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Technological capability dynamics through cluster organizations

Abstract

Purpose – The purpose of the paper is to portrait how members of cluster organizations (COs) perceive the role of COs in enabling them to accumulate technological capability (TC) significant for their innovation.

Design/methodology/approach – The authors report the findings from their qualitative study based on an analysis of four COs. The organizational inertia and absorptive capacity (AC) theories are the theoretical underpinning of the research.

Findings – The study shows that the dynamics of TC of the cluster companies included in the study sample relates to their initial level of TC and cluster cooperation. The companies with relatively low initial TC increase it through COs if the clusters offer comparatively high benefits. On the other hand, those COs' members that present relatively high initial TC advance it, provided that the external knowledge and other benefits they can absorb in their clusters are suited to their technological trajectories.

Research implications/limitations – The research is preliminary in nature and portrays how firms with different levels of TC cooperate within COs and how this cooperation translates into TC improvements. The findings add to the state-of-the-art knowledge on the link between TC and AC of companies involved in COs by depicting the role of COs in providing knowledge and other cluster benefits that help cluster companies to accumulate TC and improve their AC. Nevertheless, the applied methodology does not allow the authors to generalize the findings.

Practical implications – The coordinators of COs should skillfully shape the levels of cluster cooperation, matching them to the desired level of the cluster companies. They should create smaller subgroups composed of companies with similar TC, which may translate into its higher dynamics.

Originality/value – The knowledge about the role of COs in providing cluster benefits that help cluster companies to accumulate TC and improve their AC is still insufficient. The study shed new light on the key role of the levels of cluster cooperation and the types of commitment related to them (i.e. technological effort), which may be a matter of importance in the dynamics of TC accumulation.

Keywords: Cluster organizations, Technological capability, Absorptive capacity, Cooperation, Organizational inertia

Article Classification: Research paper

1. Introduction

In the globalization era, companies are forced to develop dynamic capabilities and collaborate with others, e.g. in clusters or cluster organizations (COs), in order to gain and sustain a competitive advantage (Cenamor et al., 2019; Chandrashekar et al., 2018). The ample literature available on clusters emphasizes that operating in such a network gives access to learning and external knowledge repositories, i.e. those of other incumbents, which may further facilitate innovation and competitiveness of firms. Clusters enable their members to exchange know-how, business information, and technological expertise that contribute to the production of knowledge externalities and technological spillovers. Inter-organizational interactions provide opportunities for knowledge acquisition that can be applied to cluster companies and help to build their technological resources (Belso-Martínez et al., 2016; Brosnan et al., 2016; Giuliani, 2011; Wang and Helms, 2019). Consequently, their technological capability (TC), namely the "knowledge and skills needed for firms to choose, install, operate, maintain, adapt, improve and develop technologies" (Romijn and Albaladejo, 2002, p. 1054), can be improved (Caniëls and Romijn, 2003; Romijn and Albaladejo, 2002).

Technological capability is considered a vital strategic resource that enables companies to gain competitive advantage. Firms with superior TC are frequently pioneers in innovations and are more responsive to changing market conditions (Figueiredo, 2005; Jin and Zedtwitz, 2008; Kumar *et al.*, 2008; Tsai, 2004; Tzokas *et al.*, 2015). Therefore, the phenomenon has become a significant inquiry in prior research that, among others, emphasizes the role of internal and external determinants of TC development (Hansen and Lema, 2019; Hansen and Ockwell, 2014; Kumar *et al.*, 2008; Sobanke *et al.*, 2014). Absorptive capacity (AC) connects internal and external determinants of TC accumulation.

Absorptive capacity is the construct that links "an organization's internal capability to develop new products and improve existing ones, and external base of information and opportunities on the other side" (Murovec & Prodan, 2009, p. 859) High AC enables companies to apply the outside source of knowledge and manage the exchange of knowledge, which are seen as critical elements in building TC necessary for their innovation process (Cenamor et al., 2019; Cohen and Levinthal, 1990; Expósito-Langa et al., 2015; Hansen and Lema, 2019). The scope of the benefits which a company can reap from location in a cluster or COs relies on its "ability to establish a nexus with external sources of knowledge through intra-cluster and extra-cluster linkages" (Chandrashekar et al., 2018, p. 122) and is determined by AC. It reflects a degree of "openness and dynamic capability of a firm that drives interactions among firms in a cluster" (p. 122). Yet, due to organizational inertia companies with even high AC may be bound to their current technological trajectory, in turn, may not strengthen their TC.

As stated above, functioning in clusters or COs can be seen as an external determinant that helps to accumulate TC necessary for a focal firm's innovation. Research that tackles the links between TC and innovation or innovation and clustering is substantial (Hansen and Lema, 2019; Hansen and Ockwell, 2014; Kumar *et al.*, 2008; Sobanke *et al.*, 2014). Nevertheless, the knowledge about the role of clusters or COs in providing knowledge and other cluster benefits that help cluster companies to accumulate TC

and improve their absorptive capacity, and subsequently their innovation, is still insufficient (Caniëls and Romijn, 2003; Chandrashekar et al., 2018; Romijn and Albaladejo, 2002). Therefore, the authors intend to answer the following research question: Do and how do COs enable member companies to accumulate TC significant for their innovation? Cluster organizations, in the literature also referred to as bottom-up clusters or cluster initiatives (Lindqvist *et al.*, 2013, p.1), are formally established organizations which function at a higher level of aggregation, are composed of institutional members that have joined them purposefully and act actively in order to achieve some collective or individual objectives (Lis, 2018, p. 86)[1]. The aim of the paper is to portrait how members of COs perceive the role of clusters in enabling them to accumulate TC significant for their innovation.

The authors report the findings from their qualitative study based on an analysis of four COs from the metal and the highly internationalized ICT industry in Poland that concerns the role of knowledge and other cluster benefits in TC dynamics of cluster companies. The organizational inertia and AC theories are the theoretical underpinning of the research. The findings add to the state-of-the-art knowledge on the link between TC and AC of companies involved in COs by depicting the role of COs in providing benefits that help cluster companies to accumulate TC and improve their AC and, subsequently, their innovation. The research is preliminary in nature and portrays how firms with different levels of TC cooperate within COs and how this cooperation translates into TC improvements. Although, the study was conducted in Poland, it offers findings that may be verified in other states, especially in countries from Central and East Europe (CEE). There can be observed similarities among COs in CEE due to the fact that these countries' cluster policies laid the ground for their establishment and development.

Since the quantitative measure of TC and AC (e.g. patents, R&D investment, R&D intensity) created a lot of confusion and inconsistent findings in previous research (Srivastava *et al.*, 2015), the authors conducted the qualitative study.

The paper is organized in the following manner. In the beginning we define TC and describe its different levels. We show its role in the innovation process and how clusters may foster accumulation of TC important for innovation. We also explain the relationship between TC and AC referring to the theory of organizational inertia. After the methodology section, which is the subsequent part, 'Results and Discussion' uncover the different dynamic paths of TC with regard to benefits offered by the clusters. Conclusions end the paper.

[1] For simplicity, in the following parts of the article, we use the terms *cluster* and *cluster organization* interchangeably.

2. Technological capability, absorptive capacity and cluster organizations

2.1. Technological capability, its dynamics and significance

Technological capability is perceived by various authors as an attribute of a company, namely an ability, its internal competence or comparative advantage concerning its current and future technological resources and activities. It enables a firm to apply various technologies, to generate and manage technical change, to absorb and make use of technological knowledge and to create new knowledge (Hansen and Lema, 2019; Kang et al., 2017; Zhou and Wu, 2010). Srivastava *et al.*(2015) propose to perceive TC as an internal competence of a focal firm with regard to other companies. Likewise, Eum and Lee (2019) define it as comparative advantage in technologies.

Technological capability accumulation is a dynamic process. The subject literature distinguishes different levels of TC (from more routine to more innovative ones) and portrays a gradual process, yet difficult to measure, whereby firms accumulate skills and knowledge over time, enhancing their ability to manage technological changes (Dutrénit *et al.*, 2018; Hansen and Ockwell, 2014). For example, Figueiredo (2005) proposes a TC trajectory, which comprises three basic levels (i.e. basic, renewed and extra-basic) of routine activities and some more complex ones (i.e. pre-intermediate, intermediate, high intermediate and advanced) where innovative activities are carried out. Likewise, Hernández *et al.*(2017) delineate seven levels of a TC building, which is composed of capability of absorption and capability of innovation. According to Hansen and Lema (2019), TC includes routine production capability and the innovative TC. Consequently, TC is seen as a continuum from two levels of the routine production capability (the basic and the extra basic ones) to the subsequent four levels of innovative TC (basic, intermediate, high intermediate and advanced). As a result, advancement in TC produces different innovative outcomes (Eum and Lee, 2019).

Technological capability is accumulated through past experience of a firm and facilitates its innovation. According to Zhou and Wu (2010), it has a positive impact on exploitative innovation, yet in terms of explorative innovation it shows an inverted U-shaped relationship. Consequently, TC may not support every innovation, e.g. a strong TC can inhibit experimentation in emerging domains. On the other hand, firms with lower TC reveal a tendency to reduce investment related to exploration if negative shocks occurred in their sectors (Kang *et al.*, 2017). Moreover, along with an increase in TC, companies expand their innovative activities and move from innovations that are new to the firm, through innovations considered new to the local industry to innovations new to the world (Hansen and Ockwell, 2014).

Innovation usually requires investment in R&D (Eum and Lee, 2019). Prior research proved that TC determines R&D efforts due to the fact that it diminishes uncertainty associated with R&D activities. Consequently, firms with higher TC invest more intensively in their R&D activities.

Technological capability fosters innovation but innovation is also the major mechanism of building TC, which determine their further innovations (Kumar *et al.*, 2008).

To sum up, TC is a vital strategic resource that allows companies to manage their technological knowledge and technological change. Its accumulation is a dynamic yet gradual process based on past experience with divergent innovation effects. Improvements in TC enforce R&D efforts but are not always exhibited in innovation. Nonetheless, innovation is determined by TC, and TC may be strengthened by innovation.

2.2. Technological capability and cluster organizations

Although there is abundant literature that tackles the links between TC and innovation (see par 2.1) or innovation and clustering (e.g. Lyu *et al.*, 2019; Nestle *et al.*, 2018; De Souza *et al.*, 2018), research on TC accumulation in clusters is still underdeveloped (Caniëls and Romijn, 2003; Romijn and Albaladejo, 2002). The literature concerning TC delineates between internal factors (e.g. the quality of human resources in organizations or learning culture) and external ones (e.g. functioning in networks or clusters) that help to accumulate the capability (Hansen and Lema, 2019; Hansen and Ockwell, 2014; Kumar *et al.*, 2008; Sobanke *et al.*, 2014). Additionally, it distinguishes global and local sources of learning that enable to advance TC of firms (Hansen and Lema, 2019). Clusters are sources of learning in the local/national context, however, depending on the composition of cluster companies (e.g. if a cluster includes multinational corporations or their subcontractors and/or affiliates) or activities undertaken within clusters (e.g. when a cluster facilitates export, cooperation with other clusters abroad, participation in international fairs, etc.), they may also offer access to global production networks or pipeline of knowledge (Geenhuizen and Nijkamp, 2012; Upadhyayula *et al.*, 2017).

The literature on TC accumulation also emphasizes that the capability usually takes a tacit form, thus, spreading it among organizations, evolving or transmitting may face obstacles (Eum and Lee, 2019). On the other hand, the clustering literature emphasizes the role of clusters in supporting technological improvements and innovations of firms in clusters due to learning that takes a tacit form (Hansen and Lema, 2019) or, in other words, 'learning-by-interacting' (Caniëls and Romijn, 2003; Romijn and Albaladejo, 2002). Learning also happens due to other agglomeration advantages which, with regard to the paper topic, mainly reside in knowledge dissemination among entities in clusters (e.g. Aguiléra *et al.*, 2012; Boschma *et al.*, 2014; Usai *et al.*, 2017). The mechanisms that may support external learning and consequently TC development in clusters include interpersonal relationships, social networks, mobility of workforce within clusters, interactions at exhibitions, trade fairs or at other cluster meetings (Hansen and Lema, 2019). Caniëls and Romijn (2003) contend that the forces which drive TC building in clusters are agglomeration effects and learning. The technological efforts of firms combined with agglomeration advantages embedded in clusters support external learning and TC improvements. Furthermore, similarly to functioning in strategic alliances, companies in clusters may develop their TC and increase innovation due to several reasons. Cooperation among member organizations in COs introduces them to various ideas and solutions which may encourage them to divergent thinking and build their TC. Companies associated in clusters have different technological

capabilities and consequently technological resources that can be combined. In such circumstances, more active members may motivate other firms and organizations to undertake some innovative projects. Moreover, the greater availability of technological resources in COs enables members to cope with organizational inertia (see par. 2.3), which hinders innovation and decreases experimentation as well as cutting edge explorations required for innovation (Srivastava *et al.*, 2015).

Summarizing the above, TC accumulation of members in clusters needs further investigation. In view of the literature on TC and clustering, functioning in COs is an external determinant that supports building TC through learning mechanisms in interactions among incumbents. In turn, companies are offered access to agglomeration advantages that potentially enhance their technological efforts and translate into a higher level of TC.

2.3. Technological capability accumulation – absorptive capacity and organizational inertia

Companies vary in terms of their ability to process knowledge that is available in different external sources, such as COs (Dahlin et al., 2020). The construct of AC, introduced by Cohen and Levinthal (1990), reflects an ability of a recipient organization to be receptive to technological change and includes knowledge acquisition, assimilation, transformation and exploitation (Petti *et al.*, 2019). It is also seen as an ability of an organization to learn and solve problems, or to identify, assimilate and make use of knowledge from its external environment (Sobanke *et al.*, 2014; Srivastava *et al.*, 2015). Absorptive capacity allows the value of new information to be recognized, assimilated, disseminated and applied to commercial ends to produce new knowledge and innovation (Crescenzi and Gagliardi, 2018; Dahlin *et al.*, 2020; Expósito-Langa *et al.*, 2015; Kumar *et al.*, 2008; Martínez-Cháfer *et al.*, 2018). It also enhances a firm's ability to gain and maintain its competitive advantage (Murovec and Prodan, 2009). Nevertheless, AC is path-dependent and is a function of prior related knowledge (Belso-Martínez *et al.*, 2016; Cohen and Levinthal, 1990).

Absorptive capacity, in view of Srivastava *et al.*(2015), apart from TC, includes another aspect, namely technological effort. It is manifersted in the extent of commitment of the resouces directed at knowledge searching and developing, and can be measured by R&D intensity. Firms with higher technological effort, i.e. spending more on R&D activities, are more inclined to explore new knowledge and avail external knowledge. Consequently, their AC is higher (Murovec and Prodan, 2009). Companies with higher technological effort may also be percived by others in COs as more valuable and desired partners in innovation activities.

The study by Murovec and Prodan (2009) distinguishes between sciences-push and demand-pull AC, namely absorbing science-based knowledge or knowledge from the private sector respectively, and proves that science-push AC relies on cooperation with various external partners. Hence, it can be assumed that collaboration supported by COs may be indicative of an AC building that later improves TC. On the other hand, AC also contributes to the emergence of linkages (interactions) among

incumbents in clusters, which further determines access to valuable knowledge repositories (Belso-Martínez *et al.*, 2016; Dahlin *et al.*, 2020; Martínez-Cháfer *et al.*, 2018).

Technological capability is perceived as a source of AC and one of its key aspects (Srivastava *et al.*, 2015; Wood and Weigel, 2011; Zhou and Wu, 2010). Firms with higher TC may exhibit higher AC and greater chances for success in innovation (Kang *et al.*, 2017). Over time, since being rooted in organizational routines, TC becomes less imitable and substitutable; as a result, it may become more valuable for an organization as it determines AC, which is critical to an organization's innovation (Saunila and Ukko, 2012; Tzokas *et al.*, 2015; Zhou and Wu, 2010). Nevertheless, well-developed TC of a firm may impede leveraging external knowledge due to the so-called "not-invited-here syndrome". Moreover, if a company has already established a path which has proved to be successful (i.e. it has high TC), then it manifests less willingness to deviate from that path. Therefore, high TC may stimulate a firm to a more internal search for knowledge, or search for compatible external knowledge, protect its internal knowledge base from outside companies, devaluate knowledge available in the network or cluster if it differs from internal knowledge and decrease its capability to adapt (Srivastava *et al.*, 2015). The theory of organizational inertia provides an explanation of this phenomenon.

Basing on the theory of organizational inertia, it can be posited that companies may be bound to "a particular technological paradigm, regardless of how high their absorptive capacity is" (Petti *et al.*, 2019, p. 12). Organizational inertia reflects rigidity of organizations' actions and resistance against radical changes. Such organizational inertia develops over time as organizations become embedded in their routines based on their past experience (Dosi and Marengo, 2007). As a result of organizational inertia, companies follow the same resource allocation patterns and organizational processes that use the resource investment which may inhibit their adaptation to technological discontinuities. Consequently, along with an increase in TC, organizations develop their unique organizational routines which likely bind them to their existent technological trajectory, enforcing exploitive innovation and inhibiting the explorative one (Zhou and Wu, 2010).

In a nutshell, on the basis of the AC and organizational inertia theories as well as previous research, the following predictions can be stated that substantiate our further analysis. First, companies may benefit from their membership in COs if their initial TC is relatively low. Cooperation with other COs' members may help them to advance their level of TC, build AC and expand their scope of innovation. Second, if their TC is high, they still may benefit from the cooperation in clusters if the external knowledge they can absorb is compatible with their internal technological trajectories. Finally, when COs present an ability to influence technological effort of their members, then innovation may be stimulated via enhanced AC, regardless of their initial level of TC.

3. Research methods and participants

3.1. Methods and sample

We report the outcomes of our explorative, qualitative study aimed at answering the following research question: Do and how do COs enable member companies to accumulate TC significant for their innovation? Our intention is to portrait how members of COs perceive the role of clusters in enabling them to accumulate TC significant for their innovation. The findings are a section of a larger study aimed at identifying the levels of advancement of the cooperation among enterprises in selected clusters in Poland (Lis, 2018). As for the theoretical basis of the research, we predict (see. par. 2.3) that 1) cluster companies benefit from COs if their initial TC is relatively low since then their cooperation with other COs' members help them to advance their level of TC and build AC; 2) if cluster companies present high TC, they benefit from the cooperation in COs if the external knowledge they absorb is compatible with their internal technological trajectories.

We based our research on abduction deriving from Peirce's philosophy (1931, 1958). Abduction refers to the study of facts and the development of theories which explain these facts (Cunningham, 1998). However, these explanations are only hypothetical. Abduction is not about simple generalization, but rather about discovering and interpreting the observed data (Dubois and Gadde, 2002).

In our paper, we used abduction to interpret the collected data and create the best explanations for our observations. It should also be clearly emphasized that TC dynamics were not the subject of the larger study, i.e. the interview scenario did not contain questions directly referring to this phenomenon. We discovered it as a result of the analysis and interpretation of the data, which is consistent with the abductive approach. Our discoveries prompted us to conduct the literature review to better acquaint ourselves with state-of-the-art knowledge and then treat it as a theoretical background for our findings.

While reporting the empirical findings, we refer to the 'commitment to cluster cooperation' category (or 'commitment' for short), which is used as a proxy for technological effort (in terms of various resources such as money, time, people, etc., committed by a company and directed at knowledge searching and developing in clusters), and we describe the identified levels of technological effort in the analyzed cluster companies. Nevertheless, the analysis of the links between participation in clusters, technological effort and innovation are beyond the scope of this study.

Our study sample was composed of four COs located in Poland (Table 1). To select the COs we applied the extreme cases logic as it allowed us to maintain maximum variability and diversity within the research field. Sector belongingness was the main differentiating criterion according to which four COs were selected.

Table 1. The sample characteristics

Cluster organization name	Creation date	Number of cluster members	Scope	Internationalization level*	Number of interviews
Metal Cluster X	2008	35	regional	medium	11
Metal Cluster Y	2009	78	regional	low	7

Cluster ICT X	2007	200	regional	high	6
Cluster ICT Y	2009	130	regional	high	11

Note: To assess the degree of internationalization of the COs the results of benchmarking research were used (Wielec *et al.*, 2018). Internationalization was measured on the basis of the potential for internationalization, international activity, and export and pro-export activities.

Both selected sectors differ in many terms. The metal industry is in a mature stage and represents medium-low technologies. The companies in this sector cooperate with others from their value chain and established long-term relationships. Proximity of their partners is important for developing relationships among firms; as a result, the companies in this sector are concentrated in the same location. By contrast, the ICT industry is in the developing stage, represents high technology and cooperation among the companies in the sector is dynamic and frequently short-term. The location of partners is less important as they can work virtually.

There were 35 individual in-depth interviews conducted with the coordinators and the representatives of mainly COs, but also R&D institutions, educational institutions and support institutions, each selected on the basis of the snowball technique (Flick, 2010). The interviewees were the owners of the companies or top managers as well as individuals chosen to represent the organization in the clusters. They all have the most comprehensive and accurate knowledge of the COs and the role of their organizations in a given cluster.

Overall, there were 44 hours of interviews carried out in the offices of the organizations in the first half of 2016; each interview lasted 75 minutes on average.

The interview referred to the following topics: 1) cooperation in the cluster and its forms; 2) the level of commitment of the coordinator and the members in the COs; 3) the relationship and trust development in COs; 4) the cluster benefits; 5) the flows of knowledge and information within the clusters.

The additional method applied to the study included an analysis of the cluster documents and the web resources. It helped to ensure methodological and data triangulations (Maxwell, 2005) since the research used two methods of data collection (i.e. interviews and document analysis) and multiple sources of information (i.e. the interviewees representing various cluster members).

3.2. Analytic procedure

We applied the conventional qualitative content analysis (Hsieh and Shannon, 2005) as our procedure to analyze the interviews. As far as the coding schemes are concerned, each interview and theme were constantly compared to arrive at inductively delimited codes from the collected data (Glaser and Strauss, 1999). The first step in our analysis, the open coding one, concerned identifying some common themes emerging from the interviewees' accounts in each cluster (e.g. 'information exchange', 'innovation potential', etc.). In the axial coding, we classified each theme with respect to the levels of TC, the levels of cluster cooperation, the type of commitment to cluster cooperation, the type of information and knowledge, and dynamics of TC (Table 2).

Table 2. The axial coding

No.	Category	Peculiarities
1.	The level of technological capability	– Low – Medium – High
2.	The level of cluster cooperation (difficulty in achieving it)	– Level I "Integration at the unit level" (low) – Level II "Allocation and integration at the process level" (medium) – Level III "Impact on the environment" (medium) – Level IV "Creation and integration at the organizational level" (high)
3.	The type of commitment to cluster cooperation	– Meetings – Events – Task groups – Trainings – Meetings with entities from outside the cluster – Lobbing – Projects – Cooperation within a value chain
4.	The type of information and knowledge	– Access to a wide variety of general information – Access to selected information that facilitates identification of the sources of missing resources – Priority in access to significant information about the socio-economic environment – Access to confidential information – Access to new knowledge
5.	Dynamics of technological capabilities	– 0 – Low – Medium – High

All the codes were created abductively (see par. 3.1) which also applies to TC dynamics. Table 3 presents illustrative quotes to portray selected coding categories.

Table 3. Categories 3 and 4 - illustrative quotations of coding

Category		
3. The type of commitment to cluster cooperation	4. The type of information and knowledge	Selected quotations
Meetings Events	Access to a wide variety of general information	(1) "I assume that if there is a conference, discussions, meetings, and by the way we exchange views there, it offers significant benefits. […] even meetings where gossip is exchanged; it also leads us to take action, or indicates the directions in which we can work together." (B10)
Task groups	Access to selected information that facilitates identification of the sources of missing resources	(2) "This industry is so extensive, and the knowledge is so vast, that it cannot be fully understood. Therefore, it is imperative to choose the appropriate thematic threads, and someone has to do it. It is best for companies that hope to develop their business in specific directions." (D10)
Meeting with entities from outside CO	Priority in terms of access to significant information about the socio-economic environment	(3) "However, the cluster is a large institution, and thanks to this it can receive materials first-hand - not everyone has access to them, e.g. from the meetings of EU institutions." (C6)
Projects	Access to confidential information	(4) "We like each other and we trust each other because we have completed one project together. We have one, two partners, now the third one is joining, with whom we are able to cooperate. [...] Thanks to this, we are able to trust each other, exchange information, and talk about new possibilities". (D9)

Projects	Access to new knowledge	(5) "Knowledge arises in projects. Some of the documents are open to everyone, but some are only for people who have carried out these projects." (D5)

At the final, selective coding stage, the categories were grouped to feature four possible scenarios of TC dynamics observed in our research (Table 4).

Table 4. The selective coding

TC	Cluster cooperation			TC dynamics
Category 1. The level of technological capability	Category 2. The level of cluster cooperation (difficulty in achieving)	Category 3. The type of commitment to cluster cooperation	Category 4. The type of information and knowledge	Category 5. Dynamics of technological capabilities
Low-High	I (Low)	Meetings Events	Access to a wide variety of general information	0-Low
Low-High	II (Medium)	Task groups Trainings	Access to selected information facilitates, identification of sources of missing resources	Low-Medium
Low-High	III (Medium)	Meetings with entities from outside the cluster Lobbing	Priority in access to significant information about the socio-economic environment	
Low-High	IV (High)	Projects Cooperation within a value chain	Access to confidential information Access to new knowledge	0-High

4. Results and discussion

4.1. Technological capability accumulation through cluster organizations – the empirical findings

The research findings show that cooperation in COs plays an important role in the development of TC of cluster enterprises. By being engaged in activities undertaken within a cluster, enterprises obtain an additional pool of resources, including information and knowledge, which increases their initial TC as well as the AC level. However, the study reveals that the dynamics of TC relates not only to the initial TC of each of the cluster members, but also to the level of advancement of the cluster cooperation and consequently, the type of commitment.

In order to illustrate the above relationships, the paper uses the concept of the trajectory for the development of cooperative relationships in COs, developed by Lis (2018). Four levels of cooperation were distinguished in this concept. At the first level, the main objective is to create a base network of relationships among the cluster partners, which is the foundation of the cluster's development. The objectives established at the second level of cluster cooperation are to facilitate access to the increased pool of resources, increasing the quality of products and services or reducing the business costs. At the third level, the primary objective is to gain an impact on the external environment of a cluster and the companies grouped in it, while at the last, fourth level, the cluster members cooperate in order to set up conditions to create common added value by pooling their resources. The order of occurrence of the

following levels shows their level of advancement and, at the same time, the difficulty in achieving them.

The basic assumption of the created concept is that the four levels of cooperation can simultaneously occur in a given cluster, while members of the same cluster may operate at different levels, depending on their commitment. In addition, given that the cluster is a special type of a higher-order organization, the combined technological capabilities [TC_{1-n}] of the cluster members are the foundations on which cluster cooperation [CC] develops, providing the cluster with benefits (access to specific resources, including information and knowledge). The level of development of CC is also influenced by other factors, such as, for example, the competencies of the coordinator [C] and cluster policy [P], which, however, are beyond the scope of the study. The conducted research shows that CC in various ways supports the dynamics of TC of the cluster companies, measured by the difference between the input (initial) TC [TC(i)] and the output TC [TC(o)]. It relates not only to the commitment to cluster activities, but also to the degree of matching the levels of cooperation in a given cluster (and the benefits received at this level) to the initial TC of individual cluster companies and their absorptive capacity [AC]. The demarcation line between TC and AC inferred from the interviewees' accounts appears to be vague, thus we put more emphasis on AC's second dimension, namely technological effort visible in a form of commitment of various types of resources to the COs (Figure 1).

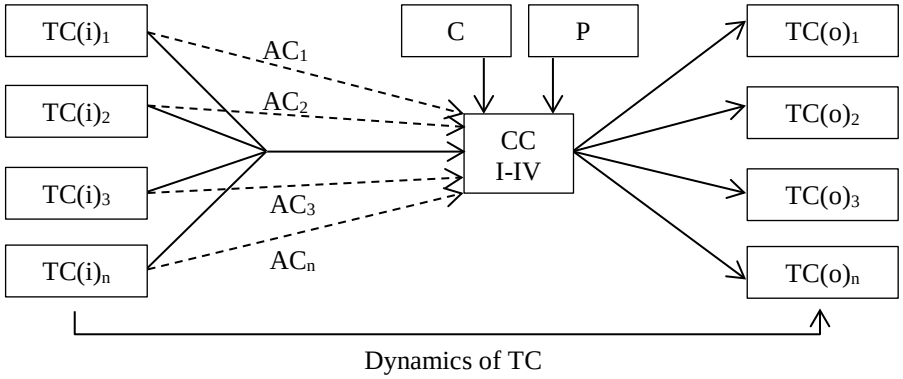

Figure 1. Relations between technological capability of cluster companies and cluster cooperation

The research results imply that the first, and also the easiest level of cluster cooperation was much more important for the companies with a low TC level than those representing a high level of TC (Table 5). At the level, the cluster enterprises, by participating in various meetings and events organized within the COs, received access to a wide variety of general information concerning other cluster partners as well as the nearest environment.

Table 5. Technological capability dynamics at the level I of cluster cooperation

TC/AC-CC-TC dynamics	Selected quotations
Low-Low-Low/Medium	(6) "The companies come to meetings of business clubs, clusters, to exchange information, to know what everyone is planning." (A7) (7) "We are focused on small and medium enterprises […]. What, as a cluster, we could propose to a large company – well, nothing. Micro and small businesses need the most support because they have the greatest potential for innovation, because these people all the time think what to do. There is also the strongest need because they occupy the lowest organizational and financial level." (C1)
High-Low-0/Low	(1) "Do we notice that meetings in the cluster have any impact on our functioning? This is not visible in my company. [...] Our innovation activity began to develop earlier than in the cluster and it is our company that could give something to the cluster." (D4) (2) "The cluster, meetings, events do not affect our company, it has no direct impact. [...] The only benefits we have are those from the cooperation in projects." (D5)

Note: A, B, C, D states for cluster A, B, C, D, respectively, while 1, 2…n denotes a particular interviewee

Basing on the conducted research, the TC dynamics of the cluster companies with low initial TC can be assessed as low or medium. The information obtained in the cluster allowed these companies to take advantage of the opportunities appearing within the cluster and outside the cluster, which might translate into better business decisions. In addition, inequalities at the level of knowledge possessed by the cluster members acted in favor of the companies with a low TC level because they – by the demonstration effect – could be inspired by observing other companies, which is supported by both forms of commitment assigned to this level. In turn, in the case of the companies with high initial TC, the TC dynamics at the first level of cluster cooperation can be assessed as low. Furthermore, if the scope of information is too low to provide these companies with any source of benefits, no increase in TC (the dynamics of TC was at level 0) is observed.

The research findings demonstrate that levels II and III, evaluated as moderately difficult to achieve, brought benefits connected with the increase in TC for both types of entities – with the low and high initial TC, however, in the case of the companies with low TC, these are levels in which the benefits are the highest possible to obtain from the cluster cooperation (from the point of view of TC dynamics) (Table 6). At level II, the cluster entities received access to additional information, which, compared to the first level, was more selected and thus more detailed and better suited to the profile and needs of a given company. Additionally, owing to the cluster cooperation, the enterprises also gained access to other resources (material, human, financial ones). Similarly to level I, meetings were the basic way for cluster members to engage in activities undertaken at this stage of cooperation, yet, in contrast to level I, meetings at this stage were organized mainly in smaller subgroups (task groups) composed of the most committed members. The trainings, organized by the coordinator or members that increase the competence of the employees of the cluster companies, were another important way of commitment at this level. At level III, the cluster enterprises gained priority in access to significant information about their socio-economic environment. The cluster companies engaged in cooperation with the key actors from outside the CO, undertaking joint actions aimed at creating more favorable legal and administrative

conditions for running a business and adjusting the educational profile in the region to the requirements and needs of the cluster companies.

Table 6. Technological capability dynamics at levels II and III of cluster cooperation

TC/AC-CC-TC dynamics	Selected quotations
Low-Medium-Medium/High	(8) "To supplement and expand my capacity, I got to know the local market intensively and, among others, the cluster allowed me to do so. And now I know exactly what machines other companies have and I can take advantage of it because we have known one another well." (A6) (9) "In a cluster, companies would gain partners who are better. Their development will be inhibited and no one will cooperate with them if the partner has to take responsibility for their quality. They must reach the standards. And in a cluster, it would be easier to achieve it because here we can jointly adopt certain standards and implement them among similar companies." (B4)
High-Medium-Low/Medium	(10) "If we run the infrastructure for prototyping, it would not be for 80 companies but for a dozen or so companies because not all of them would need it." (A7) (11) "However, the cluster is a big institution and thanks to that it can receive first-hand materials, however, not everyone has access to them (e.g. from meetings of the EU institutions)." (C6)

Note: A, B, C, D states for cluster A, B, C, D, respectively, while 1, 2…n denotes a particular interviewee

At levels II and III of cooperation, the dynamics of TC of the companies with low initial TC should be assessed as high. Access to information and other resources offered in the cluster at level II was a precise and not deferred benefit in the form of additional resources, which could significantly improve the competitive position of the cluster companies on the market. In turn, important information about the changing environment conditions obtained at level III put the cluster companies in a privileged position in comparison to the companies not belonging to the clusters. In the case of the enterprises with high initial TC, the dynamics of TC can be assessed as low or medium, depending on the value of and difficulty in imitating the received resources.

At level IV, the advantage was mainly obtained by the cluster companies with high initial TC (Table 7). At this level, the entities engaged in the cooperation obtained access to new knowledge, which is often jointly generated by them and confidential information reserved only for the trusted partners. This was achieved by launching joint ventures as well as participation in project consortia and teams focused on the development of permanent cooperation.

Table 7. Technological capability dynamics at level IV of cluster cooperation

TC/AC-CC-TC dynamics	Selected quotations
Low-High-0/Low	(12) "[…] despite the commitment of some cluster companies, their competences are insufficient to do cool, innovative things with them. These companies do not reach such a level that they can be an initiator. Unfortunately, they are too weak, they do not have specialists to do advanced projects. They take on a project and it overwhelms them. When we involved them in our projects, there were many problems." (B8) (13) "It is known that one who makes fences will not make things with graphene. First of all, such a person cannot afford it, and besides, s/he has no knowledge in this area. Unfortunately, in this industry you have to sit longer and work on it longer." (A4)
High-High-High	(14) "We are now discussing an e-commerce project with someone. And this is a conversation about what we can do. But this applies to companies that have good competences and a profile which fits this project. Here you need to be able to ask questions, use the same language." (C3)

	(15) "As far as our company is concerned, our cooperation in the cluster has been influenced by the contact with the Gdansk University of Technology. Due to the fact that the group focused around university strongly promoted this cluster, we have been invited because we operate within the same technology. [...] They work in radio technologies, and the systems they develop are part of our technology [...] They were also interested in cooperating with such an entrepreneur who would translate their theory, their R&D work into practice, which, succeeded." (D5)

Note: A, B, C, D states for cluster A, B, C, D, respectively, while 1, 2…n denotes a particular interviewee

By contrast, in the companies with low initial TC, the TC increment might be minimal, and even at a zero level, if the level of advancement (and thus the difficulty) of this level was too high for a given company. As the research suggests, it could – due to the insufficient level of employees' competences – hinder or limit the inflow and absorption of new knowledge (no increase in TC), even if the companies engaged in common activities assigned to the level (low TC dynamics) and completely prevented some companies from participating in jointly undertaken activities. Meanwhile, in the case of the companies with high initial TC, level IV guaranteed the highest possible dynamics of TC. Importantly, as the study revealed, this dynamics was high only when the areas of cooperation and related benefits corresponded to the internal technological trajectories of the cluster members involved in these activities. This encouraged the companies with a high level of TC to carefully select the cluster partners and initiate cooperation within areas closely related to the company's profile. The research also discovers that the increase in TC of the cluster companies was related to their ability to cooperate with R&D institutions. Participation in jointly implemented projects favored mutual knowledge sharing and facilitated the transfer of technology from the R&D sector to business. Projects with the participation of R&D institutions were often implemented in international consortia, which was an additional stimulus for the development of TC in the companies involved in these projects.

On the basis of the study, it was also possible to identify differences between the selected sectors (Table 8). The members of the surveyed metal clusters mostly represented a fairly low initial level of TC, which translated into the clusters' cooperation levels and the received benefits. The entities from these clusters managed to achieve the first three levels of cooperation, out of which level III was the best developed. The cooperation with the key external actors of the most active cluster members allowed them to improve their initial level of TC.

Table 8. Technological capability dynamics in metal and ICT clusters

TC/AC-CC-TC dynamics	Selected quotations
The metal clusters	
Low-Medium-Medium/High	(16) "If something starts in the country, or politicians show that something will be preferred, then […] you must have this knowledge, and show companies (that have capital and some human potential for innovation) in which direction these funds will be distributed." (B2) (17) "Our company develops cooperation with a technical and vocational school. Let these schools teach how they want, but the teaching program must be prepared for our needs. [...] Thanks to such a cooperation of our cluster we have better people in our companies." (A1)
The ICT clusters	
Low-High-0/Low	(18) "Such a high-level creation is good because there are such innovative initiatives as the project of smart cities. It is going in the right direction but it is a lot too high for what a small company needs. A small company has no resources to reach some long-term projects." (D6) (19) "Some projects are difficult and even if businesses are open, life shows that it would be difficult for some people to handle it." (D5)
High-High-High	(20) "We have a direct impact on the international projects that we launch, this is the best thing we can do in the cluster." (D9) (21) "On Tuesday, we are establishing a new area [intelligence of things]. There is a man who knows something about it, has his own technology and wants to gather a few companies around him. It may be selfish but I think that there must be fuel to make people want. Even if he has his own interest in it, then such egoism is useful for giving this energy." (C1)

Note: A, B, C, D states for cluster A, B, C, D, respectively, while 1, 2…n denotes a particular interviewee

On the contrary, both researched ICT clusters managed to develop the four identified levels of cooperation on the basis of connected TC potentials of the cluster entities. Nevertheless, only a few cluster enterprises representing a high level of TC were able to climb to level IV. As the study demonstrates, in many cases, it resulted from internationalization of the cluster activity and cooperation with foreign partners engaged in R+D projects, implemented in the COs. As it was emphasized earlier, this concerned only those foreign entities whose TC level was similar (and therefore high enough) to the level represented by the cluster members taking part in these projects.

The cooperation of the selected cluster members with the participation of entities from outside the CO in joint projects contributed to the increase in the TC of these companies. However, this was not experienced by the companies with too low an initial TC level. They were not able to reach the level of other partners, which was a significant barrier to enter into the created subgroups. In the case of these companies, the pool of benefits from the cooperation at the fourth level (measured by the dynamics of TC) was small and even completely unnoticeable.

4.2. Discussion

The empirical findings are partially in line with our theoretical predictions (par. 3.1) and prior research (par. 2.2 and 2.3). First, we assumed that cluster companies benefit from COs if their initial TC is relatively low since then their cooperation with other COs' members help them to advance their level of TC and build AC. Our second prediction was that if cluster companies present high TC, they benefit from their cooperation in COs if the external knowledge they absorb is compatible with their internal

technological trajectories. The empirical findings suggest that the cooperation in the clusters might have supported accumulation of TC of the cluster firms. This observation is consistent with the literature on external sources of TC building (e.g. Caniëls and Romijn, 2003; Murovec and Prodan, 2009; Sobanke *et al.*, 2014; Srivastava *et al.*, 2015). Our study has additionally indicated that the dynamics of TC of the companies with low and high initial TC differed with regard to the level of development of the cluster cooperation and commitment. We have discovered that this dynamics correlates with the combined TC of the cluster members, their initial TC and AC. The combined TC have appeared as a foundation of the cluster cooperation, generating various benefits, mainly information and knowledge (see Figure 2).

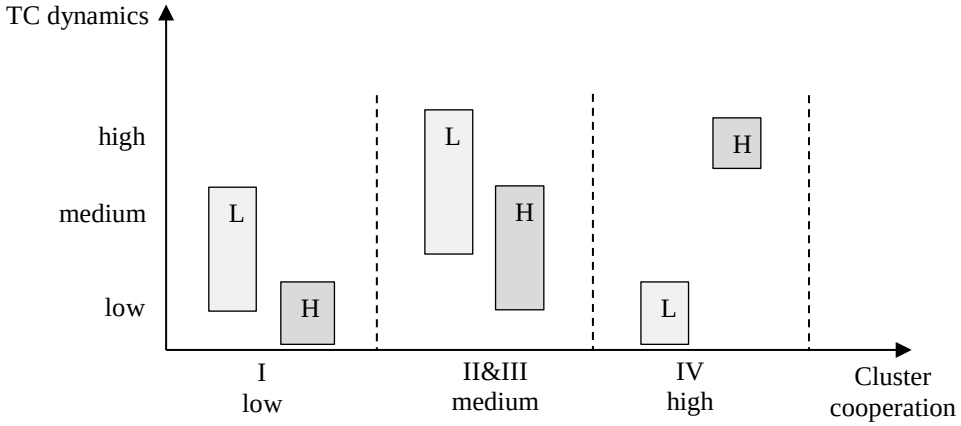

Figure 2. The dynamics of technological capability through cluster cooperation

For the companies with low TC, levels II and III occurred to be the most important levels of cluster cooperation. It allowed the involved entities to benefit from the access to information and other resources (as an essential complement to the pool of their own resources), contributing to the increase of their initial level of TC (Figure 2). However, advanced cluster cooperation at level IV made it difficult or even completely impossible for these companies to take advantage of the benefits reserved for this stage. Insufficiently developed TC was a barrier to the development of interactions at this stage with the firms presenting higher initial TC. Hence, incumbents with low TC improved it only at levels II and III of their cluster cooperation. Our first prediction is, therefore, partially confirmed by the empirical findings.

For the enterprises with high initial TC, the first level of cluster cooperation has turned to be the least beneficial from the point of view of TC dynamics, while level IV, the highest one, turned out to be the most beneficial. The access to knowledge and confidential information offered at this level of cooperation could have helped these companies achieve an even higher level of TC. In addition, we have observed that the companies with high TC might have improved it if the benefits offered in the clusters had been consistent with their technological trajectory. This finding confirms previous research and the theory which state that a company can be bound to its current technological paradigm due to organizational inertia embedded in its functioning (e.g. Petti *et al.*, 2019; Srivastava *et al.*, 2015; Zhou & Wu, 2010). It is also consistent with our second prediction.

5. Conclusions

5.1. Theoretical and practical contributions

The research is an initial study that explores how firms with different levels of TC cooperate within COs and how this cooperation may translate into TC development. Our findings add to the state-of-the-art knowledge on the link between TC and AC of companies involved in COs. They depict the role of COs in providing knowledge and other cluster benefits that help cluster companies to accumulate TC and improve their AC which may further support their innovation. In particular, the study supports the notion from the theoretical underpinnings that well-developed TC may inhibit companies' external search for knowledge due to their organizational inertia reflected in the resource allocation pattern, organizational processes and routines. As we observed, the cluster firms with high TC improved it only when the cluster benefits suited their existing technological paradigm. Moreover, the study shed new light on the key role of the levels of cluster cooperation and the types of commitment related to them (i.e. technological effort), which may be a matter of importance in the dynamics of TC accumulation.

The empirical findings can also provide some practical implications for COs' coordinators and members. The identified relationships among the initial TC of cluster companies, the level of cluster cooperation, the commitment level and the scope of information and knowledge obtained in COs as well as TC dynamics can be helpful in design and development of COs. The coordinator (and other entities involved in the development of a CO) should skillfully shape the levels of cluster cooperation, matching them to the desired level of the cluster companies. If there are firms with different levels of TC in the CO, it is reasonable to create smaller subgroups composed of companies with a similar TC level. According to the research results, this may translate into higher dynamics of their TC. Cluster companies can take more conscious actions related to their level of commitment in COs, knowing that this can impact on greater dynamics of their TC. Furthermore, in order to assess the potential of cluster cooperation to advance TC, they need to develop reliable methods of measuring TC dynamics.

5.2. Limitations and further research

We have analyzed how cluster members perceive the role of COs in supporting their TC and, as a result, AC. Improved AC may also contribute to the development of TC (Wood and Weigel, 2011), however this path has not been investigated in the current study and remains as a potential study matter for future research. Furthermore, we have not scrutinized how COs may strengthen technological effort of cluster companies, which also appears as an insightful avenue of further research. The study was primarily supposed to consider the assumption that dynamics of TC should result in innovation. Nevertheless, we have not examined whether such innovation genuinely occurred, which suggests future research could tackle this issue as well. Furthermore, our interviewees' accounts have not allowed us to provide a clear distinction between TC and AC beyond the technological effort aspect. Therefore, we should resolve this drawback in our subsequent study.

The conducted research also has some limitations resulting from the specifics of the qualitative research, which are another starting point for future empirical studies devoted to TC of companies grouped in COs. Our sample was a fairly small, which does not meet the criteria of representativeness. The applied data and the analysis techniques are subjective. The obtained data are of the static nature – the study in each cluster organization was carried out at a specific point in time, while the subject of considerations in the article is the dynamics of TC. In our study, we have focused on the occurrence of such a phenomenon (recognized as a result of abduction), rather than on the actual measurement of these dynamics. Therefore, in the study, we have not sought to determine the specific segment of time in which these dynamics occurred. In addition, since our study is based on interviews, it has allowed for retrospection in the interviewees' accounts regarding their perception of TC dynamics, yet it hardly provided quantifiable data in that respect.

Moreover, we have talked to one person in each company. On the one hand, it increases subjectivity of our findings, on the other hand, we have interviewed the so-called key informants (Kumar *et al.*, 1993), namely the individuals with the most accurate knowledge about the analyzed phenomenon. The research design has not allowed us to verify the initial level of TC and its dynamics in the sample with other more objective measures. Yet, it would be difficult to separate the influence of cluster cooperation on TC dynamics from other factors that shape it such as for example collaboration with companies outside COs, hiring new employees, their trainings, changes in board of directors, etc.

Finally, our study was conducted on Polish COs; consequently, the implications are limited to the Polish context. However, we assume that the dynamics of TC which we have discovered may also occur in other countries with a similar cluster policy. Our study can therefore contribute to some very preliminary works aiming to understand how cluster firms with different levels of TC cooperate.

Basing on the study results the following conceptual model can be put forward for a further quantitative investigation (see Figure 3) to verify its conceptual validity.

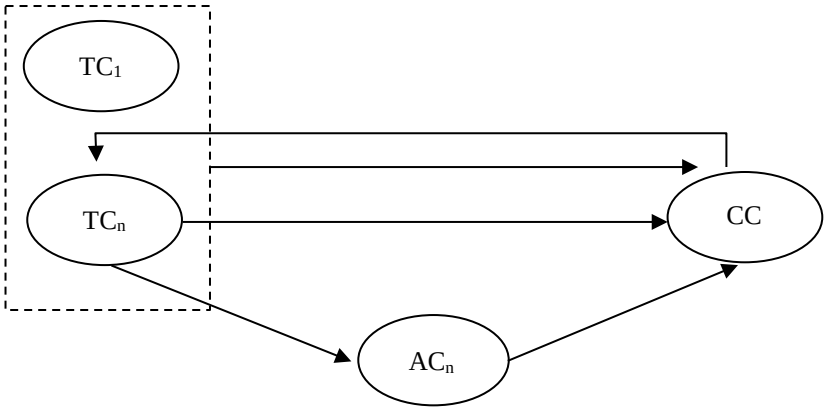

Figure 3. The conceptual model

As aforementioned, our study has implemented the abductive approach; as Peirce (1931, 1958) admits, the abductive conclusion is logical but problematic or conjectural. Therefore, the only possibility of confirming the model inferred from our data is to validate it in subsequent empirical studies. In order to test the conceptual model, it is necessary to carry out quantitative research in a larger, more representative sample (taking into account additional sectors of the economy and COs in other countries). For a better understanding of the dynamics of TC in cluster companies, it would be required to establish at least two measurement moments, keeping an appropriate distance between them. The relationships among the variables would be best tested on the basis of a structural equation modeling, which is also advantageous to estimate the mediation mechanism with regard to AC capacity of cluster enterprises.

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