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THE EFFECT OF KNOWLEDGE COLLABORATION ON INNOVATION PERFORMANCE: THE MODERATING ROLE OF DIGITAL TECHNOLOGY

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ABSTRACT

The aim of this study is to examine the implications of knowledge collaboration in open innovation and the role of digital technology therein. The paper draws on a survey of manufacturing firms having more than 10 employees in Italy, Sweden, France and Spain. The results show that knowledge collaboration with external partners has a significant effect on innovation novelty but not innovation efficiency. In addition, the results show that digital technology moderates the relationship between knowledge collaboration and innovation efficiency but not the relationship between knowledge collaboration and innovation novelty. Overall, this study contributes to the growing discussion about the benefits of adopting digital technologies in open innovation processes by investigating whether and under which conditions knowledge collaboration is beneficial.

Keywords: *Knowledge collaboration; digital technologies; innovation novelty; innovation efficiency*

1. INTRODUCTION

Existing studies in the field of open innovation (OI) consistently identify external partners as one of the most important sources of knowledge regarding innovative processes that help create market value (He et al., 2013). In order to effectively capture such value, manufacturing firms are required to combine their knowledge with their external partners to quickly create and commercialize innovations successfully (Bengtsson et al., 2015). Growing evidence suggests that digital technology may play a beneficial role in external collaboration in areas such as logistics (e.g., Prajogo and Olhager, 2012), co-creation (e.g., Agrifoglio et al., 2017) and innovation (Yoo et al., 2012)

Digital technologies are supposed to support external collaboration by providing instant connectivity, accessibility and information sharing. Together, these functionalities can have the ability to create external knowledge collaboration by supporting the activities in innovation process. Despite the growing potential digital technologies offer to (open) innovation processes (e.g. Urbinati et al., 2018), the effectiveness and viability of digital technology integration into current systems related to innovation activities are still understudied (Tortorella et al., 2019). Thus, one purpose of this study is to investigate the effect of digital technologies on the relationship between knowledge collaboration and

innovation performance (Felin and Zengar, 2014). Furthermore, existing studies have demonstrated the challenges related to knowledge crossing boundaries (Parmentier and Gandila, 2013). However, little attention has been paid to the effectiveness and efficiency of crossing knowledge to and from external partners, particularly by implementing digital technologies. Therefore, the second purpose is to investigate how digital technology moderates the relationship between knowledge collaboration and innovation performance.

2. THEORETICAL BACKGROUND

In this study, we adopt the knowledge-based view (KBV), given that, in today's economy, knowledge is one of the most important strategic resources firms possess (Grant and Baden-Fuller, 2004; Nonaka, 1994), allowing them to develop and sustain competitive advantage (March, 1991). In this view, firms actively pursue collaborative relationships with partners that are assumed to have complementary knowledge. In so doing, firms can leverage their internal knowledge by relying on the knowledge and skills attained through external collaboration. However, the success of this approach is contingent on the firm's capability to bridge organizational boundaries, which is not easy in practice. Therefore, additionally, the theory of dynamic capabilities is adopted, as it directly relates to a firm's ability to collaborate and apply external and internal competencies when dealing with fast-changing environments (Teece et al., 1997). This necessitates the adoption of routines that can enhance effectiveness, which can be developed through collective activities within the firm, as well as jointly with external partners. In line with the KBV, dynamic capabilities entail that a firm relies on knowledge and capabilities. However, authors of existing studies in this field have failed to elucidate how knowledge and capabilities create value in uncertain environments (Ambrosini et al., 2009). This gap can be addressed by examining how firms create, extend and modify their knowledge base to adapt to technological changes (Ambrosini et al., 2009; Teece et al., 1997). In rapidly changing environments, firms need to renew their competencies and resources and adopt innovative responses. This is particularly important in the digital transformation context, as digital technologies can contribute to more effective open innovation collaboration, while also facilitating development of a firm's specific capabilities when collaborating with external partners (Mikalef and Pateli, 2017; Parida et al., 2019; Warner and Wäger, 2019). Digital technologies allow a firm's resources and information to be connected digitally, while also facilitating sensing and presenting knowledge to external partners to better respond to fast-changing markets. Thus, using digital technologies in conjunction with dynamic capabilities may enable firms to enhance their performance.

2.1 KNOWLEDGE COLLABORATION AND DIGITALIZATION

External partners are an important source of innovation for most firms (West and Bogers, 2014), but the success of such initiatives relies on reciprocal knowledge sharing (Huang and Newell, 2003). Collaboration with external partners can be considered as comprising of knowledge capture and use in innovation project activities and thus relies on arrangements that allow for reciprocal access to knowledge (Berggren et al., 2011; Marsh and Stock, 2006). Consequently, in line with the KBV, knowledge collaboration is central to collaborative activities with partners and typically includes accessing similar/related knowledge (Teece et al., 1997) or a combination of specialized, differentiated, but complementary knowledge bases (Kogut and Zander, 1996; Tiwana and Mclean, 2005).
In this context, digital technologies enable firms to go a step further by applying already existing digitized data to generate new opportunities through, e.g., the Internet of Thing (Souder, 2015; De Vass et al., 2019). The particular value of digital technologies stems

from their ability to capture data in real time for simultaneous analysis (Kohler, 2018). This can lead to a new level of opportunities that can be gained through collaboration. Previous studies have operationalized digital technologies as internet-oriented, things-oriented or semantically-oriented (e.g., Atzori et al., 2010). The internet-oriented aspect refers to the usage of global digital networks and platforms, such as cloud technology, for the facilitation of data transmission. The things-oriented aspect pertains to the physical attributes of digital technologies that should architecturally allow real-time data capture. The semantic orientation of digital technologies includes the data processing and synthesizing capability. Considering these attributes, it is apparent that digital technologies may have a similar enhancing effect as ICT has on external collaboration (Santoro et al., 2018; Solima, 2016). However, as digital technologies are not fully utilized in all business domains, there is limited evidence on the outcomes of their adoption (Reaidy et al., 2015). Nevertheless, due to its potential for autonomous and extensive application, together with its increasing affordability, digitalization has been a favourable approach in the open innovation context (Urbinati *et al*., 2018; Verdouw et al., 2016).

2.2 THE EFFECTS OF KNOWLEDGE COLLABORATION

Authors of previous studies argue that, in innovation projects, external collaboration yields successful outcomes (e.g., Laursen and Salter, 2006; Anzola-Román et al., 2019), albeit not under all conditions (Menguc et al., 2014). Most of these researchers claim that external collaboration can lead to increased project innovativeness and better resource deployment (West and Bogers, 2014). In the context of open innovation, demand for new ideas pushes firms to rely increasingly on their external partners' input when sharing ideas (e.g., Lakemond et al., 2016). This suggests that firms will increasingly need to tap into the knowledge of other firms to meet their business goals. In fact, knowledge collaboration with external partners enables firms to discuss the development activities involved in different innovation phases, which helps them develop new solutions more effectively (Parmigiani and Rivera-Santos, 2011). In addition, knowledge collaboration might expedite the development process, as it allows elimination of unimportant features from new projects, resulting in superior solutions (Zhou and Li, 2012; Eslami and Lakemond, 2016). All in all, knowledge collaboration with external partners during the different phases along which the innovation funnel unfolds, can be interpreted as a means to tap into new ideas, advanced technologies and radical product innovations to be introduced into the market, i.e. a means to achieve novelty. Thus, we formulate the following hypothesis:

H1: Knowledge collaboration with partners has a positive significant effect on innovation novelty.

Despite the expected positive effect of knowledge collaboration on innovation novelty, firms need to ensure that the benefits of collaboration do not outweigh the cost (Enberg et al., 2007). This necessitates a careful selection of knowledge collaboration practices and their scope. For instance, by sharing new ideas and solutions in the early stages of a new project, firms may detect possible sources of issues. This might increase project innovation efficiency in terms of reducing cost, risks, and time to market. In addition, Lakemond et al. (2015) recommend using knowledge-matching, as greater awareness of the partner's technological knowledge would reduce knowledge redundancy and costly knowledge transfer (Cassiman and Valentini, 2016). These issues are overcome by creating a common base that allows different experts in the collaborating firms to evaluate

and assess each other's knowledge. In terms of knowledge type, tapping into the partners' knowledge on market demands and satisfying those needs will allow firms to provide innovative solutions with minimal defect levels (Cui and Wu, 2017). Thus, we formulate the following hypothesis:

H2: Knowledge collaboration with partners has a positive effect on innovation efficiency.

2.3 DIGITAL TECHNOLOGIES IN KNOWLEDGE COLLABORATION

Digital technologies such as ICT tools facilitate generation of new ideas, which leads to knowledge diversity, thus enhancing firms' knowledge base and capabilities (Urbinati et al., 2018). This process can be coordinated by establishing practices that enable alignment among diversified knowledge flows. Previous studies (Madakam et al., 2015; Santoro et al., 2018) indicate that technology diversity aids in this process by allowing knowledge to flow seamlessly between partners. By using the appropriate digital technologies for the relevant task, data sharing would enhance collaboration among partners (Tse et al., 2016). Studies in this field argue that external collaboration not only needs commitment from all actors, but also the adoption of appropriate tools (Jitpaiboon and Sharma, 2013). In fact, by using digital technologies, firms are able to develop safe and trustworthy knowledge exchange on new solutions with other firms (Mishra et al., 2018). This signifies that, in collaborative partnerships, digital technologies can surpass the benefits of information and communication technology by capturing more data in real time, which would contribute to the timely resolution of any issues, and thus to new project success. Therefore, we hypothesize:

H3: Digital technologies moderate the relationship between knowledge collaboration and innovation novelty positively.

Firms' responsiveness can also be increased through digital technologies, as the resources and time required for interpreting the data would rapidly decline, making the firms more responsive to market demands (Yu et al., 2015). In particular, greater attention can be paid to product features, designs and cost. Moreover, digitalized systematic compatibility with partners facilitates sharing of time-sensitive knowledge such as inventory and forecasts. Pearcy and Giunipero (2008) similarly argue that keeping partners up to date regarding changes reduces the potential for missing project deadlines. As digital technologies allow knowledge to be shared and activities optimized in real time, external partners can respond quickly to any changes and make joint decisions (García-Alcaraz et al., 2019). Thus, we propose:

H4: Digital technologies moderate the relationship between knowledge collaboration and innovation efficiency positively.

Figure 1 depicts the conceptual model examined in this study.

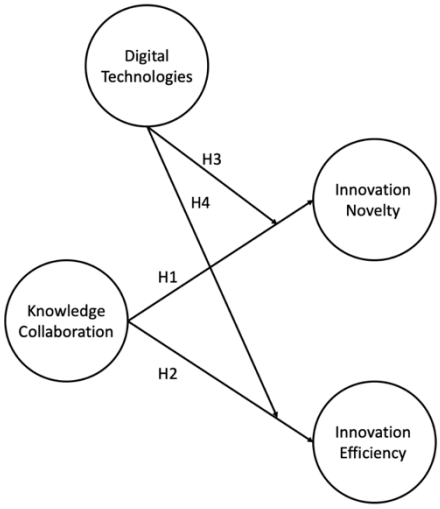

Figure 1. Conceptual model

3. RESEARCH DESIGN

The data has been collected through a cross-sectional survey of manufacturing firms (Codes 10-32 NACE Rev.2) each having more than 10 employees in Italy, Sweden, France and Spain. The questionnaire was sent to CEOs, R&D managers or anyone involved in open innovation decision making. The survey questionnaire was assessed in a pilot study in which knowledgeable academic/practitioner colleagues were included. The questionnaire was issued by using an online survey platform and was distributed by email to all participants in the four countries.

Employees	Frequency	Percentage
0-10	31	9%
11-50	99	30%
51-250	66	20%
>250	134	40%
Missing	4	1%

Table 1 Sample Description: Employees

Annual Gross Sales	Frequency	Percentage
< $20 million	135	40%
$20–50 million	28	8%
$50–100 million	38	11%
$100–500 million	35	10%
>$500 million	80	24%
Missing	18	5%

Table 2 Sample Description: Gross Sales

The analysis focused on the collaboration between manufacturing firms and their key partners involved in OI projects. To keep up the response rate, the initial invitation mail was followed up with three reminders. This resulted in 334 valid responses, which are

distributed as: 117 in Sweden, 116 in Italy, 52 in France and 49 in Spain. The sample was distributed equally among micro, small, medium and large firms (Table 1). The average annual gross sales was about 103 million euros. Around 40% of the firms sold less than $20M, 29% of the firms sold between $20M and $500M, while the remainder 24% sold more than $500M (Table 2).

3.1 MEASUREMENT

We measured all the construct variables based on Likert-type scales, ranging from 1 (strongly disagree) to 7 (strongly agree) to certify statistical variability through the survey responses.

Innovation efficiency was constructed based on four items: (1) reduce the lead time of new product/service/process development, (2) reduce production throughput time, (3) increase product/service delivery speed and (4) increase product/service delivery dependability (Lazzarotti et al., 2015). Innovation novelty was constructed based on five items: (1) develop new products /services, (2) improve existing products/services, (3) enter new markets, (4) extend the product/service portfolio and (5) offer wider product/service range (Lazzarotti et al., 2015).

Knowledge collaboration was measured in terms of the extent to which employees: (1) have access to partners' knowledge resources, (2) achieve synergy by combining knowledge together with the partners and (3) tap into the resources and capabilities of partners which complement firm's resources and capabilities (Lin and Chen, 2006).

Digital technologies was measured using four items: (1) using online platforms to collaboratively create knowledge, (2) external social networks to present user-profiles in terms of skills and support the interaction between users, (3) discussion online forums to allow people to discuss specific topics and (4) online platforms used to regularly publish new information, comments, graphic elements and videos (Michaelides and Kehoe, 2007).

In addition, firm size, turnover rate (in natural logarithms) and technological environment were used as control variables. The technological environment construct was measured using the following items: (1) closely observing technological development is important for long-term success in our industry, (2) technological changes provide big opportunities in our industry, (3) the complexity and inter-sectoral nature of new technologies is increasing in our industry, (4) cross-fertilization of scientific disciplines and fields of technology is high in our industry, and (5) monitoring a spectrum of technologies is necessary in our industry (Lazzarotti et al., 2017).

A confirmatory factor analysis (CFA) was used to examine the quality of the measures. We have set a value of 1 to the loadings within each of the constructs in order to evaluate the low factors loading, modification indices and residual variances. Regarding model fit, we used four measures: the comparative fit index (CFI), the root mean square error of approximation index (RMSEA), the chi-square test and the Tucker–Lewis Index (TLI) (Gerbing and Anderson, 1992). The CFA showed acceptable fit (x2/df= 2,552; x2= 456 ($p<0.000$); RMSEA = 0.068; GFI = 0.93; CFI = 0.942; NFI = 0.91). In addition, we used different procedures for convergent validity of the results (Anderson and Gerbing, 1988). The average variance extracted (AVE) was greater than .60, the minimum to validate the use of a construct. The composite reliabilities (CR) ranged from .82 to .91, which met the satisfactory level. All tests of discriminant validity were supportive. Table 3 shows statistical measurement items, including standardized loading, *t*-value, AVE, CR and Cronbach's alpha. Table 4 presents the descriptive statistics of the constructs including validity and reliability. Moreover, to assess potential issues related to common method bias, we used Harman's one factor procedure to evaluate common method variance.

Measurement items	SFL	CR, AVE & Cronbach's alpha
Innovation Novelty		CR = .888
Develop new products /services	.75	AVE = .616
Improve existing products/services	.63	Alpha = .884
Enter new markets	.75	
Extend the product/service portfolio	.88	
Offer wider product/service range	.88	
Innovation Efficiency		CR = .932
Reduce the lead time of new product/service/process development	.84	AVE = .776
Reduce production throughput time	.88	Alpha = .932
Increase product/service delivery speed	.92	
Increase product/service delivery dependability	.89	
Knowledge Collaboration		
Access to partners' knowledge resources	.73	CR = .823
Synergy is created by combining knowledge together with the partners	.83	AVE = .608
The resources and capabilities of partners complement firm's resources and capabilities	.77	Alpha =. 819
Digital Technologies		CR = .880
Using online platforms to collaboratively create knowledge.	.75	AVE = .647
External social networks to present user-profiles in terms of skills and support the interaction between users	.75	Alpha = .875
Discussion online forums to allow people to discuss specific topics	.86	
Online platforms used to regularly publish new information, comments, graphic elements and videos	.85	
Technological Environment		CR = .932
Closely observing technological development is important for long-term success in our industry	.78	AVE = .681 Alpha = .913
Technological changes provide big opportunities in our industry	.80	
The complexity and inter-sectoral nature of new technologies is increasing in our industry	.85	
Cross-fertilization of scientific disciplines and fields of technology is high in our industry	.83	
Monitoring a spectrum of technologies is necessary in our industry	.86	

Table 3 Item measurement and factor analysis

	CR	AVE	MSV	IN	IE	KC	DT	TU
Innovation Novelty (IN)	0,888	0,616	0,311	0,911				
Innovation Efficiency (IE)	0,932	0,776	0,397	0,936	0,163**			
Knowledge Collaboration (KC)	0,823	0,608	0,311	0,830	0,558***	0,047		
Digital Technologies (DT)	0,880	0,647	0,397	0,890	0,193**	0,630***	0,060	
Technological Uncertainty (TU)	0,914	0,681	0,373	0,917	0,137	0,584	0,154	0,611

Table 4 Descriptive statistics

To test H1 and H3, we conducted regression analyses (Tables 5 and 6), using ordinary least-square estimations. Model 1 includes all the control variables. Model 2 consists of the effect of knowledge collaboration on innovation novelty. Model 3 includes the impact of digital technologies as a moderator on the relation between knowledge collaboration and innovation novelty. In addition, to test H2 and H4, we performed another regression

analysis in regard to the innovation efficiency performance, following the same above-mentioned models.

	Model 1		Model 2		Model 3	
	Coef.	S.E	Coef.	S.E	Coef.	S.E
Size	.193***	(.031)	.113*	(.028)	.108*	(.028)
Sales	-.329***	(.018)	-.230**	(.017)	-.233	(.016)
Technological Uncertainty	.170**	(.049)	.113	(.045)	.004	(.053)
Knowledge Collaboration (KC)			.419***	(.056)	.392***	(.103)
Digital Technologies (DT)					.087	(.237)
Moderation KC * DT					.112	(.040)
N	334		334		334	
F	17.89***		35.26***		26.26***	
Adj R2	.132		.292		.313	
R2	.140		.300		.325	

Table 5 Regression analysis based on innovation novelty

Note: *P < 0.05, **P < 0.001, ***P < 0.001

	Model 1		Model 2		Model 3	
	Coef.	S.E	Coef.	S.E	Coef.	S.E
Size	-.180***	(.035)	-.183***	(.036)	-.183***	(.032)
Sales	.032	(.020)	.036	(.021)	.022	(.019)
Technological Uncertainty	.572	(.056)	.570***	(.056)	.315***	(.061)
Knowledge Collaboration (KC)			.015	(.070)	-.183*	(.129)
Digital Technologies (DT)					-.288	(.270)
Moderation KC * DT					.767**	(.046)
N	334		334		334	
F	56.48***		42.27***		48.97***	
Adj R2	.333		.334		.464	
R2	.339		.339		.473	

Table 5 Regression analysis based on innovation efficiency

Note: *P < 0.05, **P < 0.001, ***P < 0.001

4. RESULTS

The results show that knowledge collaboration has a positive effect on innovation novelty, thus H1 was supported. However, the study also shows that knowledge collaboration does not have a significant effect on innovation efficiency, meaning that H2 is not supported. In addition, the use of digital technology moderates positively the relationship between

knowledge collaboration with external partners and innovation efficiency, which supports H4. However, digital technology does not moderate the relationship between knowledge collaboration and innovation novelty, which therefore indicates that H3 is not supported.

5. DISCUSSION AND CONTRIBUTION

The findings yielded by this study contribute to the further development of the ongoing discussion on the implications of knowledge collaboration in open innovation and the role of digital technology therein. In particular, (1) knowledge collaboration was shown to expedite open innovation processes and enhance the potential for innovation novelty while (2) digital technologies moderate the relationship between knowledge collaboration and innovation efficiency.

5.1 THEORETICAL CONTRIBUTION

First, this study addresses the call made by Cassiman and Valentini (2016) for empirical studies focusing specifically on the knowledge collaboration outcomes. Thus, by investigating the relationship between knowledge collaboration and two aspects of innovation performance, our study contributes to the extant innovation management literature. In particular, we demonstrate that by exchanging knowledge with external partners in open innovation projects, firms can increase the potential for novelty, as inter-organizational collaboration brings relevant competences together. However, when pursuing knowledge collaboration, the cost, time and effort needed to capture and utilize partners' knowledge must be carefully evaluated against the benefits (Cassiman and Valentini, 2016). This argument is supported by the results reported by other authors (e.g. Enberg et al., 2010), indicating that external knowledge collaboration requires more time and effort than "simpler" intra-organizational innovation processes.

Second, our study contributes to the growing discussion about the benefits of adopting digital technologies in OI processes by investigating the effects of digital technologies on the association between knowledge collaboration and innovation performance. Interestingly, our findings indicate that digital technologies do not further enhance the novelty aspects of OI performance, but improve the efficiency effects of knowledge collaboration significantly, i.e. they play a key role in reducing the cost, time and efforts involved in interfirm collaboration but do not make the collaboration more creative.

Consequently, digital technologies can extend and overcome the boundaries of innovation firms. Together, these findings suggest that digital technologies reduce the negative effects of physical distance on the efficiency of communication between partners in that it creates virtual colocation. However, digital technologies do not necessarily enhance the effectiveness of important innovation activities such as problem-solving, brainstorming, and other creativity-supporting mechanisms.

5.2 MANAGERIAL IMPLICATIONS

The findings presented in this paper have important managerial implications for firms seeking to collaborate with external partners in innovation projects. First, firms can use our empirical results to evaluate whether and under which conditions knowledge collaboration is beneficial. Our analyses provide specific guidance on how firms can attain the desired benefits from collaboration with external partners. In particular, collaboration with "good" partners, i.e. partners with complementary knowledge bases, helps creating more novel outcomes. Second, digital technologies help increase the efficiency of, i.e. reduce the cost, time, efforts put into, the knowledge collaboration but do not necessarily also further enhance the creativity of the collaboration and, in effect,

the novelty of the PI outcomes.

5.3 LIMITATION AND FURTHER RESEARCH

This study is subject to some limitations, which should be addressed in future research. For example, it would be beneficial to examine the effects of antecedents (e.g., innovation culture and capabilities) on knowledge collaboration (Pekovic and Rolland, 2016). Similarly, the effects of relevant routines and competencies on the benefits of adopting digital technologies in OI processes should be explored further. Finally, future studies should examine strategies for implementing organizational changes associated with the digital transformation of OI processes.

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