SMEs in Collaborative Innovation Networks: A Maturity Model Evaluating Their Absorptive Capacity

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Abstract: SMEs increasingly engage in Collaborative Innovation Networks (CINs) to access valuable knowledge for innovation from complementary partners. They deploy their absorptive capacity (ACAP) to make efficient use of this new external knowledge. Despite the importance of ACAP to support the contribution of SMEs to innovation throughout the lifecycle of a CIN, there is no operational measure to guide them regarding ACAP implementation to reach the network common innovation goal. We propose to design a grid-based maturity model allowing SMEs to evaluate their ACAP given their embedding contexts in CINs. We follow a mixed methods' Design Science approach to define the content of the maturity model and adjust it by predicting the ACAP aspects that an SME should primarily master considering its context in a CIN. Our results expand academic understanding on the contingent peculiarities of ACAP by unveiling the natures of its practices and its contextual variability for the examined SMEs. We improve practice by providing SMEs with an assessment tool to early spot their ACAP deficiencies and implement the relevant corrective actions.

Keywords: SMEs; Collaborative networks; Collaborative innovation; Absorptive capacity; Maturity models

1. Introduction

Innovation helps SMEs differentiate themselves from competitors and thrive in increasingly dynamic environments. However, the lack of resources and knowledge hinders their innovation efforts (Lubatkin et al. 2001). Hence, they rely on open innovation alternatives especially by participating in collaborative innovation networks (CINs), involving heterogeneous actors that work together to achieve a common goal. This strategy has become critical for organizations to enhance their resilience in times of crisis (Ramezani and Camarinha-Matos 2020) such as the COVID-19 pandemic. CINs enable SMEs to pool their resources with other actors and share the risks and benefits inherent in innovation development. Most importantly, they facilitate access to complementary knowledge provided by these actors to jointly develop mutually beneficial innovations (Lubatkin et al. 2001).

This collective blending of knowledge requires coordination to capitalize on the complementarities between the actors while protecting the key expertise of each from possible leaks (Lubatkin et al. 2001). These challenges are significant for SMEs whose lack of resources prevents them from dedicating a team to the CIN. Also, their competitive positions may be jeopardized when they collaborate with large firms that can easily appropriate the key knowledge of these SMEs (Hallen et al. 2014). Despite the substantial literature on CINs, no study guides SMEs towards the appropriate approach to efficiently integrate and use new external knowledge to contribute to a CIN.

Accordingly, we rely on Absorptive Capacity (ACAP) concept to uncover the peculiarities of new knowledge integration by SMEs in this interorganizational innovation setting. ACAP refers to a firm's ability to identify relevant external knowledge, assimilate it, and apply it to commercial ends (Cohen and Levinthal 1990). Several instruments were developed to measure it in intraorganizational contexts (e.g., Ter Wal et al. 2011) or interorganizational long-term alliances of large firms (e.g., Thuc Anh et al. 2006), but none for SMEs within CINs. Extant measures are not suitable to these SMEs as they overlook the contingency incidence of CINs on ACAP, in terms of limited temporality (Sydow and Braun 2018), SME nature, the partners' cognitive distance, etc. (Lubatkin et al. 2001).

We follow a Design Science approach to develop a maturity model measuring ACAP of SMEs for their contribution to CINs. Maturity models raise firms' awareness of best practices, identify trouble spots, and stimulate improvement activities (Maier et al. 2012). The proposed model will guide the SME towards the practices most suitable to its CIN embedding context. It predicts such practices considering ACAP's contextual determinants such as the SME's role in the CIN, or its cognitive distance from the other actors.

2. Theoretical Foundations

2.1 Collaborative Innovation Networks for SMEs

Collaborative innovation networks (CINs) involve entities largely autonomous, geographically distributed, and heterogeneous in terms of their structures, cultures, and goals, but that collaborate to better achieve a jointly beneficial innovation (Camarinha-Matos et al. 2009). The network actors are organized across two distinct stages as an external community of practice (Dewhurst and Navarro 2004) to reciprocally learn, through artefacts and exchanges, explicit and tacit knowledge for accomplishing the common innovation. They first implement a network setting-up phase by frequently participating in fairs to gain inspiration and identify complementary partners (Van Egeraat et al. 2013). Then, the development stage requires intensive exchanges within the network, for instance using boundary objects to facilitate the joint integration of knowledge for innovation development and commercialization (Mäenpää et al. 2016).

CINs are a fundamental open innovation alternative for SMEs to share with other partners the financial and development risks of innovation and to balance their relative dependence and power in negotiation with buyers. These networks also enable SMEs to overcome their lack of knowledge and skills to manage the entire innovation process (Smolander et al. 2020) by accessing complementary knowledge for innovation from other CIN actors. An SME would then remain focused on developing specific expertise in the few technological areas that provide it with a stable market position, while accessing new external knowledge to generate an innovation (Lee et al. 2010).

2.2 Absorptive Capacity

To make efficient use of external knowledge for innovation in CINs, firms deploy their absorptive capacity (ACAP), referring to a firm's ability to recognize valuable new information and knowledge, assimilate it, and apply it to commercial ends (Cohen and Levinthal 1990). It is a dynamic learning capability enabling firms to align with their turbulent environments by efficiently using external knowledge (Najafi Tavani et al. 2018). In interorganizational contexts, ACAP also embodies the degree to which an organization learns from its partner (Omidvar et al. 2017).

Most empirical research mobilizes the ACAP conceptualization of Zahra and George (2002) to measure it. It gathers dimensions of acquisition, assimilation, transformation, and exploitation. Acquisition reflects the organization's ability to identify and access externally generated knowledge critical to its operations. Assimilation refers to the analysis of externally acquired knowledge to assess its potential. Application or exploitation refers to the firm's ability to leverage and create competencies by incorporating acquired knowledge into its operations (Cohen and Levinthal 1990). For the studied SMEs, we do not include transformation as it conveys a firm's efforts to create perceptual schemas from newly acquired knowledge that will be exploited for long-term value creation (Zahra and George 2002). Hence, it is not consistent with the ACAP in our study which focuses on the SME's contribution to achieving the temporary network's innovation goal.

ACAP of a firm in a CIN is subject to several contextual determinants that influence its deployment. First, external activators such as rapid technological evolution would drive an intense activation of ACAP (Zahra and George 2002). Second, internal activators conveying specific performance objectives such as strengthening technological and financial capitals can trigger new knowledge integration (Gluch et al. 2009). Third, units with central roles in innovation networks efficiently use new knowledge only if they deploy an intense ACAP (Tsai 2001). Fourth, a firm in a reciprocal learning partnership such as CINs, is required to deploy an intense ACAP when its cognitive distance regarding the other actors is substantial; and when the network includes members with expertise and commercial orientations close to the SME, which may generate liabilities (Lubatkin et al. 2001).

3. Methodology

We propose to develop a maturity model measuring ACAP for an SME contributing to a CIN. These improvement instruments assume that processes correctly defined, managed, and executed, lead to better performance (Dooley et al. 2001). The first type of these models is CMMI that was developed to certify organizations' maturity for delivering a software compliant to the requirements. Its certifying usage has been extended to institutionalized processes other than computer programming. The second type is maturity grids that are designed to communicate good practices in an efficient way (Maier et al. 2012). Grid-based maturity models are less expensive and less time-consuming compared to CMMI. This helps quickly measure the gap

between an organization's current practices and the ones to target, thereby making them adequate for the examined SMEs.

To develop our maturity model, we follow the design science approach suggested by Maier et al. (2012) consisting in four phases: planning, development, evaluation, and maintenance. Our investigation covers the two first phases. We are currently proceeding with the model's evaluation in real-life case studies. Maintenance is rather related to the continuous upgrade of the model as it is applied. The model's design requires determining the key process areas (KPAs) that are mutually exclusive and collectively exhaustive to describe the evaluated object. Each KPA is defined through associated practices, implemented collectively to satisfy important improvement goals. KPAs are described at different levels of performance. The highest maturity level is where the KPA's practices are efficiently applied and culturally rooted. We complement this approach with a quantitative study to contextualize the ACAP of SMEs contributing to CINs. This capacity varies according to several contextual determinants. Hence, the ideal maturity level of ACAP KPAs and practices should be defined according to the SME's context.

3.1 Planning

This phase determines the model's audience, its aim, scope, and its success application criteria. To inform these elements, we performed a literature review on SMEs' collaborative innovation, complemented by 10 exploratory semi-structured interviews. We interviewed four CEOs of SMEs in France that have operated in several CINs within the multimedia and textile sectors. We also interviewed two innovation management consultants used to applying maturity models and four representatives of French industrial clusters from sectors with different technological intensities, who frequently support collaborative innovation projects. The interviewees confirmed that collaborative innovation is a major focus of European policymakers to capitalize on synergies between organizations in an environment where knowledge is highly scattered.

For the model's audience, they recommended addressing the key members of the SME's project team including the CEOs, as they are involved in the strategic and operational aspects of innovation projects. The model should aim to quickly identify the SME's capabilities' strengths and gaps since the CIN early phases. For the scope, the maturity grid must be applicable to SMEs in all sectors and CIN configurations. Finally, the model's application is successful when the SME perceives it as useful, usable, and complete to guide improvement (Moultrie et al. 2007).

3.2 Development

The development phase defines the KPAs, the maturity scale, the content formulation, and the administration mechanism. To inform these elements, we combined an muti-topic literature review and three empirical sources. First, 19 semi-structured interviews were conducted in three different CINs in the mechanical, software, and medical sectors. These CINs involved 13 SMEs embedded in various collaboration configurations considering the ACAP contextual determinants. We interviewed key project team members within these SMEs and within some of their partners, resulting in 23 hours of recordings that were transcribed and grammatically sub-divided to enable their thematic analysis with NVivo. We reached semantic saturation by the 16th interview. Second, we organized two focus groups with 14 experts including researchers in knowledge management and practitioners in CINs to discuss the interviews' outcomes and define the appropriate architecture of the maturity model. Third, we performed a quantitative analysis to elaborate the contextualization approach of the maturity model. The resulting architecture is explained below.

First, for the KPAs, our literature review underlined six exclusive dimensions that holistically describe the SME's ACAP. They refer to knowledge acquisition, assimilation, and application by the SME to contribute to CIN setting-up then development. Their accuracy as KPAs was confirmed following the empirical process. Second, for ACAP maturity, we reviewed several studies around maturity models and selected two criteria, namely capability and willingness. The relevance of these criteria and their associated scales for the studied SMEs were discussed and validated during the focus groups. Third, to formulate the model's content, we applied a hybrid approach recommended for cognitive rather than technical concepts as is the case of ACAP (Cohen and Levinthal 1990). The approach consists in describing the KPAs with set of questions expressing best practices. The respondent scores the KPA's practices on a Likert scale ranging from 1 to n, where n is the highest maturity level of the KPA. To define these best practices, we combined the outcomes of an in-depth review of the existing ACAP multidimensional measures, those of the interviews, and the outputs of the focus groups. Fourth, both focus groups recommended an interactive administration mechanism in the presence of a

moderator and the SME's representatives, as it is more engaging and stimulating for the participant than individually informing the model.

Finally, as the SME's ACAP varies according to its embedding context in the CIN, we designed a prediction process to guide the SME toward the most important KPAs and practices for its context. Under SmartPLS4.0, we used PLS (partial least squares) algorithm because of its forecasting virtues (Tenenhaus et al. 2005), to quantitatively analyze 74 responses of a survey conducted with SMEs contributing to CINs. PLS allows prediction with latent variables by performing regressions from the scores obtained through a succession of factorial analyses. Accordingly, the contextual determinants and ACAP practices were refined and the prediction equations formulated.

4. Results

4.1 Practices Associated with the ACAP KPAs

As underlined in Table 1, 56 practices were determined to describe the six KPA. 31 were adjusted from the extant ACAP multidimensional measures. The interviews confirmed some of these adapted practices and highlighted 25 new ones. Most of these emerging practices refer to the issue of risk management throughout both stages of a CIN. No new practices were proposed in the focus groups.

Table 1: Items of the Contextual Factors and ACAP Dimensions

Construct type	Label	Definition	Items	Scales
Contextual factors	*EXT*	External circumstances driving knowledge absorption by the SME	*EXT1*	Rapid evolution of the industry's technologies
			*EXT2**	High regulation of the industry's policy
			EXT3	High frequency of innovation in the industry
			EXT4	High competitiveness of the market in the industry
	ROLE	Role's centrality of the SME in the CIN	*ROLE1*	Strong involvement in exchanges with the market
			ROLE2	Strong involvement in project management
			ROLE3	Strong involvement in technical coordination
	INT	Internal circumstances driving knowledge absorption by the SME	*INT1*	Achieve an innovation that you will own
			INT2	Generate financial profit
			INT3	Acquire learnings
			INT4	Extend the professional network
			INT5	Re-orientate the firm's strategy
	COG	Cognitive distance of the SME and the CIN actors	*COG1*	Distant disciplines regarding the other CIN actors
			*COG2**	Different structure and/or culture regarding the other CIN actors
	COOP	Competition among the SME and the CIN actors	*COOP1*	Similar expertise and/or activities regarding the other CIN actors
			COOP2	Similar commercial strategy regarding the other CIN actors
KPAs for the SME's contribution in CIN setting-up	*ACQ1*	Acquisition of external knowledge for CIN setting-up	*ACQ1.1**	Investigate technological knowledge
			ACQ1.2	Investigate supply chain knowledge
			*ACQ1.3**	Investigate market knowledge
			ACQ1.4	Investigate knowledge on innovation project management
			ACQ1.5	**Investigate knowledge on collaboration innovation**
			*ACQ1.6**	Mobilize databases

Construct type	Label	Definition	Items	Scales
			ACQ1.7	Solicit the CIN actors
			ACQ1.8	Solicit experts outside the CIN
			*ACQ1.9**	Solicit the client
			*ACQ1.10**	Participate in industrial/scientific events
			ACQ1.11	Be inclined to investigate any other useful knowledge area
	ASS1	Assimilation of external knowledge for CIN setting-up	*ASS1.1*	Involve the client
			ASS1.2	Ensure a coherent vision by exchanging with the CIN actors
			ASS1.3	Exchange with CIN actors and the client using boundary objects
			ASS1.4	**Evaluate the pros and cons of a network with unusual actors**
			ASS1.5	**Be inclined to integrate a network with unusual actors**
	APP1	Application of external knowledge for CIN setting-up	***APP1.1***	**Explain your participation in the budget**
			APP1.2	**Explain your intended operational contribution**
			*APP1.3**	Designate individuals from your firm for this project
			APP1.4	Recognize your future interfacing actors in the CIN
			APP1.5*	**Set-up project management procedure**
			APP1.6	**Set-up features for monitoring the innovation performance**
			APP1.7*	**Implement the tools for collaboration and interface steering**
			APP1.8	**Explain your terms of collaboration**
			APP1.9	**Define a commonly agreed business model with the CIN actors**
			*APP1.10**	Designate boundary spanners for the CIN
			APP1.11	**Agree on the legitimacy of the boundary spanners**
			APP1.12	**Sign formal contracts with the other actors**
			APP1.13*	**Evaluate the consistency of the project with your strategy**
			APP1.14	**Be inclined to adjust your own goals for the network benefit**
KPAs for the SME's contribution in CIN	*ACQ2*	Acquisition of external knowledge for CIN development	***ACQ2.1***	**Recognize requirements of input actors for your contribution**
			ACQ2.2	**Recognize requirements of output actors for your contribution**
			ACQ2.3	Solicit the CIN actors
			*ACQ2.4**	Solicit experts outside the CIN
			*ACQ2.5**	Solicit the client
			ACQ2.6	Mobilize databases
			*ACQ2.7**	Participate in industrial/scientific events

Construct type	Label	Definition	Items	Scales
development			*ACQ2.8*	Be inclined to investigate any other useful knowledge area
	ASS2	Assimilation of external knowledge for CIN development	*ASS2.1**	Involve the client
			ASS2.2	Exchange with your interfacing actors
			ASS2.3*	**Ensure a coherent vision by exchanging with the CIN actors**
			ASS2.4	Exchange with CIN actors and the client using boundary objects
			ASS2.5	Use IT means to share knowledge with CIN actors and the client
			ASS2.6*	**Question the suggestions of the other actors and the client**
			ASS2.7	**Be attentive to leakages of your key knowledge in the CIN**
			ASS2.8	Be inclined to integrate uses other than your ways of doing
	APP2	Application of external knowledge for CIN development	*APP2.1*	Work jointly with your interfacing actors
			APP2.2	**Test the innovation with the client**
			APP2.3*	**Promote the innovation in events**
			APP2.4	**Use advanced technologies to achieve your contribution**
			APP2.5	Document your contribution
			APP2.6	Challenge your contribution's performance
			APP2.7	**Raise your doubts for development and commercialization**
			APP2.8*	**Allocate further resources to the project id required**
			APP2.9	Assist the other CIN actors to achieve their contributions
			APP2.10	**Be inclined to adjust your contributions based on the CIN needs**

*Item omitted during the quantitative analysis **Item resulting from the interviews**

Then, we performed factor analysis to eliminate the non-significant practices, which resulted in retaining 38 absorption practices. This required assessing the practices' reliability based on a bootstrapping procedure with 500 sub-samples, then evaluating the constructs' convergent validity in terms of AVE, and their reliability with Dillon-Goldstein's Rho and Cronbach's alpha. Regarding discriminant validity, all the constructs verified the Fornell-Larcker and HTMT criteria.

4.2 Prediction Process

We formulated equations predicting the scores of the relevant ACAP dimensions and practices for an SME according to its embedding CIN context. PLS generates these equations with the outer and inner models (Hair et al. 2011). The former measures the latent variables using their indicators. The latter calculates the scores of the dependent variables based on their structural links with the independent ones. KPA ACQ1 is used as an example below.

To calculate ACQ1, the inner model (equation 1) aggregates a coefficient and the scores of the contextual factors determined as the scalar products of their items and weights' vectors, pondered with their structural coefficients regarding ACQ1. The coefficients and factors' weights result from the PLS algorithm, while the items are informed by the SME to describe its context.

$$(1)\ \boldsymbol{ACQ1} = \ 0.304\ COOP + 0.406\ ROLE + 0.164\ EXT + 0.457$$

ACQ 1 in the outer model (equation 2) is the scalar product of its items (practices) and weights' vectors. These weights result from the PLS algorithm.

$$(2)\ \boldsymbol{ACQ1} = \{0.163 \quad 0.101 \quad 0.105 \quad 0.226 \quad 0.153 \quad 0.251\} \begin{Bmatrix} ACQ1.2 \\ ACQ1.4 \\ ACQ1.5 \\ ACQ1.7 \\ ACQ1.8 \\ ACQ1.11 \end{Bmatrix}$$

The equality between the two previous equations generates a new equation where the practices' vector is the unknown variable (equation 3). We solve it using the pseudo-inverse of Moore-Penrose (Penrose 1955), which determines the scores of the KPA's absorption practices as:

$$(3) \begin{Bmatrix} ACQ1.2 \\ ACQ1.4 \\ ACQ1.5 \\ ACQ1.7 \\ ACQ1.8 \\ ACQ1.11 \end{Bmatrix} = \frac{0.304\ COOP + 0.406\ ROLE + 0.164\ EXT + 0.457}{0.163^2 + 0.101^2 + 0.105^2 + 0.226^2 + 0.153^2 + 0.251^2} \begin{Bmatrix} 0.163 \\ 0.101 \\ 0.105 \\ 0.226 \\ 0.153 \\ 0.251 \end{Bmatrix}$$

To determine the relevant practices of this KPA for the SME, we first standardize the practices' predicted scores on a scale of 1 to 4. Then, we retain the practices whose standardized scores are greater than 2. This average value was discussed and validated during the two focus groups.

4.3 Maturity Scale

CMMI evaluates maturity through operational mastery, while other studies consider it a composite notion including the mastery of processes, and the attitude of individuals regarding these processes (Le Dain et al. 2008). As knowledge absorption practices do not correspond to institutionalized processes as in CMMI and integrate a behavioral dimension (Razak et al. 2016), we evaluate ACAP maturity in terms of the SME's ability to operationally implement absorption practices 'Capability', and its propensity toward these practices 'Willingness'.

A maturity level between 1 and 4 is assigned to each evaluated practice within a KPA following the SME's response to two questions related to the maturity criteria (Table 2). For capability, an SME is expert (level 4) if it perfectly applies the methods required for the absorption practice. For willingness, an SME is a firm believer (level 4) if it perceives the interest of implementing the practice and is willing to perform it whenever it is necessary.

Table 2: Scale Assessing an SME's Maturity for Each Practice Within the six KPAs

Capability				**Willingness**		
For this project, are you to capable of performing the following practice?				*For this project, do you think it is relevant that you implement the following practice?*		
Yes, I am perfectly capable	**4**	**Expert**		Of course, it is even necessary	**4**	**Firm believer**
Yes, I am capable but need more formalization	**3**	**Capable**		Yes	**3**	**Culturally rooted**
I have some ideas but don't know how to proceed	**2**	**Some ideas**		I am neither against nor convinced	**2**	**Potentially receptive**
I can't do it and have no idea about it	**1**	**Not capable**		No, I don't find it relevant	**1**	**Culturally resistant**

The SME representatives discuss with the moderator their maturity results and improvement actions for each KPA, starting with the most important KPAs predicted for the SME's context. A lack of capability will essentially require training and support for the SME's project team to better deploy the absorption practice. A lack of

willingness will mainly entail motivational and communication initiatives to improve the awareness of the SME's project team regarding the benefits of the absorption practice. In the critical case, the SME's project team is neither convinced of the interest nor capable of implementing the absorption practice. If a large number of the practices evaluated by the SME is deficient regarding both capability and willingness, participating in the CIN with such a team can be risky. Also, the necessary improvements will be substantial in terms of implementation cost and time. Thus, it seems wise, before taking improvement steps, to analyze the adequacy of these individuals to represent the SME within the CIN, as well as the SME's role in the network. This maturity scale was approved following the two focus groups.

5. Discussion and Conclusion

5.1 Theoretical Implications

First, this research unveils the contingent nature of ACAP for an SME contributing to a CIN (Lubatkin et al. 2001). On one side, although some absorption practices seem to be transverse to a CIN's lifecycle (Table 1), their implementation substantially differs according to the considered stage. For instance, the empirical study underlined that the use of databases for new knowledge acquisition is more significant in the development phase. Also, the involvement of the client for the interpretation of its specifications is rather important in the upstream stage. On the other side, a significant number of emerging absorption practices focuses on managing the risks of knowledge internalization specific to each CIN stage. Among these practices, we emphasize the necessity for an SME to assess, in the setting-up phase, the risks of collaborating with competitors and to question, in the development stage, the other actors' propositions likely to alter its contribution's quality.

Second, we demonstrate how the relative importance of each ACAP dimension differs according to an organization's context (Flatten et al. 2011) in the case of SMEs contributing to CINs. Indeed, the quantitative analysis enabled the elaboration of a predictive process that guides an SME toward the most relevant ACAP dimensions and practices for its context in a CIN. Each ACAP component is deployed differently depending on the level of the SME's external and internal triggers, its role centrality within the CIN, and the peculiarities of its partners.

Third, this study complements the information processing perspective (Galbraith 1974) of SMEs contributing to CINs. Although more knowledge improves performance, firms need to establish rules to organize themselves and guide employee behavior regarding knowledge. This is particularly important when firms are dealing with uncertain environments as they require more "*information that has to be processed between decision-makers*" (Galbraith 1974, p. 28). The examined SMEs are directly concerned by this requirement since they engage in CINs to align with their increased sectors' turbulence and to propose innovative solutions involving different stakeholders to face competitive pressure (Tojeiro-Rivero and Moreno 2019). Hence, we demonstrate that the right deployment of ACAP can help these SMEs resolve the information processing dilemmas when contributing to CINs.

5.2 Managerial Implications

We provide SMEs participating in CINs with an assessment instrument to harness external knowledge according to their CIN contexts.

Also, we raise their awareness on highly critical absorption practices that the partners should perform to achieve their common innovation goal. These practices include conceiving a business model commonly approved by the CIN actors, contracting the relationships in the CIN to establish trust, using IT means for better sharing and capitalization of knowledge, etc.

Moreover, the developed model may help SMEs determine what collaborations make sense for them and what role they can play in CINs. By assessing its ACAP, an SME can be aware of the most appropriate partners to better respond to its internal and external innovation triggers and to compensate for its ACAP deficiencies.

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