INFORMATION TECHNOLOGY AS KNOWLEDGE MANAGEMENT ENABLER IN PRODUCT DEVELOPMENT. AN EMPIRICAL EVIDENCE

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Abstract

Product development is a knowledge intensive process. It is widely recognized as a mechanism that produces firms to learn, to enter new technological areas, and to deal more effectively with market uncertainty. Since technology management has become ingrained within the field of knowledge management, product development has been viewed and studied from a knowledge management perspective. In this context, this study focuses on a specific knowledge management initiative, information technology (IT). It empirically explores how IT influences on knowledge based capabilities of product development –specifically knowledge exploitation and exploration. With this aim, we introduce a typology of IT configurations based on two main dimensions: the divergent and the convergent dimensions. The results show that the product development can be categorized in three IT configurations. Specially, our results provide statistically differences in terms of knowledge exploitation and show the advantages of a combination of the two dimensions of IT.

Keywords

Information technology, Product development, Knowledge management

1. INTRODUCTION

Over the last few decades, corporate emphasis on knowledge has stemmed from pressures such as shortened lead times, intense price pressure, mass customization, and the growth of technological advances. The literature suggests that knowledge and knowledge based capabilities are necessary elements to manage and thrive in an environment characterized by increased global competitiveness and highly dynamic markets (Mohrman et al, 2003). In these circumstances, the only way to succeed relies on the development of a steady stream of new products that generates new knowledge faster than competitors and rapidly translate it into new products (Mallick and Schroeder, 2005; Song et al., 2006). Product development is thus a knowledge intensive process (Clark and Fujimoto, 1991), that involves both knowledge creation and knowledge application to achieve competitive advantage.

Developing highly successful new products is possible through the integration of abilities of both upstream (e.g. design engineers) and downstream knowledge workers (e.g. design engineers). In this sense, a significant part of the literature has recognized the need to employ integrative techniques in the face of uncertainty (Song and Montoya-Weiss 2001). In spite of significant progress in the use of integrative techniques such as multifunctional teams, concurrent engineering, design for manufacturing and, lately, quality function deployment, it is noticeable that the complete integration of all functions involved in product development remains a major management challenge (MallicK and Schroeder, 2005; Koufteros et al, 2005). Many firms discover that their efforts to enhance product development performance fail, not necessarily because of lack of coordination, or workflow disruptions, but because of the absence of integration of cross-functional inter-specialized knowledge about problem constraints (Hoopes and Postrel, 1999). In a broad sense, one of the major barriers to achieve cross-functional integration is inherent to the way firms integrate knowledge during the product development process. Knowledge integration has to occur on a conceptual level-beyond operational work (Hong et al, 2005), which suggests the need of a cross-functional knowledge integration perspective as a key aspect of new product development. From a management perspective, this means that a central challenge to succeed in product development activities is the creation of knowledge-based capabilities to integrate and coordinate specialized knowledge.

In accordance, many product development efforts are trying to improve knowledge based capabilities (Adams, et al, 1998; Becker and Zirpoli, 2003) through knowledge management. Knowledge management requires the introduction of criteria to decide which knowledge is most critical for the organization and to govern the factors and conditions that guide the activities of knowledge creation, integration and use (DiBella and Nevis, 1998). There are only a limited number of publications addressing the importance of knowledge management as a part of the product development process, while this is a crucial source of success (Song et al., 2006). However, generating competitive value from knowledge integration in product development requires the understanding of factors influencing the capability to create and apply knowledge. Effective knowledge management consists on enhancing knowledge generation and application in the product development processes, which is consistent with the explorative and exploitative ways of learning (March, 1991).

This study focuses on a knowledge management enabler, information technology (IT) in the product development process. IT is often advanced as the anchor to develop knowledge management initiatives (Davenport and Prusak, 1998; Scott, 2000; Alavi and Leidner, 2001; Gold et al., 2001). Thus, we empirically explore how IT influences on the knowledge based capabilities of the product development process. Specially, we characterize the way product developments process may differ in their configuration of IT and the consequent effects on knowledge based capabilities. IT is characterized attending to a convergent and a divergent dimension, while knowledge based capabilities are characterized in terms of knowledge exploration (generation of new knowledge) and exploitation (application of existing knowledge).

In order to establish our research hypothesis, we first describe knowledge based capabilities and the concerns relative to IT. Next, we test our hypothesis on the basis of data generated from a questionnaire survey accomplished in a sample of product developments. Results give us a snapshot of how IT may relate to knowledge based capabilities in product development, and allow us to identify the IT configurations that perform the best for knowledge based capabilities. A discussion of the implications, limitations and future research directions concludes our paper.

2. THEORETICAL FOUNDATIONS AND HYPOTHESES

2.1. Knowledge capabilities in the product development process

The process of product development has been defined as including the set of activities beginning with the perception of a market opportunity and ending in the production, sales, and delivery of a product (Nambisan, 2003). In other words, the essence of product development is both the creation and use of new knowledge to solve problems and create products that have value in the marketplace (Mohrman et al, 2003). In ideal situations, people involved in product development bring their formal and articulated expertise of their disciplines, which has been socially constructed along time by particular professional or academic communities. While working in product development, their knowledge frames their attention when they have to approach a problem. This way, they have the opportunity of applying knowledge to problem resolution and generating new knowledge, both tacit and explicit (Nonaka, et al., 2000) .

Accordingly, the creation and use of knowledge in product development requires a high degree of members' involvement in problem recognition and problem solving processes. In the first step, members must scan, notice and construct meaning about environmental changes. The recognition of the existence of a problem occurs when some stimuli indicate the need for new actions. These stimuli then lead to the second step, when members jointly experience new work processes, tasks, technological characteristics etc. to solve the problem. Product development thus refines the understanding of the environment and improves the ability to react appropriately to future stimulus through the development of knowledge capabilities.

These knowledge capabilities compel members of the product development process to establish close relationships via language and thought in order to integrate and coordinate their knowledge. Therefore, product development members need to spend considerable time together, discuss, reflect upon their experiences, observe how their colleagues solve tasks, interact with technologies, and explain and give sense to their own actions. Through interaction with others, each member's specialized knowledge is disclosed, shared and legitimized in order to become a part of the product development process. This way, the product development process requires the integration of specialized and diverse individual perspectives during problem recognition and problem solving processes. In other words, during the product development process, cross-functional work brings together a variety of specialist who share and integrate their knowledge on customer needs, market segments, firm capabilities, competitors strategies and so on, which is considered to affect knowledge generation and application through the different phases of the problem-solving process (Naveh, 2005).

Since product development involves both the application and generation of knowledge, it is considered a learning process involving knowledge exploration and knowledge exploitation (March, 1991; Katila and Ahuja, 2002). Knowledge exploitation has to do with the use of existing knowledge in problem recognition and resolution activities. Knowledge exploration arises when existing knowledge is not enough to solve the problem, so that it is necessary to construct and acquire new knowledge.

The conceptual distinction between exploration and exploitation has been intensively studied in various disciplines (Adler et al, 1999; He and Wong, 2004) and is a common theme in the management literature. Specially, it is often argued that there is a tension between exploration and exploitation that needs to be balanced in order to succeed (March, 19991; Levinthal and March, 1993). The need of the appropriate balance between exploration and exploitation is crystallized in the recent conceptualization of ambidexterity that, as suggested by Benner and Tushman (2003), may involve both strategic logics of exploration and exploitation.

We accept that knowledge exploration and exploitation are different but complementary processes that affect a firm's potential to introduce new products. In other words, product development needs to balance both exploration and exploitation in a single activity. In fact, product development introduces new characteristics and features that improve product quality, which represents the exploration of new knowledge and capabilities. New knowledge allows the variations needed to provide a range of options enough to solve problems (March, 1991), and increases the possibilities of engendering new ideas and/or knowledge combinations. Similarly, product development involves an experience effect that comprises the application of past experience and competences, which represents the exploitation of past knowledge. Using past knowledge and experience reduces the likelihood of errors and false starts, and facilitates the development of routines (Levinthal and March, 1993). It also creates a familiarity that allows the decomposition of sequenced activities in an efficient order where unnecessary steps can be eliminated (Eisenhardt and Tabrizi, 1995). This leads to a deeper understanding of concepts, booting the firm's ability to identify valuable knowledge, develop connections, and combine it in different and significant ways (Grant and Baden-Fuller, 2004).

Katila and Ahuja (2002) found empirical support for their prediction that the interaction between exploration and exploitation will have a positive impact on new product development. These authors conceptualise exploration and exploration as orthogonal variables (not as ends of a continuum where the emphasis in one extremity excludes the other). Though there are organizations that succeed in balancing exploration and exploitation through integrative product development processes (Naveh, 2005), a tension exist between those processes, and emphasis on one may harm the other.

In practice, the levels of knowledge exploration and exploitation in product development may vary since the management practices that lead to exploration and exploitation are different and generally contradictory. Moreover, while exploitation emphasizes on the operational efficiency of the process, exploitation may lack a high degree of efficiency in behalf of innovativeness (March, 19991). Accordingly, exploration may be especially intense at the beginning of the new product development process so that it can assist seeking new ideas, especially when known solutions to specific problems are ineffective or too costly to apply. In later stages, exploitation must be emphasized so that it assists control and consolidation. Likewise, global time-based competition and a reduced product life cycle do not always allow organizations to spent time and resources in knowledge exploration since it would make the product development process a too risky undertaking. In addition, the radicalness of new products and services determines the balance of the trade-off between exploration and exploitation (Bierley and Chakrabarty, 1996). Exploration will be emphasized for radical innovations while exploitation will be higher for incremental innovations. However, exploration and exploitation in product development build on each other (existing knowledge determines the capacity to create new knowledge, while new knowledge engrosses the body of existing knowledge), so that both of them can be simultaneously gained to achieve competitiveness.

Product development may thus vary in the levels of knowledge exploration and exploitation, and in the way of balancing the trade-offs existing between the two. The analysis of these variations helps to understand knowledge based capabilities of the product development process, which also induces the identification of the management practices governing variations of knowledge based capabilities in product development.

2.2. Information technology as knowledge management enabler

Knowledge capabilities in product development depends on how effectively involved individuals are able to integrate and organize their specific knowledge competences, but also on how they use their distinctive knowledge both effectively and synergistically to produce a collaborative, ongoing learning.

Accordingly, researchers and practitioners strive for clues on how to effectively manage knowledge resources by creating an organizational context where members of the product development process may work by attending to different information, assigning new meanings, and trying new approaches when making sense of technical problems.

It is clear that, within the product development context, information is a critical resource. How a team manages the information adoption and use will be important for product development success. Interestingly, while this precept is generally accepted, what information technology types are needed to achieve different knowledge capabilities is less known.

Today, there is a lot of discussion on how to manage knowledge capabilities, due to baffling approaches coexisting about it. Throughout this discussion, information technology (IT) is often mentioned as an anchor for knowledge related activities (Alavi and Leidner, 2001; Nonaka and Takeuchi, 1995). As a part of knowledge management enabler in product development, IT may be considered as the advanced infrastructure that enhances the volume of data, information and knowledge that can be processed throughout the product development process (Nambisan, 2003).

Previous researches defend that IT is a crucial enabler for knowledge generation (Alavi and Leidner, 2001; Nonaka and Takeuchi, 1995; Song et al., 2006). IT is also accepted as a real pipeline to codify, organize and disseminate information and knowledge. IT creates an interconnected environment as a medium to vertically and horizontally integrate efforts within the product development process, thus shortening the length of the transformation cycles.

In order to promote knowledge-based capabilities, and based on the works of Van den Brink (2003), an effective information technology demands a combination of two related dimensions: the convergent and the divergent dimension. The divergent dimension concerns to having information and explicit knowledge components online, indexed and mapped, with easy access and retrieval for all members of product development. It significantly affects the way that data and information are gathered and stored. In this situation, the emphasis is on explicit knowledge. Conversely, the convergent dimension plays the role of enhancing analysis and discourse, and supports a virtual network not constrained by barriers of time and place. It improves coordination and communication between members of product development by transferring knowledge from those who posses it to those who need it. Here the emphasis is on tacit knowledge.

Several elements support the divergent dimension: integrated document management, document imagining, data warehouse, data mining , business intelligence, intranet, and internet. These tools hold collections of knowledge components that have a structured content like manuals, reports, articles, best practices, customer inquiries and needs, competitor analysis and experience with production. A content classification scheme or taxonomy is used to organize knowledge, facilitate grouping, sorting visualization, searching, publication, manipulation, refinement and navigation. It mostly helps to explicit knowledge since it can be expressed in symbols and communicated to other people. It can be easily accessed and used by product development's members.

Regarding the convergent dimension, its functionality is incorporated in tools such as e-mails, calendaring and scheduling, groupware, work management system, process support system, etc. The goal here is to facilitate group and teamwork regardless of time and geographic location. It offers product development members the opportunity to interact and exchange views and thoughts with each other. It is thus useful to transfer tacit knowledge –the one that is difficult to express and communicate to other people because it cannot be codified and articulated.

Both the convergent dimension and the divergent dimension thus shape the potential of IT to support knowledge based capabilities in product development. So, it is feasible to presume that differences in the composition of the convergent dimension and the divergent dimension of IT may produce variations in the resulting knowledge capabilities. In practice, different IT configurations emerge from the different emphasis on the divergent and convergent dimensions during the product development process. Some companies tend to emphasize one dimension over other, while using another one in a secondary position. In contrast, other companies are able to manage the correct balance between both dimensions, or even adjust them in accordance with knowledge characteristics or environmental conditions. Each configuration represents distinct knowledge management conditions, and thus generates a specific potential to create and use knowledge in the product development process.

2.3 Research Hypothesis

Just knowing that product development may have different IT configurations is not particularly compelling. What makes this interesting is that the different IT configurations of product development may significant and differentially affect the resulting knowledge based capabilities. This idea is consistent to the resource-based view since it suggest that product development has a mix of resources available so that performance differences across product development result from variances in the available resources and how those resources are used. Consequently, we assume that making sense and understanding differences in the IT configurations -on the basis of its convergent and divergent dimensions- may have implications on what can be expected in terms of knowledge exploration and exploitation. This assumption can be articulated as hypothesis to be test empirically:

Hypothesis 1. Differences in IT configurations, in terms of its convergent and divergent dimensions, may result in differences in the knowledge based capabilities of the product development, in terms of exploration and exploitation

Once proposed this general hypothesis, we next try to deeply analyse the relationships existing between the IT configurations and the knowledge based capabilities of product development. In this sense, we argue that the different emphasis on the divergent and convergent dimensions of IT will lead to different knowledge based capabilities in terms of exploration and exploitation. Following Zollo and Winter (2002), exploration activities are primarily carried out through cognitive efforts aimed at generating a necessary range of new intuitions and ideas as well as selecting the most appropriate ones through legitimation processes. By contrast, exploitation activities mostly rely on behavioural mechanisms encompassing the retention and replication of knowledge in conditions more or less similar to precedent ones.

That being so, we may assume that IT configurations focused on convergent technologies are especially supportive of exploration activities. Exploration involves developing new knowledge contents and/or replacing existing knowledge contents. Convergent IT is concerned with bringing experts together so that important knowledge is shared and amplified. This dimension of IT supports communication and discourse among members of a product development effort, so they can contribute to and share their knowledge, intuitions and ideas. So, convergent IT may increase knowledge exploration by enabling a forum (knowledge space) for constructing and sharing beliefs, for confirming consensual interpretation, and for allowing expression of new ideas (Alavi and Leidner, 2001). By providing an extended field of interaction among product development members for sharing knowledge and perspectives, and for establishing dialogue, convergent IT may enable individuals to arrive at new insights and/or more accurate interpretations than they would do by their own.

Conversely, IT configurations focuses on divergent technologies are more supportive of exploitation activities. Exploitation involves the retrieval, replication and use of existing knowledge. Divergent IT can enhance knowledge integration and application by facilitating the capture, updating, and accessibility of existing knowledge (Alavi and Leidner, 2001). So, this dimension of IT may be considered as a "memory aid" that helps in storing and reapplying workable solutions in the form of standards and procedures. This retrieved knowledge can be easily used as input for intelligent agents, which replicate prior procedures to solve recurring problems. It also increases the speed at which existing knowledge can be accessed and applied, both in a structured and unstructured form (Robey et al., 2000). Moreover, divergent IT has been designed to retrieve and use knowledge directly, without human intervention. While human intervention is a prerequisite for knowledge exploration, it is not for knowledge exploitation. We may thus enunciate the following hypotheses:

Hypothesis 2a. When product development focuses on convergent IT, resulting knowledge based capabilities will focus on exploration.
Hypothesis 2b. When product development focuses on divergent IT , resulting knowledge based capabilities will focus on exploitation.

As conceptualized by March (1991) and previously described, exploitation helps the operational efficiency and is accentuated in the last stages of the product development process so that it supports control and consolidation. On the contrary, exploration is geared toward improving product and innovativeness and is especially intense at the beginning of the new product development process. If this is so, it is logical to assume that higher performance in product development require a combination of exploration and exploitation.

Given that exploitation demands essentially the divergent dimension of IT and exploration is basically supported by the convergent dimension, product development that engages in convergent IT and exclude divergent IT is likely to suffer the cost of experimentation without gaining many of the benefits. It is Levinthal and March's (1993) "failure trap". Likewise, product development that engages in divergent IT to the exclusion of exploration is likely to find itself trapped in suboptimal equilibrium. It is Levinthal and March's (1993) "success trap".

Accordingly, low levels in both convergent and divergent IT does not lead to enhance much the level of knowledge capabilities in product development. On the contrary, when product development has a proper alignment between convergent and divergent IT, it exhibits the higher level of knowledge capabilities. We may thus enunciate the following hypotheses:

Hypothesis 3. When product development focuses on IT combining both the convergent and divergent dimension, resulting knowledge based capabilities will focus on both exploration and exploitation.

3.RESEARCH METHODOLOGY

3.1. Sample characteristics and data collection

Survey methodology has been used for the empirical analysis. The questionnaire has been designed and developed from a thorough literature review, and simplified by us in some indicators. The questionnaire was next validated through a pre-test carried out through several personal interviews with product development executives. These interviews allowed us to purify our survey items and rectify any potential deficiency. Minor adjustments were made on the basis of specific suggestions.

After the pilot study, the mailing list was obtained from Madri+d[1]. Respondents were product development managers, selected according to a representative population, and contacted by telephone or mail. Those who agreed to participate in the study received the questionnaire by e-mail or by accessing a web page where the questionnaire was available. They had to answer to questions related with a specific product development process. A researcher involved in the study personally helped to the product development managers to solve the question related to the survey. This implies that sample characteristics were not significantly different from the corresponding population parameters of the original sample provided by Madri+d. As a result, 79 products development managers provided responses. In term of industry type, we covered a wide number of industries. Table 1 summarizes respondent characteristics in terms of total number of employees.

[1] Madri+d is a society that groups firms and public research organizations aimed of improving of competitiveness through encouraging research, development, innovation and knowledge transfer.

Insert Table 1 about here

Since the original questionnaire was a larger one, we only chose the questions that helped investigate the hypotheses detailed in this research. In our particular case, a first set of questions were related to define the IT dimensions: convergent and divergent. A second set of items was associated to the knowledge based capabilities in terms of exploration and exploitation.

3.2. Measures description

The measurement of the analysis variables has been built on a multiple-items method, which enhances confidence about the accuracy and consistency of the assessment. Each item was based on a five point Likert scale and all of them are perceptual variables. Table 2 displays items used to measure the analysis variables.

Insert Table 2 about here

Knowledge based capabilities

We have modelled knowledge based capabilities in product development as a multidimensional construct where exploration and exploitation are considered as representative dimensions. As stated by Crossan et al. (1999), exploration takes place when product development generates new knowledge. Likewise, exploitation encompasses processes that take and transmit embedded knowledge that has been learnt from the past down to product development. Accordingly, and based on Lee and Choi (2003), Mohrman et al. (2003) and Katila and Ahuja (2002), knowledge based capabilities has been measured by using 8 items, four items concerning to exploration and four items concerning to exploitation. The first four items measured the degree to which product development involves the introduction of new ideas, new knowledge, and the correction of problems areas where customers were unsatisfied. The last four items measured the degree to which product development introduces lessons learnt in the past, existing competences, and combines and integrate different knowledge.

IT dimensions

As we have previously argued, we measure IT dimensions of product development from a convergent and divergent perspective. IT dimensions admit different configurations when supporting knowledge capabilities in product development. Based on Lee and Choi (2003) and Gold et al. (2001), IT dimensions were operationalized by using nine items. The convergent dimension has been assessed by evaluating how IT fosters communication and collaboration between people involved in product development, both within and outside the organization (four items). The divergent dimension has been measured by evaluating how IT facilitates the fast collection, storage, mapping and arrangement of knowledge, thereby assisting knowledge capabilities in product development (five items).

4. ANALYSIS AND RESULTS

Data analysis has involved several steps. First, since our research variables are measured through multiple-item constructs, we need to verify that items tapped into their stipulated construct. Thus, we conducted two independent factorial analyses by using SPSS 13.0 for Windows: one for knowledge based capabilities items and other one for IT dimensions items. Results obtained were factors that condense the original nominal variable information while providing continuous variables for each group of variables. Table 3 summarizes these results. The internal consistency measures (Cronbach's alpha) were obtained in order to assess the reliability of the measurement instruments.

Insert Table 3 about here

Second, we applied a cluster analysis to the factors of the IT dimensions. This cluster analysis leads us to define different IT configurations in terms of the convergent and divergent dimensions. A major issue of the clustering technique is determining the number of clusters. In our case we have applied a Ward's hierarchical method using the Euclidean distance and an agglomeration schedule to determine the number of clusters and the initial seeds (centres of the groups) that have been used in a second K-means no hierarchical analysis which has provided the final categorization of the firms (Table 4). The decision on the number of clusters was guided by an agglomeration coefficient, which displayed the squared Euclidean distance between each case or group of cases (see Table 5). The agglomeration coefficient shows quite large increases from clusters 4 to 3, from cluster 3 to 2, and from cluster 2 to 1, which in terms of the percentage change in the clustering coefficient lead us to determine that the appropriate number of clusters is 3. This final result shows clear differences between clusters 1 and 2, and clusters 1 and 3, while the distance between centres of clusters 2 and 3 is quite smaller. Both IT measures have discriminatory power, but the convergent dimension is discriminatory in a greater extend (see ANOVA test, Table 5).

Insert Table 4 and 5 about here

The characterization of clusters, which is based on the final centres, is the next. Cluster 1, including 44 product developments with high convergence and divergent IT dimensions, represents a *balanced IT configuration*. Cluster 2, comprising only 10 product developments characterized by high convergent IT dimension but very low divergent IT dimension, presents a *convergent-based IT configuration*. Cluster 3, formed by 25 firms, differs from the order two groups in its convergent dimension as it is very low. Although the divergent IT dimension of this group shows more variability (almost leading to a 0 mean) when compared to the other two clusters, it clearly shows a *divergent-based IT configuration*. Table 5 also shows the no-existence of product development with low emphasis on both convergent and divergent IT. This result do points the recognition of information technologies in enabling learning and knowledge sharing in product development.

Next, the relationship between the knowledge based capabilities –in term of exploration and exploitation- and IT configurations in product development is analyzed within each cluster/configuration. Table 6 shows descriptive statistics (mean and deviation values) and ANOVA test for the segmented configurations. As indicated by the ANOVA test, we can observe that knowledge based capabilities in terms of exploitation significantly differs as a result of variations in IT configurations in product development. Conversely, knowledge based capabilities in terms of exploration is not significantly different among the three clusters. Therefore, results provide partial significant evidence about the differences that may exist on knowledge based capabilities as a result of the differences existing in IT configurations. Our hypothesis 1 is thus partially supported.

Insert Table 6 about here

To better analyse the differences, Tukey and Duncan tests reveal that differences in terms of exploitation are especially significant between clusters 1-2 and clusters 1-3, while clusters 2 and 3 can be considered homogeneous. This means that product development combining both the convergent and the divergent dimension of IT are able to better retrieve and use existing knowledge assets. Although results do not provide important differences in terms of exploitation between convergent-based IT configurations and divergent-based IT configurations in product development, we can observe that the second one (cluster 3) works better than the first one (cluster 2). These results are consistent with our hypothesis 2b.

Insert Figure 1 about here

It is also interesting to observe that product development exhibiting a high mean value in term of the convergent dimension of IT works better in terms of exploration than product development exhibiting low mean values in this dimension of IT. Although this finding fits to hypothesis 2a, it is not significant. Finally, it is observed that product development included in balanced IT configuration (cluster 1) was the best performing (highest mean value) in terms of both knowledge based capabilities. This result also provided additional support for our framework. Balance IT configuration outperforms clearly those that were convergent-based IT configuration and divergent-based IT configuration, suggesting that the ability to have both IT dimensions is also an important predictor of performance. Again, although this finding fits to hypothesis 3., it is only significantly supported in term of exploitation.

5. DISCUSSION

The advantages of modern IT as a major issue for learning and knowledge in product development has received great deal of attention in recent years. While some claim the benefits of IT investments for learning and knowledge management in organizations, other disagree. Several studies have examined the relationships between IT and knowledge-based capabilities, but most of them have provided findings that tend to be either mixed or inconclusive (Tippins and Sohi, 2003). As result, the linkage between product development and IT must be examined to identify those areas where contribution might be made.

This study provides additional insights for the benefits provided by IT investments for enhancing knowledge based capabilities during product development. Our results offer only partial evidence to our main hypotheses. We have firstly analysed that differences in IT configurations in product development may lead to differences in knowledge based capabilities, which is significantly supported in terms of knowledge exploitation. Additionally, we have found support to the fact that divergent-based IT configurations are especially beneficial for knowledge exploitation during the product development process. This is logic if we have in mind that exploitation starts when novelty (that emerges form exploration) is reduced and consolidated into a dominant design. This involves that knowledge gets more codified, which enables a more rapid diffusion and less personalized relationships. Divergent IT is thus a key instrument for the articulation, codification, storage, systematisation, diffusion, and retrieval of existing knowledge, which is especially relevant at product development when it is necessary to rapidly replicate and reapply workable solutions in the form of standards and procedures. Such finding is consistent with the nature of knowledge exploitation, which doesn't necessarily demands any kind of human intervention to take advantage of IT investments. It is also agrees with part of the management literature (Anand, et al, 1998 and Daverport and Prusak, 1998) that increasingly view IT as a knowledge management enabler useful for store and distribute explicit knowledge, but less helpful for sharing tacit knowledge and stimulating the use and the creation of knowledge.

This research also highlights that product development should not involve an excluding trade off between the convergent and the divergent dimension of IT (whereby one is at the expense of the other), but a balance of both of them. Though only significant in terms of knowledge exploitation, our results show that the more successful product development processes, in terms of knowledge capabilities, are those ones able to simultaneously use both dimensions of IT. In fact, in order to support knowledge exploitation in product development, the question is to retrieve and combine knowledge that may be distributed across different departments or organizational units. This may not necessarily imply connecting people but, since knowledge is naturally complex and usually embedded to individuals who posses it, it is feasible that convergent IT gives "flexibility" to divergent IT. A balanced-IT configuration allows the elimination of structural and temporal barriers, and allows distributed participants in product development to collaborate and coordinate the work in an interactive way. It also supports knowledge location, within and outside the organization, so that available knowledge can be mapped in an internal knowledge base. Therefore, it is the delicate balance among both the convergent and the divergent dimensions of IT which most affects the knowledge-based capabilities of product development, at least in terms of exploitation.

Finally, the non-significant findings of the study also bear some implications. Our study shows no significant relationship between IT configurations in product development and knowledge exploration, being thus unclear the potential of providing support to the creative processes of the product development team. It seems therefore that the impact of IT cannot be considered to affect all knowledge based capabilities "a priori". This comes to validate recent critics suggesting that there has been far too much reliance on information technologies as facilitators of knowledge based capabilities. On one hand, IT configurations may impede knowledge modifications thereby hampering the exploration phase and reducing the knowledge based capabilities of the firm. On the other hand, if properly exploited, the organization's knowledge is likely to foster the exploration of new knowledge, hence strengthening knowledge based capabilities. In fact, although human intervention is a prerequisite for knowledge exploration, it also demands the use of existing knowledge as an input to produce new ideas, solutions and knowledge. Accordingly, as long as IT configurations can take part in an iterative process where each member involved contributes to recombine and use knowledge until a new idea emerges, they are facilitating its exploitation as an input to explore new knowledge. IT

Our results must be viewed in the light of the study's limitations. First, sample size is not large. As a second limitation, it is necessary say that we have tried to define our constructs as precisely as possible by drawing on relevant literature and to closely link our measures to the theoretical underpinnings through a careful process of item generation and refinement. Evidently, this measurement effort represents an advance for research but, nonetheless, our research items are far for being perfect as long as they measure facts that are neither fully nor easily measurable. Another limitation concerns the fact that all data were collected from the same respondent using the same perceptual measurement technique. Although our findings may help to explain certain relationships between variables, we are aware that replies from multiple respondents would have ruled out potential drawbacks. We should also have in mind that both the external environment (i.e. customers characteristics) and the organization's internal characteristics (i.e. the context of product development) naturally interferes with product development efforts, therefore amplifying or attenuating the organization's tendency to explore and/or exploit. This work is thus obviously only a preliminary step towards a better understanding of the impact of IT on knowledge-based capabilities in product development and, on the basis of previous limitations it naturally points out avenues for future research.

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Table 1. Respondents by firm's size.

Firms by size	
Up to 499	65,80%
500-999	9,60%
1000-4999	12,30%
5000-9999	6,80%
over 10.000	5,50%

Table 2. Description of measurement items for each construct

Construct	Measurement item	Mean	S.D.
Divergent dimension	T1: IT supports for systematic storing of information	4,04	0,94
	T2: IT supports for mapping the location of knowledge and information	3,90	0,89
	T3: IT supports for searching for and accessing a high level of information about markets and competitors	3,70	0,91
	T4: It supports for clearly formatting its product knowledge	3,63	0,88
	T5: IT supports for searching and accessing a high level of information about products and processes	4,01	0,65
Convergent dimension	T6: IT supports for collaborative work between people outside the organization	3,56	1,03
	T7:IT supports for collaborative works between the people inside organization	3,57	0,89
	T8: IT supports for communication among members inside the team of product development	4,00	0,75
	T9:IT supports for communication with people outside the organization	3,94	0,82
Knowledge Exploration	K1: Product problem areas with which customer were dissatisfied were corrected	3,27	0,95
	K2: Problem areas with which customer were dissatisfied were covered	3,23	1,01
	K3: New knowledge, methods and inventions were introduced	3,56	0,82
	K4: Many new novel and useful ideas were produced	3,49	0,86
Knowledge Exploitation	K5: Valuable knowledge elements were identified, connect and combine them.	3,94	0,78
	K6: Existing competences related to products/services that are currently being offered were used.	3,94	0,81
	K7: New and existing ways of doing things without stifling their efficiency were integrated.	4,01	0,75
	K8: Lessons learned in other areas of the organization were put in operation	3,88	0,94

Table 3. Results of factorial analysis

Construct	Measurement item	Loading factor*	Variance extracted (%)	Reliability (Cronbach's alpha)
Divergent IT dimension	T1, T2, T3, T4, T5	0.77; 0.75;0.70; 0.69;0.69	30,85	0,79
Convergent IT dimension	T6, T7, T8, T9	0.85;0.83;0.74;0.69	28,99	0,81
Knowledge exploration	K1, K2, K3, K4	0.87; 0.85;0.75;0.74	33,55	0,83
Knowledge exploitation	K5, K6, K7, K8	0.80;0.76;0.70;0.67	28,92	0,73

*Rotated varimax matrix

Table 4. Analysis of agglomeration coefficients*

Number of cluster	Agglomeration Coefficient	Change in coefficient in the next level (%)
6	29,03	31,68%
5	38,23	30,04%
4	49,71	36,39%
3	67,80	57,17%
2	106,57	46,39%
1	156,00	

*Hierarchical cluster based on Ward method and Euclidean distance

Table 5. Cluster analysis results (K-means)

		Divergent IT dimension **LOW**	**HIGH**
Convergent IT dimension	**LOW**		Cluster 3 *(N = 25)* ***DIVERGENT-BASED IT CONFIGURATION*** Mean / Deviation **Convergent** 1.90 0.61 **Divergent** 3.09 0.77
	HIGH	Cluster 2 (N = 10) ***CONVERGENT-BASED IT CONFIGURATION***	Cluster 1 (N = 44) ***BALANCE IT CONFIGURATION***

		Mean	Deviation		Mean	Deviation
	Convergent	3.62	0.42	**Convergent**	3.61	0.63
	Divergent	1.36	0.64	**Divergent**	3.57	0.68

TOTAL	**Mean**	**Deviation**	**F (ANOVA)**	**P value**
Convergent IT dimension	3.07	1.00	68.4	0.00
Divergent IT dimension	3.14	1.00	39.6	0.00

Table 6. ANOVA results for effects of IT configuration on Knowledge generation

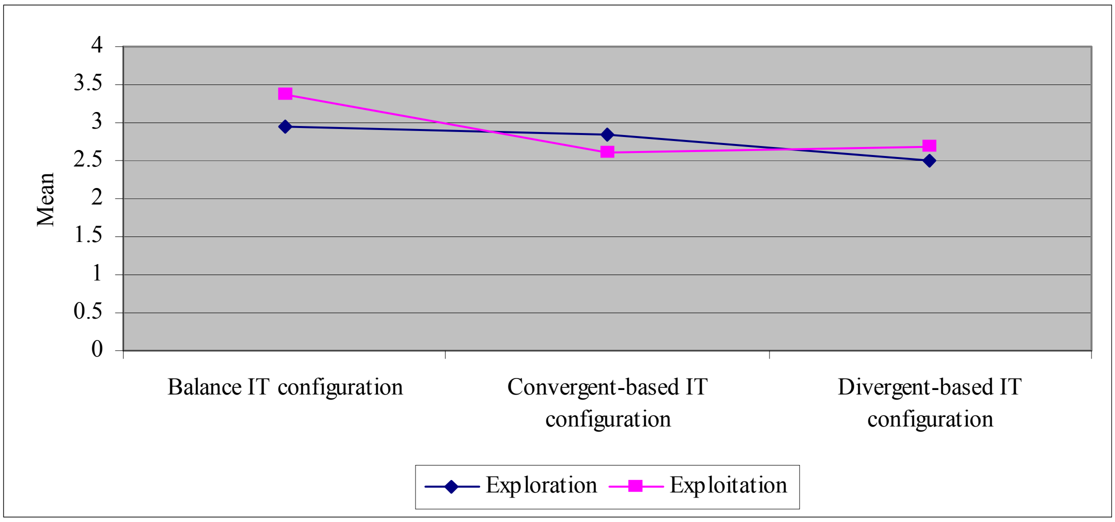
		Divergent IT dimension LOW			**HIGH**		
Convergent IT dimension	**LOW**				Cluster 3 *(N = 25)* ***DIVERGENT-BASED IT CONFIGURATION***		
						Mean	Deviation
					Exploration	2.49	1.01
					Exploitation	2.69	1.02
	HIGH	Cluster 2 (N = 10) ***CONVERGENT-BASED IT CONFIGURATION***			Cluster 1 (N = 44) ***BALANCE IT CONFIGURATION***		
			Mean	Deviation		Mean	Deviation
		Exploration	2.84	0.88	**Exploration**	2.95	1.00
		Exploitation	2.61	0.82	**Exploitation**	3.37	0.93

TOTAL	Mean	Deviation
Exploration	2.80	**1.00**
Exploitation	3.06	**1.00**

	ANOVA F (Significant) groups*	**TUKEY Main group differences***	**DUNCAN Homogeneous**
Exploration	1.69 (.19)		
Exploitation	5.23 (.01)	(1-3) (1-2)	(2-3) 1

(*) Significant differences at the 0.05 confidence level

Figure 1. Mean values of Knowledge generation factors for each group



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