DO CLUSTERS AS OPEN INNOVATION SYSTEMS ENHANCE FIRMS' INNOVATION PERFORMANCE?

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ABSTRACT

Success stories of a few regions like Silicon Valley indicate that regional technology clusters yield innovation. However, the empirical evidence on how firms acting in technology clusters may benefit in their innovation activities is scarce. This paper contributes to the micro-foundation of cluster effects by examining characteristics and activities of the cluster firms that are linked with the firms' innovation performance. We hypothesize that the interaction intensity within the cluster and the firms' innovation-related cooperation experience (relational embeddedness) will be positively associated with the innovation output of the firms. The relationship between cluster-internal interaction and a firm's innovation performance is expected to be moderated by the firms' absorptive capacity. In addition, it is proposed that cluster internal interactions need to be complemented with well-developed external cooperation to transfer critical knowledge beyond the cluster boundaries, and thus to reduce the risk of technological lock-ins resulting from 'cluster blindness'. We draw the data from a survey conducted in two regional ICT clusters located in Germany and Switzerland. Based on information received of 107 cluster firms, we employ Partial Least Square Regression Analysis (PLS) to test the structural relationships of the model.

The findings show that firms' relational embeddedness in cluster-internal and -external innovation partnerships significantly enhances their innovative success which in turn has a positive impact on their overall performance. However, we find no empirical evidence for often suggested hypothesis that cluster-internal interaction enhances firms' innovation performance per se. And although our findings indicate the existence of an indirect effect of firms' absorptive capacity on the association between intensity of cluster interactions and innovative performance, this shows not to be significant.

Using micro-level data, this study contributes to providing firms with a better basis of decision-making for investments in cluster-specific activities. Furthermore, also policy makers and cluster management can benefit from a better understanding of the effects of regional clusters at firm-level and its underlying mechanisms.

INTRODUCTION

According to the knowledge-based view of the firm (KBV), heterogeneous knowledge bases and capabilities constitute a key ingredient of value creation and innovation in firms (Grant 1996, Spender and Grant 1996, Kogut and Zander 1992, Nonaka et al. 2000). Instead of developing capabilities exclusively in-house, firms are increasingly relying on multiple external sources of knowledge which accumulate over time (Grant and Baden-Fuller 2004). In most industries, the firms resemble open systems continuously interacting with their environment. Innovative firms manage to combine 'firm-specific' and 'firm-addressable' resources which are at least partly controlled by the firm to gain competitive advantage (Sanchez and Heene 2004, Sanchez et al. 1996, Øystein 1996, p. 177). Also the relational view (RV, Dyer and Singh 1998) points to the important role of networks (i.e. inter-firm relations) as sources of competitive advantage (Dyer and Kale 2007, Lavie 2006, Duschek 2004). From this perspective, relation-specific assets such as knowledge sharing routines or effective governance structures for cooperation are major sources of so-called relational rents (Dyer and Singh 1998, Dyer and Kale 2007). Likewise, the literature on open innovation (OI) highlights the relevance of networks of interrelated firms as key factors in the ability to generate innovations (Chesbrough 2006, van de Vrande et al. 2010).

The present study investigates to what extent the information exchange and collaboration among firms located in regional technology clusters is an important element of the open innovation system of firms. '*Geographical concentrations of interconnected companies and institutions in a particular field'* (Porter 2000, p. 15), thus regional clusters are often interpreted as an important ecosystem for open innovation. Researchers have proposed that innovation in knowledge-intensive industries often remains geographically concentrated because tacit knowledge is exchanged more easily through locally embedded social networks (Ketels and Memedovic 2008, Asheim and Gertler 2006, Porter 1998). Based on the idea that proximity matters for innovation being located in a cluster is believed to enhance innovative performance. It is argued that clusters as 'knowledge accessing institutions' allow for an improved access to innovation-related knowledge, facilitate knowledge spillovers and interactive learning processes, and, by this, yield innovation (Tallman et al. 2004, Caniëls and Romijn 2005, Zaheer, Bell 2005).

With his seminal publication 'The Competitive Advantage of Nations', Porter (1990, 1999) laid the ground for a widespread resurgence of interest in the issue of regional clusters. With respect to clusters as open innovation ecosystems, the evolving knowledge-based cluster theory is of specific interest as it highlights the role of interactive learning processes and the development of relational capital as primary source of positive cluster effects (Bahlmann and Huysman 2008, Bathelt 2008, Cooke 2007, Staber 2007, Mesquita 2007). However, although knowledge on clusters has improved considerably, there are questions relating to the micro-foundation of clusters which have not been covered sufficiently. So far quantitative empirical investigations on the specific innovation-related benefits that firms derive from clusters are scarce. Little is known regarding how, and through what mechanisms proximity conveys innovation value to clustered firms (Mitchell et al. 2010, Boshuizen 2009, Nooteboom 2004). The few studies focusing on clusters and firms' innovativeness deliver partly contradictory results (Jiménez and Junquera 2010, Karaev et al. 2007). Accordingly, they provide conflicting advice to managers and policy makers how to reap the benefits of clusters for fostering innovation.

Therefore, we examine the following research questions:

(i) Does the availability and accessibility of cluster-specific resources such as knowledge and competencies facilitate clustered firms' innovativeness and performance?
(ii) Do firms' internal capabilities (e.g., absorptive capacity) have an impact on cluster-related benefits?

This study makes two important contributions to the field. Firstly, we add to the understanding of cluster effects on the firm level. So far, the research interest in clusters has been primarily on aggregated effects of cluster on the regions' innovativeness and competitiveness, leaving firm-level effects unexplored. By synthesising research from divers research streams including innovation, management and regional geography, we respond to calls by numerous authors to explore the 'black box' of cluster effects. Secondly, due to the lack of empirical evidence firms' often do not perceive the potential value of clusters for their innovation activities and competitiveness to the same extent as researchers and policymakers (Schiele 2008). Using micro-level data, this exploratory study will contribute to providing firms with a better basis of decision-making for investments in cluster-specific activities. Furthermore, a deepened understanding of the effects of cluster at firm-level and its underlying mechanisms is a prerequisite for a target design of cluster policies and management.

The remainder paper is organized as follows. First, an overview of prior research on clusters and firms' benefits is provided. From this, we develop hypotheses on the relationship between the involvement of firms in regional clusters and the firms' innovative performance. Next, the data sources and variables used in this study are presented, followed by the empirical results. Conclusions, limitations and directions for further research are outlined in the final section.

THEORETICAL BACKGROUND AND HYPOTHESES

The theoretical background section is organised in three parts. First, we provide an overview of core insights that shaped the field of cluster theory. In the second part, we present prior research on cluster effects. Based on this discussion, we formulate the hypotheses in the third part of this section.

Conceptualising clusters

As depicted in figure 1, clusters can be characterised by four constituent elements. Clusters facilitate agglomeration economies arising from **spatial proximity** (Porter 2000). They are also characterized by **sectorial concentration** meaning that most of the firms belong to a particular industry or technology field ('related variety', see Boschma and Iammarino 2009, Frenken et al. 2007). **Interactions** among regional stakeholders distinguish clusters from pure agglomerations. These links refer likewise, to horizontal and vertical relations between firms, market-based transactions, and untraded or informal relationships as well as to institutional ties between firms, research organisations and public bodies (Rocha and Sternberg 2005). Finally, clusters are characterized by a high degree of stickiness of specific **knowledge** (Gertler and Wolfe 2008, LeSage and Fischer 2012). Such 'embedded knowledge' is based on routines, habits and norms established through collaborative experience (Moodysson and Jonsson 2007, Bathelt et al. 2004).

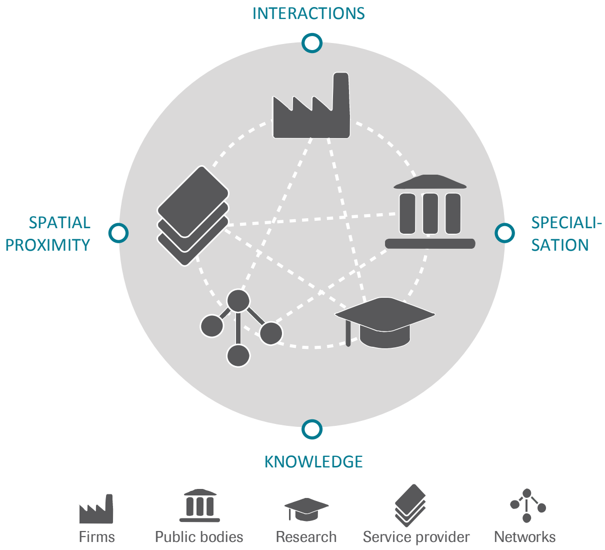

Figure 1: Clusters' constituent elements

Porter (2003, 1990) identified three mechanisms through which clusters affect firms' competitiveness: Firstly, clusters contribute to gains of productivity resulting from factor conditions such as access to specialised workforces, information, and complementary resources, as well as resulting from competition. Secondly, clusters improve firms' innovativeness due to favourable demand conditions which increase the competitive pressure forcing firms to innovate. Thirdly, clusters stimulate business formation, which in turn facilitate innovation and cluster growth. Following Porter, innovation is driven by the recursive interplay of competitive and cooperative forces, while emphasis is on competition.

Subsequent work has emphasised on the social and relational dimension of clusters. These **multidimensional cluster approaches** take an integrated systemic view of market and social relations (Kiese 2008, Bathelt 2004, Bathelt et al. 2004, Bathelt and Taylor 2002). The multidimensional concept as point of origin, innovation and learning are the key outcomes of the inter-organizational relationships, and knowledge is the core strategic resource (Bahlmann and Huysman 2008). For example, Hervás-Oliver (2011) strives to bridge RBV, the concept of dynamic capabilities and absorptive capacity to explain firms' benefits from knowledge flows within clusters. Channels of knowledge transfer and interactive learning processes comprise horizontal interactions, vertical relations among competitors, formal and informal cooperation, spin-offs and workforce mobility (Hervás-Oliver 2011, Isaksen 2007, Bathelt et al. 2004).

Spatially-bound personal contacts are a precondition for the transfer of implicit knowledge and fuel the spatial concentration of innovation activities and the formation of clusters (Bahlmann and Huysman 2008, Bathelt 2008). In addition, it is argued that the more divers the relationships between cluster actors, the better the access to new ideas and knowledge, providing enhanced opportunities for innovation (Hervás-Oliver and Albors-Garrigós 2009, Bathelt 2008). A diverse cluster-specific knowledge base allows clustered firms to continuously recombine existing and generate new knowledge as basis for future innovation.

Spatial proximity does not only contribute to an enhanced personal contacts but also to a more effective knowledge transfer in relational knowledge spillovers between co-located parties (Sreckovic and Windsperger 2011, Arikan 2009). It is also argued that cluster contribute to a reduction of transaction costs, namely the costs for the identification, accessibility and transfer of innovation-related knowledge, as well as to a reduction of innovation-related uncertainty due to the divers knowledge sources available a cluster (Gilbert et al. 2008, Malmberg and Maskell 2002, p. 434). Channels of knowledge transfer and interactive learning processes comprise horizontal interaction, vertical relations among competitors, formal and informal cooperation, spin-offs and workforce mobility (Hervás-Oliver 2011, Isaksen 2007).

Empirical research on cluster effects

A series of studies deals with spatial proximity and its contribution to dynamic agglomeration economies. While older studies on knowledge spillovers and innovation in clusters conclude that spatial proximity per se yields innovation (Baptista 2000, Feldman 1999, Audretsch and Feldman 1996), more recent studies show that spatial proximity needs to be complemented by cultural, cognitive and/or organisational proximity to give impetus for interactive learning and innovation (Torre 2006, Capello and Faggian 2005, Amin and Cohendet 2004).

Another trend in cluster-related research since the mid-2000s is the shift away from the macro- towards the micro-level as unit of analysis. This trend is reflected by an increasing number of studies devoted to the role of clusters in business formation and growth (Delgado et al. 2010, Maine et al. 2008, Rocha and Sternberg 2005).

Besides, a series of studies investigates with differing foci the interplay of cluster membership, firm performance, innovativeness and/or interactions. However, the empirical results are by no means consistent: Analysing the financial performance of firms in semiconductor and pharmaceutical industries, Kukalis (2010) revealed no significant performance differences of clustered and non-clustered firms in the early industry lifecycle, while in the later phases non-clustered firms outperformed clustered. Likewise, Beaudry and Swann (2009) show that only in half of the 56 two-digit industries in UK they examined, there is a positive and statistically significant association between firm growth and the strength of the cluster to which a firm belongs. They conclude that cluster effects are strongest in manufacturing, manufacturing-related, and infrastructure industries, but weaker in services. Isaksen (2006) finds only a weak positive correlation for the Norwegian software sector.

These results are in inconsistent with other studies finding a positive cluster effect on firms' innovative performance. Baptista and Swann (1998) suggest a positive correlation in manufacturing industries. The results of Folta's et al. (2006) comparative analysis of biotechnology firms in USA, Israel, Sweden, India and UK basically supports the existence of a positive cluster effect on the innovativeness of firms. The study also reveals, however, that this effect decreases with cluster size or even revers. Studying two information and communication clusters in Germany and China Zhao et al. (2010) show that especially soft factors, such as network mechanisms in clusters, positively affect firms' innovative performance. Moreover, their research suggests that the extent to which a given firm benefits from being located in a cluster depends on the intensity of cluster-related activities of this firm.

Likewise empirical evidence concerning the effect of dynamic agglomeration economies and firms' innovation performance are contradicting: For example, Huber (2011) does not find support for a positive correlation between knowledge spillovers, access to cluster-specific knowledge, learning processes and firms innovative performance in the Cambridge ICT cluster, while Cotic Svetina et al. (2008) find a negative correlation between inter-firm interactions and innovative performance. By contrast, Ibrahim et al. (2009) reveal for telecommunication industry in USA a statistically significant overall influence of localised knowledge sources and in particular of not-indented knowledge spillovers, pointing to the importance of clusters to firms innovative performance.

Summarising, the outlined studies exhibit quite heterogeneous results which do not allow for clear conclusions on cluster, firms' innovativeness and performance.

Hypotheses

To sustain competitive advantage firms must be able to continuously update their knowledge base (Prahalad and Hamel 1990, Zahra and George 2002). At the same time they need to find a balance between knowledge exploitation which requires diversity, and knowledge exploration which asks for specialisation (Al-Laham et al. 2011, Grant and Baden-Fuller 2004, Mahoney and Pandian 1992). Interactions with firms' external environment contributes to knowledge acquisition and enhances their learning and innovative capacities (Al-Laham et al. 2011, p. 12, Grant and Baden-Fuller 2004).

Following the relational view, networks have the potential to open the access to locally bound resources which, in turn, helps the firms in bundling complementary resources. Investments in relational assets also allow for an optimization of inter-firm business processes through co-specialisation (Dyer and Singh 1998, p. 662, Dyer and Kale 2007, pp. 67f.). Routines for a continuous inter-firm knowledge exchange foster learning and capacity building. Proximity within clusters favours the evolvement of unique mechanisms of knowledge transfer, generation and recombination. In the view of KBV, this common reference framework paves the way for an enhanced access to innovation-related knowledge and competencies. Assuming that firms rely on a multiple knowledge sources and competencies in order to innovate, we hypothesise as follows:

H1: The intensity of a firm's interaction within the cluster are, the higher the impact of cluster membership on a firm's innovation performance is.

As it is highlighted by the multidimensional cluster approaches, interactions within clusters can range from competitive to cooperative relationships at vertical, horizontal and lateral level. With respect to innovation, especially the cooperative relationships within a cluster should have the potential to create an advantage. Firms perceived as trustworthy are expected to gain access to knowledge and competences which remain hidden or non-accessible for other clustered firms. Forasmuch, firms' relational embeddedness in a cluster, measured as the level of innovation-related joint activities with other firms in the cluster, should help to get access to new ideas and complementary innovation-related knowledge. It seems reasonable that firms which are embedded in joint innovation activities develop a cognitive proximity, a common understanding of key concepts and a joint knowledge base. A common reference framework for collective learning does not only contribute to the acquisition of new knowledge but also reduces the uncertainty about the quality and usefulness of the acquired knowledge (Bathelt 2005, Maskell and Lorenzen 2004, Bathelt and Taylor 2002).

A track record on cooperative innovation activities also fosters the development of trust, cooperation routines, habits and shared norms which, in turn, should facilitate the exchange of sticky information and should enhance the willingness to transfer valuable knowledge (Moodysson and Jonsson 2007, Bathelt et al. 2004, Maskell and Malmberg 2007, Asheim and Gertler 2006).

In sum, a firm's relational embeddedness seems to have a great potential for enhancing the cluster firms' capabilities in developing a constant stream of successful innovations.

H2: Firms' relational embeddedness in a cluster has a positive impact on its innovation success.

In the management literature it is widely accepted that firm's absorptive capacity, - i.e. their ability to identify, acquire, understand and exploit external knowledge - directly influences its innovative capacity and performance (cf. Al-Laham et al. 2011, Escribano et al. 2009, Hervás-Oliver and Albors-Garrigós 2009, Boschma and Ter Wal 2007, Lichtenthaler 2009). In this study, however, we emphasise on the enabling role of absorptive capacity. The relationship between the interaction intensity in the cluster and the firms' innovation performance (see H1) is expected to be moderated by the firms' absorptive capacity (Cohen and Levinthal 1990, Zahra and George 2002, Todorova and Durisin 2007, Camisón and Forés 2010).

In the context of clusters, the ability of a firm to participate in interactive processes of learning is limited by its internal resources and capacities. The better a given firm manages to achieve compatibility between its internals knowledge base and the knowledge embedded in the cluster network, the more it will benefit from knowledge transfer in the cluster. It is therefore to be expected that firms with high levels of absorptive capacity are in a better position to identify and exploit cluster-specific knowledge that complements what they already know. We therefore propose:

H3: A firm's absorptive capacity moderates the association between the intensity of cluster internal interactions and a firm's innovation performance. The relation is stronger for firms with higher levels of absorptive capacity.

It is a commonly held assumption that there is a need of a continuous inflow of knowledge into a cluster. These 'inflows' are vital to maintain the clusters' innovation dynamic, to prevent negative lock-in effects due to 'cluster blindness" or 'overembeddedness', and therewith, keep up firms' innovativeness and competitiveness (Boschma 2005, Bathelt et al. 2004, Bathelt and Taylor 2002).

This insight on the cluster level can also be transferred on the level of the cluster firms. It is proposed that interactions within the cluster *('local buzz')* need to be complemented by well-developed external linkages *('global pipelines')* to rejuvenate their knowledge base over time (Boschma and Ter Wal 2007, Giuliani 2008, Rocha and Sternberg 2005, Bathelt et al. 2004). Particularly because the number and the variety of potential cooperation partners within a cluster is usually limited, clustered firms probably benefit clearly from the interaction with partners beyond the cluster's boundaries. In contrast to cluster internal interactions the establishment of trustworthy relationships with external partners is due to a lack of cognitive proximity always characterised by higher uncertainty and investments (Morrison 2008). However, these relationships can be expected to complement the knowledge transferred and exploited through cluster-internal relationships. We therefore propose an interaction effect between the level of cluster-internal and cluster-external communication.

H4: A firm's intensity of cluster-external interaction moderates the association between cluster internal interactions and a firm's innovation performance (cluster-orientation). The relation is stronger for firms with higher levels of cluster-external interaction.

In addition, a direct effect of a firm's relational embeddedness in external networks on its innovative success is expected.

H5: A firm's relational embeddedness in external networks is positively associated with its innovative success.

As firms rely on continuous innovation activities to sustain their competitive position in dynamic markets, it is assumed that innovation performance and innovative success positively impact a firm's performance.

H6: A firm's innovation performance and innovative success is positively associated with its overall performance.

In order to test the outlined hypotheses, we formulate a structural equation model comprising five latent exogenous variables – *cluster-internal interactions, cluster-orientation, cluster-internal and –external relational embeddedness and absorptive capacity* – and three latent endogenous variables – *innovation performance, innovative success and firm performance*.

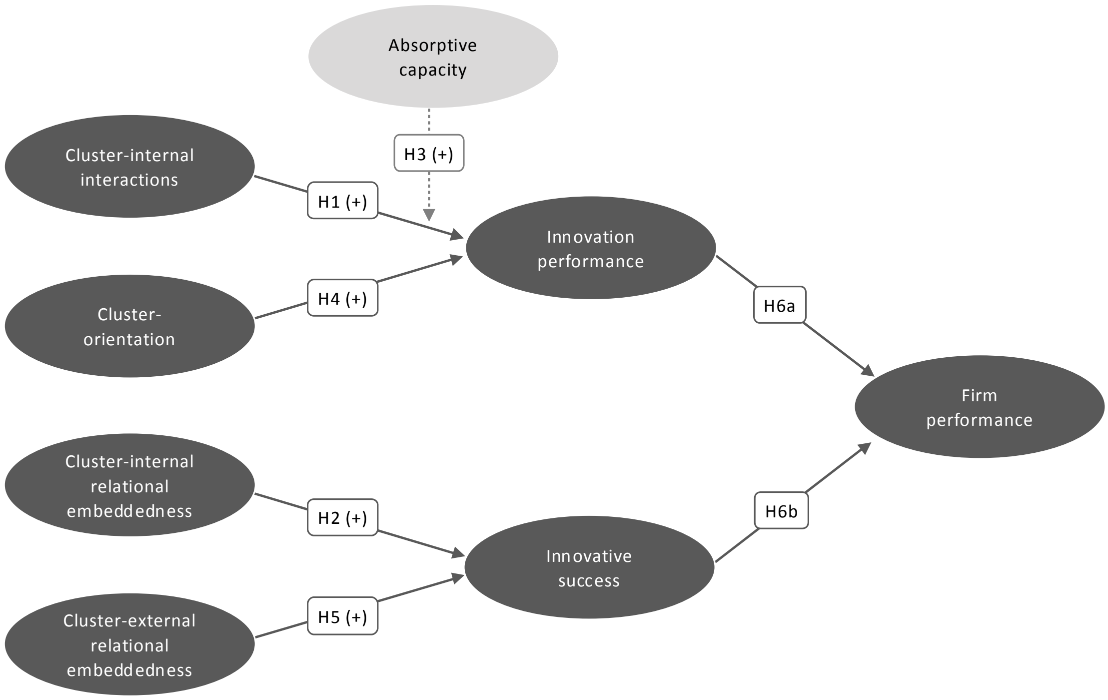

Figure 2: Theoretical deduced structural equation model

DATA AND METHODOLOGY

The empirical field of the present study is composed of two regional ICT clusters located in Germany and Switzerland. ICT sector was chosen as it is regarded as a key sector in knowledge economy characterised by knowledge-intensity and a high pace of innovation (Weterings and Boschma 2006, Tsang 2005). In addition, ICT sector as a whole as well as its sub-segments tend to cluster (Zhao et al. 2010, Koski et al. 2002, Quah 2001). The data analysis employs Partial Least Square analysis to explicitly account for moderating effects, as well as for formative and reflective constructs.

Sample description

The data is collected from questionnaire surveys from company managers. The two clusters comprise 505 cluster members from Germany (325) and Switzerland (180) including firms, research organisation and public bodies. The data was collected by means of an electronic questionnaire that was sent to the companies with a cover letter personally addressed to the contact person listed in the cluster organisations databases

After two written reminders and several telephone reminder calls, 150 completed questionnaires were received, representing a response rate of 29.7%. Omitting those with incomplete data at the central questions, 107 questionnaires were used in this study (rate of usable responses = 21.2%). The relatively high rate of non-responses to central questions such as innovation activities might be attributed to the high number of rather small firms which were not willing to provide the related information.

Approximately 30% of the respondents are micro enterprise with less than 10 employees, 60% are small and medium-sized enterprises (10 to 249 employees) and the remaining 10% are large enterprises with more than 249 employees. The distribution of firms by age is as follows: 28% younger than 9 years, 33.6% between 10 to 19 years, 32.7% between 20 to49 years and 5.6% older than 49 years.

More than half of the respondents are highly specialised in their respective segment, while only 20% of the sample reported to generate the predominant share of their turnover with many different products/services. More than half of the firms surveyed are active in soft- and hardware, about 33% in software and 10% in hardware only. The vast majority of respondents target regional and national markets (81.3%), additional 8.4% international markets and about 10% reported to serve equally regional, national and international markets.

As depicted in figure 3, the most respondents in the sample (96.3%) can be classified as 'innovative firms' having introduced either new products/services, processes or both.

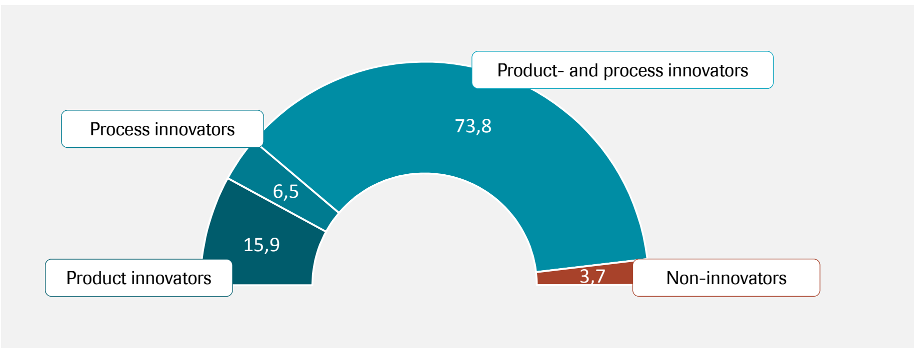

Figure 3: Innovative firms (%)

Methodology and measures

As aforementioned, the developed structural equitation model is estimated using Partial Least Square (PLS) approach introduced by Wold (1982) and further developed by Lohmöller (1989). Considered as a ‘soft modelling’ approach, PLS has proven to be particularly advantageous with non-normal distributions, small sample sizes and combinations of formative and reflective measurement models (Vinzi et al. 2010, Henseler et al. 2009, Diamantopoulos et al. 2008). PLS distinguishes between two sets of linear equations: the inner model (structural model), defining the relationship between latent variables, and secondly, the outer model (measurement model), linking latent variables with a set of manifest variables (Henseler et al. 2009).The estimation comprises three stages: (i) the iterative estimation of latent variable scores, (ii) the estimation of outer weights/loadings and path coefficients and (iii) the estimation of location parameters (Tenenhaus et al. 2005).

All constructs considered in this survey addressed clusters’ corporate members only, and were, therefore, specified for the firm-level. Multi-item measures are used for the interaction frequency and relational embeddedness inside and outside the cluster (Alegre and Chiva 2008, Boshuizen et al. 2009, Ter Wal and Boschma 2009), the absorptive capacity (Lichtenthaler 2009, Abreu et al. 2006, Jansen et al. 2005), as well as for the innovative success (Forsman 2009, Carter 2007, Powell and Grodal 2006). Respondents were asked to rate the single items in the questionnaire on seven-point Likert scale, where 1 = fully disagree and 7 = fully agree. Innovation performance is measured by the number of radical and incremental product/service innovations, improvements of existing products/services as well as process innovations introduced during the past three years.

For two of the five exogenous variables a formative measurement model was applied and the remaining three were specified as reflective constructs. All endogenous variables were measured reflective. The reflective manifest variables are determined by the latent variable and should be highly correlated. In contrast, formative measurement models are applied when an explanatory set of indicator variables underlies the latent construct and, therefore, do not necessarily be correlated (Diamantopoulos et al. 2008, Jarvis et al. 2003, Diamantopoulos and Winklhofer 2001). That is, the direction of causality is from the indicators to the latent construct.

Exogenous variables

Cluster-internal interaction and cluster-external interaction are specified as reflective constructs with five items representing the horizontal, vertical and lateral cluster dimension. The decisive criterion here was that according to knowledge-based cluster theory interactions along the horizontal (competitors), vertical (complementary firms and customers) and lateral dimension (research organisations and public bodies) are equally important for interactive learning and knowledge generation. Respondents were asked to assess the frequency with which they interact internally and externally with the above stakeholders.

Firms’ *cluster-orientation* is specified as formative construct consisting of five items reflecting their orientation in respect to the aforementioned stakeholders. For each item a quotient from cluster-internal and –external interaction frequency was calculated.

Relational embeddedness expressed by the quality of interaction within and outside the cluster is specified as formative constructs. The respondents were asked to indicate whether they cooperate in the framework of their innovation activities in the field of knowledge exchange, joint projects or both with the aforementioned stakeholders in course of their innovation activity.

Adapting scales from earlier studies, firms’ *absorptive capacity* is modelled as reflective construct consisting of variables referring to the acquisition, assimilation, transformation, and exploitation of external knowledge (cf. Camisón and Forés 2010, Lichtenthaler 2009).

<u>Endogenous variables</u>

Innovation performance is modelled as reflective construct of five items representing the different types of innovations: (i) product/service innovation new to the market, new to the firm and incremental innovation in terms of improvement of existing products/services, and (ii) process innovation in form of cost-cutting innovations and quality-enhancing innovations.

Innovative success is measured by assessing the degree to which (i) the introduced market and firm innovation launched more successfully in market, (ii) more additional markets beyond the core business could be entered, and (iii) the overall market success was higher compared to its competitors.

A *firm's performance* is measured reflective by the single indicator development of revenues during the past three years.

RESULTS

In the first section we present some descriptive findings of the study.

The contacted firms were asked to indicate, for which purposes they use the network of firms and organizations located in the cluster. The answer to this question shows that the participating firms use the cluster most frequently for knowledge transfer and general market observation, while more direct and cooperative forms of interaction such as joint projects, joint internationalization activities and scanning for potential cooperation partners in the cluster are less relevant (see figure 4). Asked for the importance of the cluster for their innovation activities during the past three years about 8% of firms attributed the cluster a high importance, 48.6% a medium and 42.1% no significance. Also, the firms do hardly perceive that they benefit from the cluster in terms of the recruitment of graduated students or high potentials.

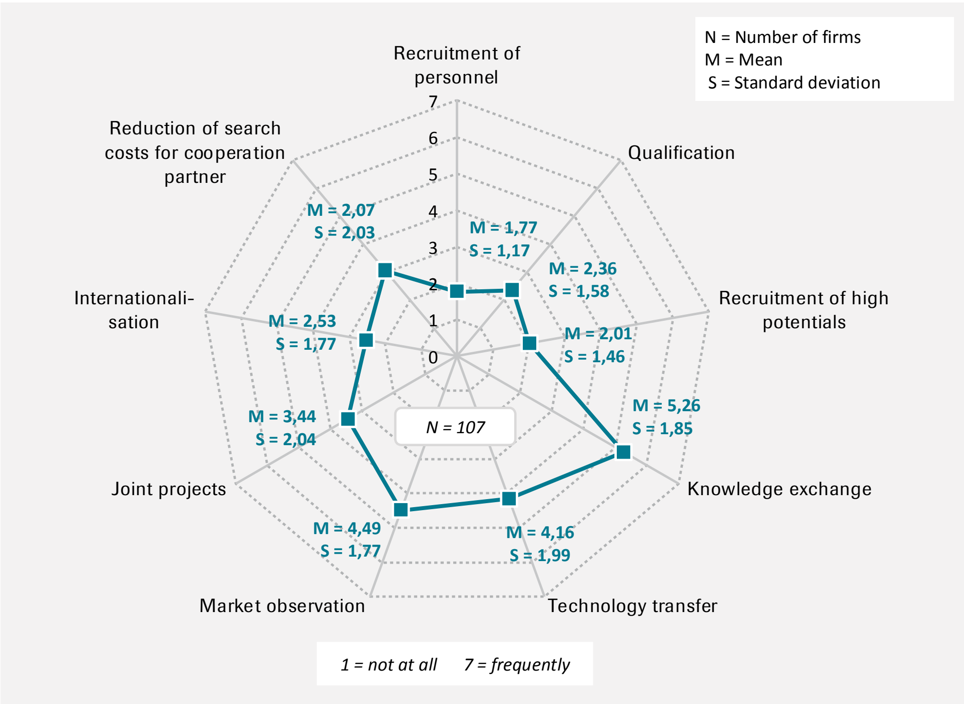

Figure 4: Cluster usage

The relatively low frequency of joint projects and technology transfer can be explained by ICT firms giving high priority to the protection of their proprietary knowledge. This is consistent with the response to safeguards for intellectual property applied by firms: More than two-thirds of the responding firms report to use secrecy and/or patents and copyrights to protect their intellectual property.

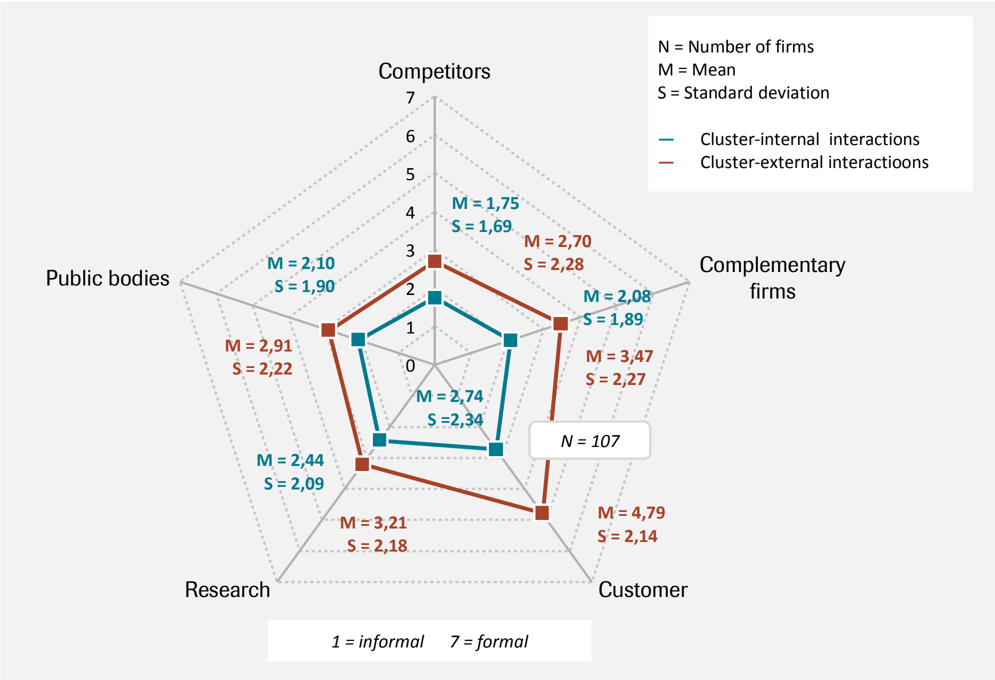

Figure 5: Cluster-internal/-external interactions – degree of formality

The descriptive results illustrate that the vast majority of respondents are involved in cluster-internal and -external interaction, although with varying degrees of intensity (see figure 5). Comparing the cluster-internal and external linkages, the findings indicate that both interaction fields are characterized by a different degree of formalization. While interactions with competitors, complementary firms, customers, research and public bodies within the cluster are rather informal, external interactions are more often based on formal arrangements. These results are in line with prior research on successful regional clusters. For example, Saxenian (1996) proposes in her study that one of the primary reasons for the relative success of Silicon Valley over Route 128 in Boston is that knowledge is easily shared through informal relationships of individuals belonging to competing firms and other cluster actors in Silicon Valley.

Analysis of measurement model

In the following we evaluate the reflective and formative measurement models applied in this study.

Evaluation of the reflective measurement model

In order to ascertain *unidimensionality* an explorative factor analysis was conducted for each reflective construct. In accordance with the Kaiser criterion, only those factors with an eigenvalue above one were extracted. In addition, factors with loadings of less than 0.4 were eliminated. Based on these results two of the nine indicators of the construct 'absorptive capacity' were dropped.

Next *indicator reliability* was assessed by examining the factor loadings. For a variable to be reliable a minimum loading of 0.7 is required, indicating that more than 50 per cent of the variance of the measure is accounted for by the construct. All factor loadings lie well above this threshold.

Composite reliability (CR) indicates a construct's internal consistency (Chin 1998). CR coefficient is superior to Cronbach's alpha as it does not assume that all indicators are equally weighted (Fornell and Larcker 1981). As illustrated in table 1, all constructs meet the threshold value of 0.7. In addition, the predictive relevance of the reflective constructs was evaluated using Stone-Geisser criterion Q^2. In our analysis, all Q2 values range above the threshold value of zero.

Finally we assessed the *discriminant validity* of the constructs indicating extent to which the items of a given construct vary from those of other constructs in the model by using Fornell and Lacker's (1981) measure of average variance extracted (AVE). To meet the requirements of discriminant validity, the square root of a construct's AVE should be above the correlation between the construct and other constructs in the model (Chin 1998, Fornell and Larcker 1981). That is, discriminant validity.

Construct	CR (>0.7)	AVE (≥0.5)	Q^2 (communality > 0)	Fornell-Lacker criterion
Absorptive capacity	0.87	0.51	0.49	passed
Innovation performance	0.84	0.63	0.62	passed
Innovative success	0.87	0.68	0.68	passed
Cluster interaction	0.89	0.62	0.62	passed

Table 1: Reliability and validity of reflective constructs

Evaluation of the formative measurement model

Quality criteria for reflective measurement models cannot be applied to formative models due to their revers causality. Therefore, careful specification is a necessity before data collection. In addition, *multicollinearity* of indicators should be assessed, because substantial correlations among formative indicators result in unstable estimates for indicator coefficients making it difficult to separate the distinct influence of individual indicators on the formative construct (Diamantopoulos et al. 2008). As related measure Variance Inflation Factor (VIF = $1//1\text{-}R^2$) assess the degree of multicollinearity and should not exceed the threshold of 10 (Diamantopoulos, Winklhofer 2001). All formative constructs are below the threshold.

In order to evaluate the quality of formative indicators, indicators weights as well as their significance can be assessed. Although weights might reach value below those of reflective indicators, they should not simply be eliminated (Diamantopoulos et al. 2008).

Analysis of structural model

The *squared multiple correlations* (R^2) of the latent endogenous variables are the essential criterion for the assessment of the structural model (Henseler et al. 2009). It indicates the explanatory power of model. Chin (1998) describes R^2 values of 0.67, 0.33 and 0.19 as essential, moderate, and weak. According to these suggestions, only the constructs of innovation performance ($R^2 = 0.22$) meets the threshold at low level. Nevertheless, the interpretation of R^2 depends on the question analysed. The relatively low values for innovative success ($R^2 = 0.12$) seem reasonable, because cluster-internal and external relational embeddedness are only two factors among other not considered factors that impact a firm's innovative success. Also, innovation performance and innovative success are just two factors effecting firms' performance. Forasmuch, R^2 values from 0.10 to 0.20 are not unusual.

Construct	R^2	Q^2 (redundancy)
Innovation performance	0.221	0.1531
Innovative success	0.121	0.0544
Firm performance	0.072	0.0384

Table 2: Structural model – squared multiple correlations and Stone-Geisser criterion

Predictive relevance for the structural model is also assessed by Stone-Geisser criterion Q^2 (redundancy) for the reflective constructs. As illustrated in table 2, all constructs are above the zero.

Testing of hypotheses

Figure 6 shows the estimated model for with its squared multiple correlations for the latent endogenous variables and the related path coefficients.

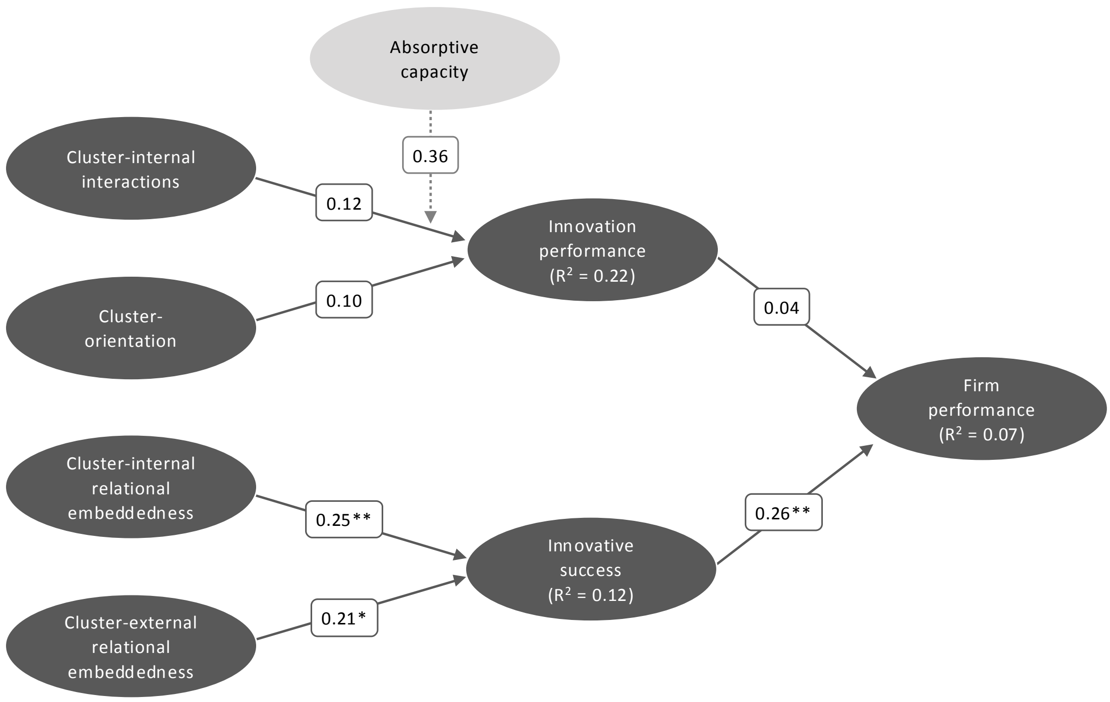

Figure 6: Results estimated model

With a weight of 0.253 the factor 'cluster-internal relational embeddedness' expresses the largest explanatory share for a firm's innovative success, while the weight of 'cluster-external relational embeddedness' (0.205) is slightly lower.

Hypothesis 2 and 5 are, therewith, confirmed. A significant positive impact of innovation-related cooperation experience (cluster-internal → $p < 0.02$; cluster-external relational embeddedness → $p < 0.05$) on firm's innovative success exists. As was expected, innovative success significantly ($p < 0.02$) impacts firms' performance *(hypothesis 6a)*.Innovation performance, in contrast, has barely any effect on firms' performance *(hypothesis 6b)*.

Most surprisingly and contrary to the expectation, the intensity of cluster-internal interactions seems not to have a significant impact on firms' innovation performance *(hypothesis 1)*. Firms' 'absorptive capacity' shows a high path coefficient (0.358), indicating its relevance as moderator variable. However, the missing significance of cluster-internal interactions, results inevitably in a non-significant moderating effect of a firm's 'absorptive capacity' on the association between the intensity of cluster internal interactions and a firm's innovation performance. Thus, *hypothesis 3* cannot be confirmed.

Likewise, the *hypothesis 4* has to be discarded, because the estimation results show barely any effect on firms' innovation performance. The results indicate that higher levels of cluster-external interactions do not complement cluster-internal interactions as was expected.

Discussion of results

This study was conceptualised to investigate whether the availability and accessibility of cluster-specific resources such as knowledge and competencies facilitate clustered firms' innovation performance, innovative success and their overall performance, while accounting for the heterogeneity firms in terms of their absorptive capacity. It is against this background that we estimated direct effects of a firm's cluster-internal interactions and cluster orientation on innovation performance as well as the moderating role of absorptive capacity. Furthermore, direct effects of a firm's prior cooperation experience, expressed by it cluster-internal and -external relational embeddedness, were considered. This distinction between frequency and quality has proven to be useful to verify the formulated hypothesised correlations.

Our empirical finding substantiate that firms' benefits from being located in a cluster originate particularly from high quality relational ties. Being engaged in innovation-related joint projects and/or intended knowledge transfer contributes to firms' innovation success and overall performance. Likewise, this applies to innovation-related cooperation with partners beyond the cluster boundaries. Therefore, it seems reasonable to conclude that firms embedded in both, cluster-internal and -external innovation-related networks, profit most from being located in a cluster. However, one has to take into consideration that maintaining relationships with distant partners bear higher risks resulting from uncertainty and missing cognitive proximity than cluster-internal partnerships. Accordingly, firms, and especially those with limited resources such as micro- and small-enterprise, need to find a balance between internal and external embeddedness which on the one hand allows for a sufficient access to and inflow of knowledge and competences, and an efficient maintenance of these relationships on the other.

Unlike other studies (cf. Zhao et al. 2010, Cotic Svetina et al. 2008) revealing positive respectively negative impacts of firms' cluster-internal-interaction on innovation performance, we could not observe any significant effect. Hence, the conclusion could be drawn that high levels of interaction per se do not enhance firm's innovation performance, but requires some form of strategic orientation. However, this does not necessarily mean that cluster-internal interaction are not valuable for the clustered firms, but might be attributed to the fact that the survey firms did not perceive the value of untraded interdependencies (e.g., intended and unintended knowledge spillovers) for their innovation activities. A further explanation could be that the majority of firms in the sample is highly specialised. As a consequence, overlapping knowledge bases as precondition for absorbing cluster-specific resources might exist only to a limited extent. Also a lack of transparency in resources available in the cluster may partly explain the low impact of cluster-internal interactions. If this is the case, cluster organisations could function as 'boundary spanners' respectively 'knowledge brokers' channelling the available resources among clustered firms.

Summarising, this study leads to a better understanding of cluster-benefits and its underlying mechanisms at the firm level, and thus contributes to the micro-foundation of clusters. Moreover, the results not only have implications for cluster theory, but also for firm and cluster managers. In order to attain substantial cluster-benefits, entrepreneurs as well as cluster manager should focus on the quality of relations rather than on the quantity (e.g., frequency of meetings, events, etc.).

Based on these findings, future studies should conduct more detailed investigations of specific cause-effect relationships, especially with regard to the motivation of firms to establish close relational ties within a cluster, as well as concerns further cluster-, inter-firm and firm-specific factors with a potential impact on innovation performance, innovative success and firm performance.

Our findings are subject of some limitations. Firstly, the sample size is small. Notwithstanding that the sample replicates the clusters' population and PLS approach is applicable to small populations, a larger dataset would lead to more robust results. Secondly, the relationships between the latent exogenous and endogenous variables should be accepted with caution, as all variables to measure the constructs were collected during a specific time period. By replicating the findings for the same sample, robustness could only be validated.

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