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Yassine Talas, Lamiae Benhayoun-Sadafiyyine, Marie-Anne Le Dain. How does IT effective use impact NPD project success? An IT functional approach for collaborative buyer-supplier NPD. ECIS 2020 : 28th European Conference on Information Systems. "Liberty, Equality, and Fraternity in a Digitizing World", Jun 2020, Marrakech, Morocco. pp.20. hal-02643299

HAL Id: hal-02643299

<https://hal.science/hal-02643299v1>

Submitted on 28 May 2020

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Recommended Citation

Talas, Yassine; benhayoun, Lamiaeh; and Le Dain, Marie-Anne, "HOW DOES IT EFFECTIVE USE IMPACT NPD PROJECT SUCCESS? AN IT FUNCTIONAL APPROACH FOR COLLABORATIVE BUYER-SUPPLIER NPD" (2020). *ECIS 2020 Research Papers*. 20.

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HOW DOES IT EFFECTIVE USE IMPACT NPD PROJECT SUCCESS? AN IT FUNCTIONAL APPROACH FOR COLLABORATIVE BUYER-SUPPLIER NPD

Research paper

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Abstract

Buying firms collaborate with suppliers in New Product Development (NPD) to better leverage their resources and knowledge. Prior studies' results on IT contribution to NPD project performance are mixed, and none investigated this effect for collaborative buyer-supplier NPD projects. This study adopts a contextual functional approach to explore how the effective use of IT functionalities for the three classical IT-enabled NPD activities, namely Project and Process Management (PRM), Knowledge Management (KM), and Cooperative Work (CW), impacts NPD project success in terms of project performance but also regarding the contextual factor of collaboration quality. A series of multiple linear regressions is performed to test these effects using data from a survey with 90 firms involved in collaborative NPD projects with suppliers. As results, the effective use of all IT functionalities directly improves collaboration quality, while only KM directly affects project performance. PRM and CW contribute to this performance only indirectly through collaboration quality. Hence, this study emphasizes the importance of considering a functional approach when studying the impact of IT effective use on NPD project success, and of taking into account the project context. Additionally, it incites practitioners to build a conducive collaboration climate to benefit from using IT functionalities.

Keywords: Information Technologies, New Product Development, Buyer-supplier collaboration, Multiple linear regression.

1 Introduction

New Product Development (NPD) projects are characterized by parallel tasks and the simultaneous contribution of diversified expertise and knowledge (Juan et al., 2009). In such projects, the effective use of IT (Information Technologies) enables extending the information and knowledge base of NPD teams (Ettlie and Pavlou, 2006; Kroh et al., 2018), supports the flow of relevant knowledge at the right time, and promotes the automation and monitoring of tasks (Kawakami et al., 2015). Regarding the NPD project performance, numerous theoretical studies underlined that the effective use of IT could result into better commercial performance, reduced time to market and lower development costs (Menon et al., 2002; Nambisan, 2003; Ozer, 2000; Sethi et al., 2003). Nevertheless, the few empirical studies that investigated the impact of IT effective use on NPD project performance report mixed results. While most of this research suggest a positive impact, other scholars were not able to demonstrate this effect or even highlighted a contrary influence (e.g. Heim et al., 2012; Kawakami et al., 2015; Mauerhoefer et al., 2017). According to Barczak et al. (2008), these mixed results on IT's contribution to NPD project performance justify their underutilization in this process despite their proliferation. Indeed, NPD project actors are not able to value the return on investment on IT nor to appreciate their benefits for project performance, which withholds them from adopting these technologies (Markham and Lee, 2013).

A main reason that could explain the mixed results on the impact of IT effective use on NPD project performance is that the context of their utilization is not taken into account (Barczak et al., 2008; Montoya et al., 2009). As underlined by Peng et al. (2014), it is important to consider the peculiarities of the NPD context in order to grasp the specific contribution of IT use to project performance. Most studies that investigated this impact addressed generic or non-precise NPD contexts (e.g. Kawakami et al., 2015; Marion et al., 2014; Reid et al., 2016). One specific project configuration which has been rarely explored (Terwiesch et al., 2002) and for which no incisive results have been reached is collaborative buyer-supplier NPD projects (Bensaou, 1997; Vaccaro et al., 2010). Indeed, firms gain competitive advantages by collaborating with suppliers in NPD because they represent a source of innovation and knowledge (Koufteros et al., 2012; Luzzini et al., 2015). However, they may face collaboration challenges with them as these alliances require specific abilities for coordination and inter-organizational knowledge and resources management (Chang, 2017; Lau, 2011; Loebbecke et al., 2016). IT tools use can support such activities and hence reduce challenges of collaborative development with suppliers (Kroh et al., 2018). Another explanation regarding the mixed findings could be that the extant literature did not investigate how the effective use of different IT functionalities contributes to NPD project performance. In fact, this IT effective use in NPD is a three-dimension construct capturing how NPD units leverage IT functionalities for Project and Process Management (PRM), for Knowledge Management (KM) and for Cooperative Work (CW) (Pavlou and El Sawy, 2006). Leveraging capabilities have differentiated impacts regarding NPD project performance (Parente et al., 2011).

Hence, this study investigates the impact of IT effective use on NPD project performance, considering the particular effect of the collaborative buyer-supplier context and following a functional approach that distinguishes the contributions of the three IT functionalities. To take into account the peculiarities of this collaborative context, we analyse how IT effective use indirectly influences NPD project performance through the factor of collaboration quality. Also, since this factor represents a critical success indicator in the case of NPD projects involving suppliers additional to NPD project performance (Hoegl and Gemuenden, 2001; Marion et al., 2014), we explore how it is directly affected by IT effective use. Accordingly, we raise the following research question: « *How does the effective use of IT functionalities (for PRM, KM and CW) contribute to the success of collaborative buyer-supplier NPD projects?* ». This paper is structured as follows. Section 2 describes our theoretical foundations, while section 3 introduces the conceptual model that gathers the hypothesized impacts of IT effective use on collaborative NPD project success. Section 4 is devoted to the research methodology, a quantitative approach to analyze 90 responses collected through a survey with buyer project team members involved in collaborative NPD projects with suppliers. The results are depicted in section 5. Finally, this study is concluded by the discussion of its main theoretical and managerial implications, as well as the suggestion of its future research avenues.

2 Theoretical background

2.1 Collaborative buyer-supplier NPD projects

Firms are increasingly collaborating with their suppliers in NPD in order to better leverage the supplier's resources, expertise and knowledge (Bodas Freitas and Fontana, 2018; Cao and Zhang, 2011). Indeed, collaboration with suppliers leads to an improved NPD project performance (Mishra and Shah, 2009) by lowering development costs, enhancing product quality and reducing time to market (Wasti and Liker, 1999). Achieving the targeted NPD project performance, combining cost, quality and time performances (Naveh, 2005), is a fundamental success criterion for collaborative buyer-supplier NPD projects (Mishra and Shah, 2009). Cost performance expresses the adherence to the total objective cost to develop and manufacture the new product, while time performance corresponds to the achievement of the project's targets in terms of development duration and time to market (Rauniar and Rawski, 2012). Quality performance is the compliance of the technical performance and the product quality to the contractual customer expectations (Tatikonda and Rosenthal, 2000).

Additional to NPD project performance, several authors emphasize the necessity to also consider the collaboration quality (Bstieler, 2006; Jin and Hong, 2007) in order to evaluate the success of collaborative buyer-supplier NPD projects. Indeed, since these projects involve several actors carrying out a multitude of interdependent tasks, their success holds to a high collaboration quality (Marion et al., 2014). Such quality is perceived when the project actors openly communicate information, successfully coordinate their tasks, support each other and fully assume their responsibilities to achieve the project goals (Hoegl et al., 2004; Yan and Dooley, 2014).

2.2 IT functionalities supporting NPD

Based on the resource based view, firms build a competitive advantage from IT-related resources by combining them to form an IT capability that is valuable, rare, nonimitable, and nonsubstitutable (Pavlou and El Sawy, 2006). Accordingly, Bharadwaj et al. (2002, p. 4) define IT capability as the "firm's ability to acquire, deploy, and leverage its IT resources to shape and support its business strategies and value chain activities". In an NPD context, Pavlou and El Sawy (2006) argue that IT capability should be examined at the NPD process level by focusing on the leveraging capabilities of NPD work units. Indeed, "the impact of IT should be assessed where the first order effects are expected to be realized" (Ray et al. 2005, p. 626), which relates to the process level more than to the firm level in the context of NPD projects. Also, the leveraging of IT capability is more likely to help NPD work units differentiate themselves and build a competitive advantage in NPD (Pavlou and El Sawy, 2006).

IT capability is a complex multidimensional construct, and prior research proposed several IT-related resources that combine to devise an IT capability (e.g. Feeny and Willcocks, 1998; Tippins and Sohi, 2003). In an NPD context, three key dimensions form IT capability and convey the leveraging competence of NPD units (Pavlou and El Sawy 2006): Effective use of IT functionalities for Project and Process Management (PRM), for Knowledge Management (KM) and for Cooperative Work (CW):

- Project and Process Management (PRM) IT functionalities help NPD teams better synchronize and coordinate their activities (Pavlou and El Sawy, 2006). They support the project planning through its different phases (Ahlemann, 2009) and enable the project actors to respect its milestones and deadlines (Raymond and Bergeron, 2008). These systems help the teams organize the NPD through features of tasks' sequencing (Pavlou and El Sawy, 2006), project steering (Peng et al., 2014) and management of deliverables (PMI, 2017). To ensure this project steering, these PRM functionalities provide the project actors with relevant information (e.g. resources' availability) in real-time or near real-time (Braglia and Frosolini, 2014). In addition, they facilitate monitoring the NPD project performance and progress against its objectives (Cooke-Davies et al., 2009). Indeed, PRM IT functionalities enable to better deploy the product development process through the modelling and execution of its different phases (Barczak et al., 2008).

- Knowledge management (KM) IT functionalities cover three main features (Pavlou and El Sawy, 2006). The authors first distinguish the codification and sharing of information and knowledge (Barczak et al., 2008; Sambamurthy et al., 2003) throughout the NPD project (García-Álvarez, 2015). On the one hand, codification includes the storage of knowledge to ensure its visibility and availability (Wang et al., 2007), its search and reuse (Shehata, 2015) and the management of its evolution (Ramesh and Tiwana, 1999). On the other hand, sharing features allow teams to exchange project knowledge and information (Choi et al., 2010). Secondly, KM functionalities support the creation of knowledge repositories (García-Álvarez, 2015). These directories allow the localization and mapping of knowledge, expertise and best practices (Bowman, 2002). The third and last feature consists of knowledge networks (e.g. discussion forums) that connect the project actors and allow them to benefit from each other's knowledge (Apostolou et al., 2008).
- Cooperative Work (CW) IT functionalities support the interactions of project actors across time and space (Thomas, 2013) which enhances their collective spirit (Montoya et al., 2009). They enable distant collaborative work (Banker et al., 2006) and facilitate face-to-face interactions (Addas and Pinsonneault, 2016). According to Pavlou and El Sawy (2006), CW functionalities cover three subcategories namely transmission, presentation and convergence. First, transmission reflects the exchange of raw information between the project actors, who will then interpret and use it according to their own objectives (Dennis et al., 2008). In an NPD context, IT for transmission allow the visualization and joint description of product structures (Zhang et al., 2004). Then, presentation functionalities make it possible to generate and convert the tacit ideas and knowledge of the project actors into representations and collective models (Pavlou and El Sawy, 2010). An illustration would be the use of CAD tools (computer-aided design) for common and simultaneous modelling (Li et al., 2015). In addition, these features enable combining and integrating information and knowledge (Pavlou and El Sawy, 2006), for instance tools for ideas' collection and analysis to support innovation (Lopez Flores et al., 2015). Finally, convergence functionalities help develop a shared meaning among team members with different skills and cultures (Wheeler et al., 1999). Unlike transmission, convergence features provide access to the individuals' opinions and ideas and thus to information already processed by the project actors and inclined to their own interpretations (Dennis et al., 2008).

3 Hypotheses' development

As explained in the introduction, this study investigates the impact of IT effective use for the main NPD-related activities on the success of collaborative buyer-supplier NPD projects. The hypotheses underlying these impacts are depicted in our conceptual model (Figure 1) and detailed hereafter.

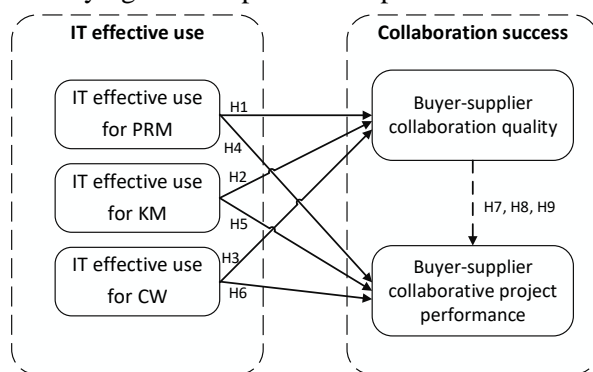


Figure 1. Conceptual model

3.1 Direct impacts of IT effective use on quality of buyer-supplier collaboration in NPD projects

Based on the social exchange theory, Han et al. (2008) showed that IT capability positively influences the buyer-supplier collaboration quality in terms of communication, participation and information sharing. Other scholars demonstrated such impacts in the particular context of NPD projects. For

instance, the survey conducted by Song and Song (2010) with NPD project leaders and IT managers highlighted that these technologies (availability to project actors, the use of advanced technology, etc.) contribute to the successful integration of R&D and marketing actors. Also, through an international study with NPD actors representing the customers of an IT editor, Marion et al. (2014) showed that the usage frequency of some of these tools was positively associated with the intensity of collaboration, including cross-functional collaboration and collaboration with customers and suppliers. Reid et al. (2016) reached a similar result from a survey with NPD project actors operating in Australian companies. The IT considered in these studies were traditional tools (i.e. e-mails, shared databases, project management tools), novel tools (i.e. wiki, clouds, innovation platforms) as well as collaborative tools (e.g. corporate social network, videoconferencing, collaborative CAD) (Reid et al., 2016).

Other studies underlined the positive influence of using specific IT functionalities on collaboration quality in NPD. For instance, the study of Banker et al. (2006) with managers and executives of companies strongly focusing on NPD showed that KM systems supporting documentary exchange and structuring had a significant positive impact on the collaboration extent between the internal NPD project teams. Also, using data from an international study on manufacturing performance conducted in nine countries and three industries, Peng et al. (2014) proved that PRM features, communication tools (e.g. e-mail, instant messaging, videoconferencing) and specialized CW systems (e.g. CAD and collaborative simulation) could improve cross-functional collaboration as well as collaboration with customers and suppliers in NPD. Based on these prior studies that emphasize the contribution of the three IT functionalities to buyer-supplier collaboration quality in NPD, we hypothesize that:

- *H1: The effective use of IT for PRM has a positive impact on the quality of buyer-supplier collaboration in NPD projects.*
- *H2: The effective use of IT for KM has a positive impact on the quality of buyer-supplier collaboration in NPD projects.*
- *H3: The effective use of IT for CW has a positive impact on the quality of buyer-supplier collaboration in NPD projects.*

3.2 Direct impacts of IT effective on performance of collaborative buyer-supplier NPD projects

Innovation activities such as NPD are fostered by the effective use of IT tools supporting information flows within and outside the firm (Kroh et al., 2018). Indeed, the information system effectiveness theory suggests that the effective use of IT resources contributes to market, process and economic performance (Grover et al. 1996). In an NPD context, several conceptual and empirical studies proposed that IT capability positively affects NPD performance. For instance, by studying international projects of a computer manufacturer, Boutellier et al. (1998) reported that the use of IT was “vital” to the performance of these NPD projects as they allowed the company to coordinate decentralized tasks, ensure the exchange of technical data and promote creativity. In the same vein, the positive contribution of IT to performance criteria of NPD projects has been the focus of several prior studies. Ozer (2000) explains how the use of IT in NPD for industrial firms improves the speed of development and the product quality, thereby increasing the chances of the products’ commercial success (Clark and Fujimoto, 1991). Also, Menon et al. (2002) and Alavi and Leidner (2001) suggest that IT facilitate the rapid exchange of relevant information, which improves the speed of NPD. Smith and Reinertsen (1991) argue that IT contribute to reducing development time, improving the flexibility of the NPD process, and integrating different cross-functional knowledge. Other authors highlighted the particular contributions of each IT functionality to the performance of NPD projects as detailed below.

First, PRM functionalities improve the visibility of project data, automate tasks, and enable tracking and managing the project and its resources (Nambisan, 2009). Therefore, the effective use of these systems reduces coordination efforts and improves the quality of information for decision-making (Mauerhoefer et al., 2017). In addition, these PRM features ensure continuity and connectivity between the different stages of the NPD process, thus contributing to the reduction of cost and development time (Sethi et al., 2003). Second, KM functionalities enable capturing, coding and sharing all types of knowledge in NPD

(Hong and Ghobakhloo, 2013). As a result, they offer project actors the opportunity to review project information and data, which significantly improves NPD project performance (Lynn et al., 2000). Also, they allow the integration of knowledge and information from various functions (Durmuşoğlu and Barczak, 2011), hence positively affecting the product quality (Sethi et al., 2003). In addition, Banker et al. (2006) observed that the implementation of KM tools in NPD reduces the number of design errors and late adjustments. This implementation enhances the product quality, reduces the time spent by the actors in the reengineering and cuts down the costs associated with this activity. Finally, CW functionalities support a rich communication between the project actors. This leads to the development of better quality products that meet functional requirements and customers' expectations (Durmuşoğlu and Barczak, 2011). Through this rich communication, these systems also increase the number of generated ideas, thus giving rise to more innovative products (Troy et al., 2001). In addition, CW features support real-time distant work, which facilitates design review and simultaneous simulation (Bacciotti et al., 2016). As a result, product design is optimized and its quality is enhanced (Durmuşoğlu and Barczak, 2011). This simultaneous work enabled by these IT functionalities also help resolve design problems (Becker et al., 2005) and provide instantaneous access to information (Sethi et al., 2003), thus reducing cost and development time (Thomke and Fujimoto, 2000). Based on this literature, we raise the following hypotheses:

- *H4: The effective use of IT for PRM has a positive impact on the performance of collaborative buyer-supplier NPD projects.*
- *H5: The effective use of IT for KM has a positive impact on the performance of collaborative buyer-supplier NPD projects.*
- *H6: The effective use of IT for CW has a positive impact on the performance of collaborative buyer-supplier NPD projects.*

3.3 Indirect impacts of IT effective use on NPD project performance through collaboration quality

Banker et al. (2006) advocated that collaborative IT positively contribute to NPD project performance (i.e. development cost and time, and product quality) when there is an efficient collaboration between the NPD project teams. Indeed, the authors showed that collaboration partially mediates the impact of collaborative IT on the performance of NPD projects. They concluded that it is important to consider as much the direct effects of using IT as its indirect effects. This study of Banker et al. (2006) is aligned with the extensive literature that associates the performance of NPD projects with the quality of collaboration (Bodas Freitas and Fontana, 2018; Mishra and Shah, 2009; Um and Kim, 2018). Accordingly, we hypothesize that:

- *H7: The effective use of IT for PRM has a positive indirect effect on NPD project performance through the collaboration quality.*
- *H8: The effective use of IT for KM has a positive indirect effect on NPD project performance through the collaboration quality.*
- *H9: The effective use of IT for CW has a positive indirect effect on NPD project performance through the collaboration quality.*

4 Research methodology

4.1 Data collection and sample

To investigate the proposed hypotheses, we performed a cross-sectional international survey with companies that have been engaged in a buyer-supplier collaboration for NPD. To determine a sample size that is sufficient for the multiple linear regression approach to be used in this study, we performed an *a priori* power test following the recommendations of Cohen (1988), with G*Power 3.1.9.2 software (Franz Faul et al., 2009). By considering the parameters of three predictors (Figure 1), an effect size of 0.15 (moderated value), a test power level of 85%, and a maximum allowed error of 5%, the software calculated 87 responses as the minimum adequate sample size. To form our sample, we contacted via e-

mail the alumni of a French industrial engineering management Master's degree and the members of a professional global product development community. To assess the adequacy of these potential participants to our study, we asked them whether they have been involved in an inter-firm NPD collaboration and requested them to inform their hierarchical position in the firm. As a result, we identified 361 suitable respondents and sent them the questionnaire link. Two reminding emails were sent out over a four months' period from January 2018 to April 2018. We obtained 90 complete responses, which represents a response rate of 25%. Table 1 shows the composition of the sample.

Category	Description	(%)	Category	Description	(%)
Firm sector	Automotive	23%	Respondent function	R&D	41%
	Computers and electronics	22%		Engineering	28%
	Basic metal products	10%		Others	31%
	Chemicals and pharmaceutical	10%	NPD team size	Less than 5	18%
	Machinery and equipment	8%		Between 5 and 10	38%
	Food and beverage	5%		Between 11 and 15	24%
	Plastics and non-metallic products	5%		More than 15	20%
	Textiles, wearing products	5%			
	Wood and paper products	4%			
	Others	8%			
Firm location	Europe	44%	Firm size	Less than 250 employees	22%
	America	39%		Between 250 and 5000 employees	63%
	Asia & Oceania	14%		More than 5000 employees	15%
	Africa	3%			

Table 1. Sample composition (n=90 respondents)

4.2 Measurement scales

The dependent and independent variables of our study are measured with multi-item scales (Appendix A) adapted from extant literature. The variables representing effective use of PRM, KM and CW IT were inspired by the constructs of Pavlou and El Sawy (2006) proposed for NPD contexts and not particularly developed for a buyer-supplier collaboration. Then, for buyer-supplier collaboration quality, we relied on the multi-item scale of Yan and Dooley (2014) which encompasses the different facets of buyer-supplier collaboration quality namely sufficiency of efforts, quality of communication, coordination, and mutual support. Lastly, NPD project performance was assessed with a three-item scale proposed by Tatikonda and Rosenthal (2000), which considers product quality, product objective cost and development time. All items were measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Three additional control variables were included in the analysis. First, NPD team size was used to control for its potential influence on IT usage. Indeed, it is more difficult for large team members to get to know each other, which might affect coordination, knowledge sharing and communication (Akgün et al., 2005). Second, we included firm size as a control variable because the adoption and the benefits gained from IT use can vary according to the size of a firm (Caldeira and Ward, 2002). Finally, we controlled for the effect of project priority, as a high project priority encourages NPD units to work harder in order to achieve a superior performance (Peng et al., 2014).

4.3 Biases related to quantitative survey studies

To ensure that the obtained sample of responses was representative of the population, non-response bias was assessed by verifying that early and late respondents were not significantly different in terms of responses to key questions related to the constructs of the study (Armstrong and Overton, 1977). The results of the t-test that was performed to compare early and late (i.e. fourth quartile) waves showed no statistically significant difference between the means of the two groups ($p\text{-value} > 0.05$), suggesting that non-response bias is not a concern in our study. Furthermore, we investigated the existence of significant differences among the respondents' groups given the heterogeneity of their functions. In this respect, we performed a t-test to compare the means of each couple of groups within our sample (R&D,

Engineering and Others). The results indicated that, except for three items (*Perf1*, *CQ6* and *CQ8*) comparing Engineering to Others group, the responses do not vary for all the remaining 48 comparisons ($p\text{-value} > 0.05$).

As our data are self-reported, and given that the same respondents answered the questions on IT effective use and on NPD project success, we used two tests to check for common method bias before analysing our model. First, we carried out a Harman's single-factor test by performing a principal component factor analysis on all items used in this study (Podsakoff and Organ, 1986), which resulted into a 30.63% variance explained by the single factor. As this percentage did not account for the majority of the variance in the model, the test indicated that common method bias is unlikely to be a problem in this study. Second, we used the marker variable technique suggested by Lindell and Whitney (2001). This method examines the correlations between the study's constructs and a marker variable that is theoretically unrelated to at least one of the study's substantive variables (Williams et al., 2010). Hence, we used the newness of the product's technology as a marker variable. The resulting correlations varied from 0.159 to -0.01 (average correlation value = 0.059) and none of them was significant (average $p\text{-value}$ = 0.478). Therefore, this test confirms the absence of common method bias issues from our study.

4.4 Constructs' validity and reliability

Before testing the model's hypotheses, we first assessed the validity and reliability of our constructs using Stata 13.0® (Anderson and Gerbing, 1988). In this respect, a series of confirmatory factor analyses (CFAs) was performed to test the measurement scales on their unidimensionality. We divided our measures into three theoretically different subsets: the three IT effective use variables (for PRM, KM, and CW), the buyer-supplier collaboration quality construct, and the NPD project performance construct. This division into subsets is due to our small sample size, which violates the rule stating that the ratio of the sample size to the number of free parameters must not exceed 5:1 (Akgün et al., 2005; Bentler and Chih-Ping Cho, 1988). For each subset, the CFA model was fitted to the data and the items that were not unidimensional or had low loadings were dropped (Appendix A) in a step-by-step purification process until a satisfactory fit was achieved (Hair et al., 2010). The model's fit was adequate for the first two subsets: IT effective use ($\chi^2=53.1$, $p\text{-value}=0.1$, RMSEA=0.06, CFI=0.97, TLI=0.96) and buyer-supplier collaboration quality ($\chi^2=0.64$, $p\text{-value}=0.73$, RMSEA= 0, CFI=1, TLI=1.03). Unidimensionality of NPD project performance was not assessed, since one item was removed during the purification process. This resulted in a two-item CFA model for NPD project performance, which is an under-identified model with less parameters to observe than to estimate.

Then, all the measures of the conceptual model were simultaneously subjected to a one-factor model CFA (Hair et al., 2010). Due to small sample size, the analysis was performed using parcels or subsets of items (i.e. mean of several items that measure the same construct) instead of individual items as recommended by different authors (e.g. Akgün et al., 2006; Schmit and Ryan, 1993). In this respect, two parcels of items for each scale were computed. Each parcel consisted of a randomly divided subset of the scale's items. The one-factor CFA produced a good fit ($\chi^2=34.46$, $p\text{-value}=0.10$, RMSEA=0.06, CFI=0.98, TLI=0.96) providing more support to the unidimensionality of all the scales.

Variables	Mean	S. D	1	2	3	4	5
1 NPD Project performance	3.59	0.87	<i>0.76</i>				
2 Buyer-supplier collaboration quality	3.51	0.77	0.675**	<i>0.74</i>			
3 Effective use of IT for PRM	2.8	0.85	0.156	0.429**	<i>0.76</i>		
4 Effective use of IT for KM	2.85	0.82	0.242*	0.420**	0.665**	<i>0.73</i>	
5 Effective use of IT for CW	2.52	0.87	0.071	0.365**	0.639**	0.577**	<i>0.73</i>
Average Variance Extracted (AVE)			0.58	0.55	0.58	0.54	0.53
Composite reliability			0.73	0.83	0.84	0.77	0.82
Cronbach's alpha			0.73	0.82	0.83	0.77	0.81

*N=90, * $p < 0.05$, ** $p < 0.01$; Numbers in italics (on the diagonal) are square roots of AVE*

Table 2. Bivariate correlation matrix with descriptive statistics and reliability estimates

Next, the constructs' convergent validity was verified by checking their items' loadings (which should exceed 0.5) and calculating their AVE (which should exceed 0.5) as recommended by Hair et al. (2010).

All items strongly loaded on their constructs with p-value <0.001. Also as explained in Table 2, all AVE values exceeded 0.5 and all constructs' reliabilities (Cronbach's α and Composite Reliability) were beyond the 0.6 threshold recommended for exploratory research (Hair et al., 2010).

Finally, we assessed the discriminant validity of the constructs in our model. We checked the criteria of Fornell and Larcker (1981) by ensuring that the square root of each construct's AVE is greater than its correlations with the other constructs (Table 2). We also tested discriminant validity based on the approach of Bagozzi et al. (1991), who suggested a series of two-factor model estimations. In this respect, we performed two CFA models for each pair of constructs and compared their respective goodness of fit. In the first model, we restricted the correlation between the two constructs to unit, while in the second model we freed this restriction and calculated the goodness of fit for the original constructs. The overall results of this test confirmed discriminant validity ($\Delta\chi^2 > 3.84$, p-value < 0.05).

4.5 Data analysis

After refining our constructs, we analysed our conceptual model (Figure 1) using multiple linear regressions to test the direct and indirect effects on IT effective use on NPD project success. In this respect, we first evaluated the assumptions of normality, linearity and homoscedasticity of the residuals between all dependent and independent variables under IBM® SPSS® Statistics 21. We examined respectively the probability-probability (p-p) plots, plots of partial regression and plots of standardized residuals against the predicted value (Field, 2013). These tests confirmed the required assumptions for multiple linear regression.

Hence, we tested our hypothesized direct and indirect impacts of IT effective use on NPD project success by performing a series of multiple linear regressions. To estimate the indirect impact on NPD project performance through collaboration quality of effective use for each IT functionality, we performed a bootstrapping procedure under IBM® SPSS® Statistics 21 (Hayes, 2018), itself based on multiple linear regressions (Preacher and Hayes, 2004). This approach has become popular to evaluate indirect effects of mediating variables (Hayes, 2009; Maruping and Magni, 2015). If « a » is the direct effect of the independent variable on the mediator, and « b » is that of the mediator on the dependent variable, the bootstrapping aims at proving that « axb », which represents the magnitude of the indirect effect, is statistically significant (Preacher and Hayes, 2004). This technique relies on a random re-sampling with a discounted draw, performed from the original sample (Efron and Tibshirani, 1993) in order to create a distribution resampling for the « axb » product. When the generated confidence interval does not include the null value, the indirect effect is statistically significant (Preacher and Hayes, 2004).

5 Results

5.1 Direct impacts of IT effective use on success of collaborative buyer-supplier NPD projects

We performed multiple linear regressions following a hierarchical procedure to test the direct effects of IT effective use on the two success criteria of collaborative buyer-supplier NPD projects, i.e. collaboration quality (Hypotheses H1, H2 and H3) and NPD project performance (Hypotheses H4, H5 and H6) as depicted in Table 3. For each of these two dependent variables, two multiple linear regression models were estimated (Field, 2013; Hair et al., 2010). The first regression was performed only with the control variables and the dependent construct, while the second regression model also included the independent variables representing the effective use of the three IT functionalities (i.e. for PRM, KM and CW). The VIF values were below 3.0 in all models, thereby indicating that multicollinearity is not a major issue.

For the dependent variable « Collaboration Quality », the regression of this construct on the control variables was not statistically significant (Model 1). Following the introduction of the three independent variables in the second regression (Model 2), the model became statistically significant ($F= 7.147$, $p < 0.01$) and explained 29.3% of variance for collaboration quality (Adjusted $R^2 = 0.293$). Moreover, the change of R^2 was also significant ($\Delta R^2 = 0.302$, $p < 0.01$), suggesting that the introduction of the independent variables increased the predictive power of the model. As for the control variables, « Firm

size » and « NPD team size » displayed negative significant associations with collaboration quality. Hence, the larger the sizes of the firm and the project team, the more it is difficult to reach a good collaboration quality. Finally, the regression results of the three independent variables showed that the effective use of IT for PRM (unstandardized regression coefficient $B = 0.204$, $p < 0.1$), for KM ($B = 0.212$, $p < 0.1$), and for CW ($B = 0.209$, $p < 0.1$) have positive significant impacts on collaboration quality. These results therefore confirmed the hypotheses H1, H2 and H3 of the conceptual model. The standardized coefficients of these three effects are $\beta = 0.225$ for PRM, $\beta = 0.224$ for KM, and $\beta = 0.230$ for CW IT functionalities and are hence equivalent.

For the dependent variable « NPD project performance », both regression models (Model 3 and Model 4) were statistically significant. Also, Model 4 was characterized by a significant change in R^2 ($\Delta R^2 = 0.113$, $p < 0.05$) and explained 17.3% of variance for NPD project performance (Adjusted $R^2 = 0.173$). Such result implies that the introduction of the independent variables improved the model's predictive power. As for the control variables, we observed that, similarly to collaboration quality (Model 2), « Firm size » and « NPD team size » displayed negative significant associations with NPD project performance. Finally, regression results for the three independent variables showed that only the effective use of IT for KM has a positive significant impact on NPD project performance (unstandardized regression coefficient $B = 0.325$, $p < 0.05$), therefore confirming hypothesis H5. No statistically significant effect was observed regarding the effective use of IT for PRM and for CW, hence providing no support to hypotheses H4 and H6.

	<i>Buyer-Supplier Collaboration Quality</i>		<i>NPD project performance</i>	
	<i>Model 1</i>	<i>Model 2</i>	<i>Model 3</i>	<i>Model 4</i>
Ctrl 1: Firm Size	-0.054	-0.299**	-0.272*	-0.440**
Ctrl 2: NPD Team Size	-0.142*	-0.182**	-0.214**	-0.214**
Ctrl 3: Project Priority	0.008	0.08	0.05	0.101
Effective use of IT for PRM		0.204*		0.034
Effective use of IT for KM		0.212*		0.325**
Effective use of IT for CW		0.209*		0.048
F-value	1.159	7.147***	3.760**	4.111***
R²	0.039	0.341	0.116	0.229
Adjusted R²	0.005	0.293	0.085	0.173
ΔR^2		0.302***		0.113**
VIF interval	[1.013-1.034]	[1.037-2.320]	[1.013-1.034]	[1.037-2.320]

*N=90, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$*

Table 3. Results of the direct impacts of IT effective use on success of collaborative NPD project

5.2 Indirect impacts of IT effective use on NPD project performance through collaboration quality

We followed the recommendations of Hayes (2018) to evaluate the indirect effects of the three independent variables (effective use of IT for PRM, for KM and for CW) on NPD project performance through collaboration quality. In this respect, we simulated $K = 5000$ bootstrap samples to estimate three distinct models. Indeed, the indirect effect « axb » was estimated for one independent variable at a time, while controlling the direct effects of the other independent and control variables. A 90% confidence interval was set to align with the significance level for the direct effects of IT effective use for PRM, KM and CW on NPD project success ($p < 0.1$), obtained in section 5.1. The results of these tests are presented in Table 4.

For PRM IT functionalities, the indirect effects estimated by the bootstrapping were between 0.017 and 0.306 with 90% confidence. Similarly, the estimated indirect effects for KM IT functionalities ranged between 0.016 and 0.298 with 90% confidence. Finally, the indirect effects for CW IT functionalities varied between 0.022 and 0.294 with 90% confidence. We concluded that for each of the tested indirect effects, the 90% confidence interval is strictly positive and therefore does not include the null value. Hence, the effective use of IT for PRM, KW and CW positively and significantly ($p < 0.1$) contribute to NPD project performance through collaboration quality, which provides full support to H7, H8 and H9.

Independent Variable (IV)	IV's direct effect on collaboration quality [a]	Direct effect of collaboration quality on project performance [b]	Indirect effect [axb]	Bootstrap	
				90% confidence interval for the indirect effect	
				Lower threshold (delimited by the 5% percentile)	Upper threshold (delimited by the 95% percentile)
Effective use of IT for PRM	0.204*	0.755***	0.154 (0.089)	0.017	0.306
Effective use of IT for KM	0.212*		0.160 (0.086)	0.016	0.298
Effective use of IT for CW	0.209*		0.157 (0.083)	0.022	0.294

$p < 0.1^*$, $p < 0.05^{**}$, $p < 0.01^{***}$
Control variables for all the tests: Firm size, NPD team size, Project priority
The standard error of the final estimate is shown between parentheses.

Table 4. Results of the indirect impacts of IT effective use on NPD project performance through collaboration quality

6 Discussion and conclusions

6.1 Theoretical implications

The purpose of this study was to examine how IT effective use impacts the success of collaborative buyer-supplier NPD projects. Our study completes the literature on IT capability applied to innovation management and New Product Development (Pavlou and El Sawy, 2010; Rai et al., 2012) by shedding light on the contributions of each of the three IT-leveraging capability dimensions, which have usually been treated as equal. Indeed, the results point that IT effective use has different effects on NPD project success depending on the considered IT functionality and the success criterion.

On the one hand, our results provide evidence that each dimension represents a complementary yet a different resource to achieve performance improvement as underlined in the resource based view. In this respect, we showed that the direct impact of IT effective use on NPD project performance is positive and significant for KM functionalities, with no significant effects for PRM and CW. These findings regarding the impact of IT effective use for KM functionalities are consistent with those of Vaccaro et al. (2010) which, to the best of our knowledge, is the only study that focuses on the specific context of buyer-supplier collaboration in NPD. The insignificance results regarding IT effective use for PRM and CW functionalities can be accounted for the fact that such tools are usually highly sophisticated, which may cause the users' reluctance to adopt them (Marion et al., 2014; Parida et al., 2016). More broadly, insignificant effects of IT use on NPD project performance were underlined by prior research (Durmuşoğlu and Barczak, 2011; Marion et al., 2014). However, these studies highlighted an insignificant effect at an aggregated level of IT use without taking into account the different roles played by each IT functionality. In contrast to these prior studies, our research unveils differentiated effects of these functionalities, thereby emphasizing the importance of considering a detailed functional approach when studying the impact of IT effective use, at least on the NPD project performance criterion. On the other hand, our study confirmed that the IT effective use for PRM, KM and CW have direct, positive and equivalent impacts on buyer-supplier collaboration quality. In this sense, our results extend those of prior research in two ways. First, the majority of studies that proved a similar impact focused on intra-organizational or even non-precise collaborative contexts (e.g. Banker et al., 2006; Song and Song, 2010). Therefore, our study is consistent with their results and further extends them to the context of buyer-supplier collaboration in NPD. Second, while some scholars aggregated IT use into a single construct (e.g. Han et al., 2008; Reid et al., 2016), our research offers a deeper understanding to this “black box” as we prove that the different IT functionalities contribute in a similar magnitude to improving buyer-supplier collaboration quality in NPD.

This study also completes literature on IT use in the supply chain context that questions the direct effects of IT capabilities on firm performance by contending that the effects are mediated by other capabilities (Liu et al., 2013; Sambamurthy et al., 2003). In the context of inter-firm product innovation, it empirically demonstrates that the effective use of the three IT functionalities (for PRM, KM and CW)

has an indirect impact on NPD project performance through buyer-supplier collaboration quality as a mediator. While our previous results have proved the direct impact of IT for KM, a major contribution of our study is to show that the impact of IT effective use for PRM and CW on NPD project performance is made possible only through an enhancement of collaboration quality. Hence, these findings offer an interesting insight for a better understanding of the mechanisms by which IT foster value in this specific context of NPD. Our result echoes the call of Melville et al. (2004) to consider intermediary processes in order to shed light on the contribution of IT effective use. By demonstrating the mediating role of collaboration quality, our study adds another piece to resolve the puzzle of IT productivity paradox (Barczak et al., 2008; Montoya et al., 2009; Pavlou and El Sawy, 2006). More specifically, our findings are consistent with the conclusions of Banker et al. (2006), who argues that the contribution of IT effective use to improving project performance lies within a better collaboration of NPD actors.

Furthermore, the mediating role of buyer-supplier collaboration quality stresses the subjective context-specific nature related to IT use, as suggested by different authors (e.g. Montoya et al., 2009; Nambisan, 2003). As IT use should be aligned with its context (Premkumar et al., 2005), we could expect different mediators for each context. Consequently, one contribution of this study is to posit that for IT use in the collaborative buyer-supplier NPD context, collaboration quality is a key contextual variable to consider.

6.2 Managerial implications

This research advances managerial understanding in two ways. First, our findings highlight the need to manage the effectiveness of IT use in order to promote the success of inter-organizational collaboration with suppliers in NPD. In this respect, managers need to pay sufficient attention to the effective use of IT by NPD actors and think about ways to build this effective use in this context. This could be done by ensuring that users develop high competency of IT use regarding each IT enabled NPD activity (PRM, KM, CW) through training to enhance their practical abilities, but also by promoting and communicating on the importance of inter-organizational IT to foster the users' willingness to efficiently use these IT functionalities. This sensitization should highlight the advantages of IT to meet the needs of both buyer and supplier project teams, at least for the most strategic partnerships. Second, our study informs IT managers about the strategic potential of inter-organizational IT investments. As these systems eventually allow for savings in development costs and enhancement of product quality, IT managers could remove the top management doubts concerning the value of such IT, especially if the firm is frequently involved in collaborative buyer-supplier NPD projects.

6.3 Limitations and future research avenues

Our findings should be interpreted in the light of some limitations that future research could address. From a methodological standpoint, we first believe that other types of studies might compensate for the limits of the cross-sectional survey used in this research. Indeed, as the development of IT effective use is an ongoing phenomenon, future research could examine the same issues addressed in this study using time-series panel data. Second, regarding firm performance, IT effective use can be an endogenous explanatory variable and accordingly prior research provided guidelines to control for such bias (e.g. Maiga and Jacobs, 2011; Zhang et al., 2016). Although no study underlined such effect at collaborative NPD level, we believe future research could explore the endogeneity of IT effective use regarding collaboration quality and NPD project performance. Indeed, firms with better buyer-supplier relationships may per se show more effective use of IT, and better project performance may induce even further effective uses of IT in the relationship. Hence, regarding such potential endogeneity effect, it would be relevant to rely on a 2SLS technique (Benitez-Amado et al., 2016) to separately estimate each structural equation in our model.

From a theoretical point of view, we first underline that the generalization of our findings to specific industries or firms should be made with caution. Further research could explore the significance of the conceptual framework under various industry characteristics. Second, the theoretical coverage of IT effective use for KM was altered during the purification process of the scale. Items regarding the tacit nature of knowledge were dropped. A possible perspective for future research could be the separation

of the KM construct into two different latent variables related to explicit and tacit knowledge management. Third, our research only examined two aspects of NPD project success. There are potentially other important outcomes to consider such as innovativeness or market success. Further studies could investigate in more depth the impact of IT effective use on the multidimensional nature of NPD project success. Fourth, the direct effects of IT effective use for PRM and CW on NPD project performance were not significant, and their indirect effects through collaboration quality were significant only at $p < 0.1$. Future empirical research might investigate additional mediators that explain the contribution of IT effective use to the performance of inter-organizational collaborative NPD projects. Fifth, our conceptual model can be enriched by introducing extra-firm control variables (e.g. market turbulence, competitive dynamism) which might explain variance in collaborative NPD project success. Finally, our study is based on data from only one informant, which may decrease the quality of the results. Future research would overcome this weakness by assessing the NPD project performance from secondary data or from another informant within the firm involved in the project.

7 Appendices

Appendix A. Latent variables and their associated items

Effective use of IT for PRM (PRM)	PRM1	Project planning and tasks' sequencing	Collaboration quality (CQ)	CQ1	Both (buyer and supplier) teams took full responsibility for achieving the project objectives
	PRM2	Control and monitoring of the project progress		CQ2*	Both teams fully contributed to the project workload*
	PRM3	Project management and provision of the necessary information for this purpose		CQ3*	Both teams were fully satisfied with how quick the information was made available by the other team*
	PRM4	Access to project documentation and real-time update of project deliverables		CQ4	Both teams were fully satisfied with the accuracy of the information provided by the other team
	PRM5*	Management of the co-development process and workflows*		CQ5*	The different activities carried out by the members of both teams matched well*
Effective use of IT for KM (KM)	KM1	Codification and storage of information and knowledge over time		CQ6	The members of the two teams who worked together did their job properly and efficiently
	KM2	Share of information and knowledge between project actors		CQ7*	All activities were completed at the right time with regard to the project schedule*
	KM3	Search, extraction and reuse by project actors of information and knowledge		CQ8	Important ideas and information were exchanged openly between the two teams
	KM4*	Management of the documents and data evolution*		CQ9*	The actors of both teams adapted well to each other*
	KM5*	Creation and support of knowledge networks*		CQ10*	The general atmosphere was cooperative*
	KM6*	Identification and localization of relevant expertise*	NPD project performance (Perf)	Perf1	The initial objective of product quality has been achieved
Effective use of IT for CW (CW)	CW1	Description and collective redefinition of the products' architectures		Perf2	The initial target of product cost has been achieved
	CW2	Use of graphical representations to transform and manipulate tacit knowledge (e.g. use of an electronic whiteboard)		Perf3*	The initial goal of product development time has been achieved*
	CW3	Contextualization and attribution of meaning to existing information and knowledge (e.g. comment on a diagram or a file)			
	CW4	Combination and integration of information and individual knowledge for decision-making and / or joint problem solving (e.g. analysis or simulation tool, concept maps)			
	CW5*	Simultaneous real-time work and virtual design reviews*			

*Item deleted following the confirmatory factor analysis (CFA)

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