge transfer imposed by large geographical distances, and is necessary to actually benefit from such collaborations.

### *5.1 Implications*

For managers and business owners in high-tech small firms our findings suggest that remote collaboration by itself is not a sufficient condition to enhance innovative performance. In order to harvest distant expertise, high-tech small firms need some level of absorptive capacity to enable tacit knowledge transfer and inter-firm learning. Our results indicate that a highly developed absorptive capacity is particularly crucial for collaborations at distances (i.e. those partners who cannot be easily reached in a day and with whom personal interactions are inevitably more limited – in the present study, beyond the Netherlands, Belgium or Germany, or more specifically, beyond 500 kilometers). From this perspective, spending a higher share of revenues on R&D or, more

broadly, increasing investments in workforce knowledge and competences, will better place the organization to communicate and interact with cognitively distant partners. This, in turn, implies that the firm has effective access to a broader pool of knowledge.

Moreover, where high-tech small firms dedicate only a limited part of their revenues to R&D, concentrating collaboration efforts on local partners would seem the first best strategy – our results tentatively suggest that ‘local’ denotes the ability to conduct face-to-face meetings with partners in one day trips. Beyond this, firms might consider finding others ways to ensure cognitive proximity with remote partners. The work of Boschma (2005) suggests that smaller organizational, social and institutional distances may also facilitate successful collaboration. This, then, would imply that search activities (and subsequent engagement) is more limited in scope. For instance, emerging collaborations may be better limited to culturally similar countries and organizations. We must stress, however, that this latter recommendation does not directly draw from our evidence, though echoes of it have featured elsewhere (Gertler, 1995).

For innovation policymaking regarding high-tech small firms, our findings shed a new light on policy interventions which are driven by geography. A first observation is that many current policy instruments revolve around stimulating interactions (Tsipouri, Reid and Miedzinski, 2008), and such policies frequently focus on geographically bounded regions (e.g., regional clusters or countries). As Torr  (2008) claimed: ‘the search for synergies between local actors has become the basis for most policies of local development’ (p. 875). Current cluster policies are biased towards local networking while the potential benefits of extra-local knowledge transfer are ignored. A necessary condition for adding this dimension to policy, however, would be that targeted firms develop or maintain some threshold level of absorptive capacity. An emerging trend, however, is that policymakers are starting to explore the development of global innovation policies (OECD, 2008). Influenced by Open Innovation theory (Chesbrough, 2003), it is thought that global knowledge search and transfer strategies are increasingly necessary and that existing policies needs to be modified accordingly (OECD, 2008). Advanced absorptive capacities, again, become a crucial ingredient for companies seeking to engage with these ‘global pipelines’ (Bathelt, Malmberg and Maskell, 2004).

As a consequence, and as private enterprises appear to downsize their commitment to fundamental research (EIRMA, 2004), traditional R&D policies will still be needed.

### *5.2 Suggestions for future research*

Our study has limitations which directly inform opportunities for future research, and these go beyond the usual plea for replication in different contexts to enable generalization. Firstly, we were constrained by data collected for a broader purpose. Our reasoning revolved around the necessity of geographical proximity and absorptive capacity in relationship to high-tech firms' ability to learn. Measurements of other forms of proximity, including organizational, social and institutional proximities (Boschma, 2005), were not available. In future work it would be interesting to collect data on the potential alternative explanations why and when remote collaboration would work.

Another limitation is the conceptualization and measurement of absorptive capacity. How to operationalize the concept has been subject of a debate which still continues today (e.g., Zahra and George, 2002; Xia and Roper, 2008). For example, Zahra and George (2002) suggested a distinction between potential and realized absorptive capacity. The former is concerned with the acquisition and assimilation of external knowledge, and the latter on transformation and exploitation. Practically our indicator is narrow, as absorptive capacity is determined by more than R&D (e.g., employee embodied competences). On the other hand, cumulative R&D was central in Cohen and Levinthal's (1990) original work and its cross-sectional intensity has been broadly applied in empirical studies. Moreover, we suggest that it is a suitable indicator in our specific sample, as high-tech firms' core activity is the commercialization of technologies by (also) engaging in R&D. Nevertheless, in broader samples other and more encompassing indicators for absorptive capacity will ideally be employed.

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