DYNAMISM AND COMPLEXITY AS ANTECEDENTS OF THE KNOWLEDGE STRATEGY IN PRODUCT DEVELOPMENT

IE Business School Working Paper DO8-143-I 07-03-2008

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Abstract
Focusing on product development, this study extends the understanding of the environment-strategy framework and investigates the relative effect of two classical environmental variables, dynamism and complexity, on the knowledge strategy. Adopting a knowledge-based view, and assuming that the strategy's locus is knowledge creation –exploration- and knowledge application –exploitation-, the study suggests that the development of a knowledge strategy is a managerial strategic choice that is related to the environment. The results of a survey on product development managers indicate that product development efforts operating in highly dynamic environments mostly pursue exploratory strategies. Results also show a significant positive relationship between complexity and exploitation. Finally, the study finds that product development efforts in environment characterized by high levels of both dynamism and complexity pursue and reinforce both explorative and exploitative activities through the knowledge strategy.

1. INTRODUCTION

As competition intensifies and the pace of change accelerates, the development of a steady stream of new products is seen as the only way to ensure firm's survival and success (Mallick and Schroeder, 2005). According to the knowledge base view, product development is a key strategic activity in numerous firms since it creates and applies knowledge for effectively dealing with their competitive environment. Specially, product development lets firms renew themselves by both exploiting existing knowledge and exploring new one (Floyd and Lane, 2000; Katila and Ahuja, 2002).

The conceptual distinction between exploration and exploitation (March, 1991) has emerged as an underlying theme in research on organizational learning and strategy (Levinthal and March, 1993; Bierly and Chakrabarti, 1996; Vera and Crossan, 2004), innovation (Rothaermel and Deeds, 2004), and organization theory (Holmqvist, 2004). Exploration is a manifestation of organizational learning that entails activities such as search, variation, experimentation, challenging existing ideas, and research and development. It is thus about improving and renewing the organization's expertise and competences to compete in changing markets by introducing the variations needed to provide a sufficient amount of choice to solve problems (March, 1991). Exploitation is a different manifestation of organizational learning that involves efficiency, selection, implementation, control, refining and extending existing skills and capabilities. It reflects how the firm harvests and incorporates existing expertise and competences into its operations, not just for economizing the efficiency of existing resource combinations (Levinthal and March, 1993), but also for creating new ones.

Some studies (Ghemawat and Costa, 1993; Bierley and Chakrabarty, 1996) suggest that exploration and exploitation are competing activities, which results in the need for organizations to emphasize one at the expense of the other. In contrast, most studies (Tushman and O'Reilly, 1996; Eisenhardt and Martin, 2000; Katila and Ahuja, 2002; He and Wong, 2004; Auh and Menguc, 2005) propose that exploration and exploitation are complementary activities, so companies should strike the correct balance between them. In practice, it has been argued that firms need to define a "knowledge strategy" as the overall approach that, based on the balance between explorative and exploitative activities, determine which knowledge should be developed or acquired (Zack, 1999; Vera and Crossan, 2003). Regarding this last concern, the issues of business strategy (Vera and Crossan, 2003) and environmental characteristics (i.e. environmental dynamism) are considered to shape the strategic choices between exploration and exploitation.

At this point, the question is: Does the environment of product development affect the selected knowledge strategy in terms of exploitation and exploitation? The environment-strategy theoretical framework indicates that environmental factors are an important consideration for a firm that is determining its strategy (Venkatraman, 1989; Lou and Park, 2001). The foundation of this theoretical framework is in the literature stream of both strategic co-alignment (Astley and Van de Ven, 1983) and the strategic choice (Child, 1972, 1997). This literature argues that the firm is a proactive participant in the environment, and is capable of adapting its strategy to be responsive to that environment (Child, 1997). There is a rich history in the strategy literature that demonstrates the direct influence of the environment on a firm's strategic initiatives (Venkatraman and Camilus, 1984). Accordingly, it is possible to argue that effective product development requires the "fit" between the environment and its knowledge strategy. In other words, it is possible to suggest that, if a product development strategy's locus is knowledge (as the knowledge-based view holds), the study of the links between knowledge exploitation and exploration and the environmental context should play an important role in product development performance.

Although the environment-strategy alignment has been found to be important at a general strategic orientation level, the knowledge-based view has most focused on the process of knowledge management, but less on the influence on the environment (Cui et al, 2005). Despite the theoretical strength of this idea, whenever the influence of the environment has been examined, it is just conceptualized as a moderator of the relationship between knowledge management and firm performance (e.g. Grewal and Tansuhaj, 2001; Jaworski and Kohli, 1993; Benner and Tushman, 2003).

Therefore, it is clear that the relationship among the environment characteristics and the knowledge strategy remains unclear and calls for additional empirical investigation. Accordingly, this study applies the environment-strategy theoretical framework to investigate the relative effects of two classical environmental variables, dynamisms and complexity, on the knowledge strategy in product development. With this aim, the paper begins by characterizing the knowledge strategy in product development. Next, we give reason for the role of environmental dynamisms and complexity as antecedents of the knowledge strategy in product development, and introduce our proposed hypotheses. Then, we test the hypothesis on the basis of data generated from a questionnaire survey accomplished in a sample of product development programmes. Such test gives a snapshot of the resulting differences in terms of knowledge strategy. A discussion of the implications, limitations and future research directions concludes the research paper.

2. KNOWLEDGE STRATEGIES IN PRODUCT DEVELOPMENT

Success in product development demands firms to exploit their existing knowledge and competences while, at the same time, explore new knowledge to avoid dysfunctional rigidities (Leonard Barton, 1992). Product development is therefore a knowledge intensive process, aimed to create new knowledge and recombine existing knowledge to create new products that have value in the marketplace. Specifically, exploitation and exploration activities emerge throughout a problem resolution process aimed to create new products (Mohrman et al, 2003). Knowledge exploitation occurs with the utilization of existing knowledge for innovative problem solving. Knowledge exploration occurs when existing knowledge is not sufficient to solve the problem identified, so that new knowledge needs to be constructed and acquired to contribute to the existing body of knowledge. In other words, individuals generate new knowledge by recognizing and defining problems and applying knowledge to solve problems (Nonaka, et al., 2000).

Exploration and exploitation activities reflect firm's attitudes that configure a "knowledge strategy". The idea of the "knowledge strategy" has been recently developed by authors in the field of organizational learning and organizational knowledge. In example, Bierly and Chakrabarti (1996) define the knowledge strategy as the strategic choices that shape the organizational learning processes. Zack's (1999) defines knowledge strategy as "the overall approach an organization intends to take to align its knowledge resources and capabilities to the intellectual requirements of its strategy (p.135)". The knowledge strategy is thus determined by decisions regarding the creation, development, and use of a firm's knowledge. These decisions are the managerial choices between knowledge exploration and exploitation, together with choices between internal and external knowledge (Vera and Crossan, 2003).

Therefore, it seems acceptable that product development involves the choice of a knowledge strategy that determines the reliance on new knowledge and competences versus existing knowledge and competences, as required by the problem recognition and resolution processes. Following Gupta et al. (2006), it is still unclear if the balance between knowledge exploration and knowledge exploitation should be achieved via ambidexterity (synchronous pursuit of both exploration and exploitation) or punctuated equilibrium (cycling through periods of exploration and exploitation). Existing literature is silent on the question of whether these two mechanisms are equally viable, and whether exogenous and endogenous contextual factors should drive the choice between them. Although the need of further elucidations, we may consider that the balance between exploration and exploitation in product development, and thus the choice of the knowledge strategy, is determined by managerial decisions shapep by numerous exogenous and endogenous factors that characterizes the environmental context of product development. These factors and their influence in the knowledge strategy are explained in the next section.

3. DYNAMISM AND COMPLEXITY

Following Dröge et al. (2003), the environmental context refers to factors descriptive of a product development current environment and operations, which are stable or enduring in the short term. The impact of the environment on innovativeness has been widely acknowledged (Zahra, 1996, Zahra and Bogner, 1999). The key question is to identify which ones of the many environmental factors should be under consideration in any given piece of research. As already stated in the previous sections, we view knowledge (exploration and exploitation) as the locus of product development strategy. Knowledge theorists have already examined the role of the environment in deciding the combination between exploration and exploitation. For example, Teece at al (1997) have proposed a dynamic competences model rooted in the knowledge based literature wherein dynamism comes from rapidly changing environments. Researchers such as Jap (1999) and Jaworski and Kohli (1993) have also identified a direct relationship between market dynamisms and the firms' strategic usage of knowledge resources. Aragon-Correa and Sharma ((2003) explain the moderating role of environmental uncertainty and complexity in the relationship between dynamic capabilities and sustainable competitive advantage. Using a contingency theory, Koufteros et al. (2005) analyze how environmental uncertainty and the equivocality moderate product innovation. Finally, Chapman and Hyland (2004) analyze complexity in their study of learning behaviours in product innovation.

Therefore, two environmental context variables are common to most knowledge-based literature: dynamisms and complexity. In fact, every new source of change in the environment leads firms to realize that they do not possess adequate knowledge for effectively dealing with change. They need to define a product development's strategy to create and apply knowledge to enable a proper alignment with the new environment.

However, there is no evidence on how the environmental contexts influence on the knowledge strategy of product development. This research presumes that different orchestrations in the environmental dynamisms and complexity should have different effects on knowledge strategy. In other words, particular environmental contexts will induce specific combinations of knowledge exploitation and knowledge exploration. This assumption can bi articulated as the first hypothesis of this study:

Hypothesis 1. Differences in environmental context in terms of dynamisms and complexity may lead to differences in the organizational knowledge strategy in terms of knowledge exploration and knowledge exploitation.

The following sections describe environmental variables, dynamisms and complexity, thus justifying their relationships with exploration and exploitation.

3.1. The role of dynamism

Environmental dynamism refers to the rate of change (Jap, 1999) and instability of the environment (Dess and Beard, 1984). Dynamic environments may be characterized by changes in various market elements, such as customer preferences, technology, and competitor structure. Turbulence or volatility are similar in terms of dynamism, and are related to the degree of novelty in the changes or to their speed (Ansoff, 1979). Dynamism means more events per unit of time. Iansity (1995) suggests that rapid change in the external environment promotes uncertainty in product development, a concept that includes the degree of predictability concerning the changes and their effects on product development.

In highly dynamic environment, frequent changes in customer demand, technology, and business practices require firms to continuously modify their products or services to remain competitive. Change makes current product and services obsolete and requires the development of new ones (Jansen et al., 2006; Sorensen and Stuart, 2000). Likewise, sudden and unpredictable changes can decrease the value of a firm's existing knowledge and even render it obsolete (Hitt et al., 2000). To minimize the threat of obsolescence, firms need to introduce an exploratory strategy and develop new products that move away from existing product, service, and markets to meet the needs of the emerging environments. It means that firms must focus on solving new problems through new knowledge creation.

Hence, it is logic to assume that, in dynamic environments, firms invest in the development of their human resources and depend upon tacit skill development through employee involvement (Hart, 1995). Managers facing dynamic business environments tend to be more proactive, take grater risk, and use more innovative strategies than managers in less turbulent environments (Miles and Snow, 1978) in an attempt to anticipate events and implement preventive actions, rather than merely respond to events that have already occurred. When environmental opportunity is richer, there is thus strategic value in rapidly being able to develop and apply new knowledge and competencies (Pisano, 1994).

Alternatively, in less dynamic markets, customer preferences are relatively stable and, therefore, modifications in product or services are less required. Firms may thus become complacent, not learning as fast as firms facing higher environmental dynamisms. As a result, these firms will not select an exploratory strategy and invest less in the development of new products. The investment required by this strategy would be unnecessary and inefficient. We may thus enunciate the following hypotheses:

Hypothesis 2a. The higher the levels of environmental dynamisms, the higher the required level of exploration in the knowledge strategy.

3.2. The role of complexity

Complexity is defined as proliferation and diversity of factors in the environment (Duncan, 1972). The more the number of elements, and the more the difference among elements, the more the environmental complexity. It reveals the level of complex knowledge to be understood from the environment (Fuentes-Fuentes, et al, 2004). Several authors consider than heterogeneity is similar to complexity. Heterogeneity describes whether the elements in the environment are similar or different from one another (Thompson, 1967). According to Duncan (1972), the complexity of the environment is associated to the heterogeneity in the range of firm's activities. In this same line, Lawrence and Lorsch (1967) pointed out that complex environments require a high level of internal differentiation. In terms of knowledge, it refers to the number of different kind of knowledge that needs to be combined in the product development and to the variety of different kinds of organizational units producing such knowledge. Complexity, then, can be both, cognitive and organizational.

Given that each intellectual field uses different instruments, concepts, and approaches, the more the complexity grows, the more the need for developing effective coordination mechanisms within any product development initiative. Complexity increases the organizational dependency between the diverse functional knowledge areas involved in product development. In these circumstances, as pointed by Henderson and Cockburn (1994), the ability to integrate different knowledge streams and competence is a critical successful factor. According to their findings, complexity is related to difficulties with communication and the need for strong feedback between upstream (e.g. design engineers) and downstream knowledge workers (e.g. design engineers), users, suppliers, and producers. Basically, as environment complexity grows, coordination cost rise and the need for more diversity of knowledge grows.

In situations of complexity, knowledge creation requires connecting people so they can think together and create environments where knowledge can be interpreted and leveraged (McDermott, 1999). This form of learning will just happen when R&D managers, scientists, and engineers feel comfortable sharing knowledge with their counterparts from other departments. They need a high degree of mutual involvement in problem recognition and problem solving processes. In the presence of inter-departmental dependences to allow the flowing of knowledge, this can be particularly challenging (Berdrow and Lane, 2003). Differences in language, norms and mental models often inhibit personal interactions, which are critical to create an innovative environment for product development. Unless the management of product development makes deliberate efforts to avoid it, knowledge generated by a department or organizational unit will not be accessed and productively used, just remaining within it.

Miller (1987) demonstrated that there is a positive relationship between the heterogeneity of the environment and the strategy for innovation. So, firms perceiving complex environments have difficulty in determining the key factors strategically important for success (Amit and Schoemaker, 1993). Complexity increases the number of criteria to be specified by technology, manufacturing, and marketing. In essence, the more difficult the understanding of the key elements of the new product, the more difficult it is to express the type and the source of knowledge that needs to be used. In addition, environmental complexity requires the integration of a wide number of knowledge fields. According to Hitt et al. (1993), when knowledge residing in the collective organization, it is more difficult to understand the whole knowledge of the product development. This requires the use of additional resources and involves higher levels of managerial and organizational complexity. In these circumstances, extensive risk taking and strong emphasis on novelty (explorative strategies) may be hazardous. With high complexity levels, it is difficult for firms to make changes in-depth, so they therefore tend to make just small adjustments (Smart and Vertinskt, 1984). Conversely, product development reacts to high complexity by modifying or expanding current products, services, or markets (exploitative innovations). Product development thus pursues exploitative strategies to better cater to existing customers and to build customer loyalty without the substantial cost associated to exploratory strategies. Therefore:

Hypothesis 2b. The higher the levels of complexity, the higher the required level of exploitation in the knowledge strategy

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 that was 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, a mailing list was obtained from Madrid. Madrid is a society that groups firms and public research organizations located in Madrid[1] with the aim of improving competitiveness through research, development, innovation, and knowledge transfer. Innovation interests of these firms make them a suitable focus group for the purpose of this research. The Madrid area was chosen because it locates the most visible and important firms in Spain. By tapping into this area, this study can gain a better insight into the effectiveness of various practices and be able to develop more credible nomological constructs (Koufkeros, et al., 2007).

Since not all the firms that integrate Madrid develop new products (not being way to know which firms do and which do not), sending out questionnaires randomly was not considered. Respondents were product development managers, selected according to a representative population approach. As a result, sample characteristics were not significantly different from the corresponding population parameters of the original

[1] Madrid is the region that concentrated the biggest number of firms in Spain. It is also the most developed area in Spain

sample provided by Madrid[2]. Those who agreed to participate in the study received the questionnaire by e-mail or by accessing a web page where they could find the questionnaire. They had to answer questions concerning to a specific product development project. A researcher involved in the study personally helped to the product development managers to solve any question on the survey.

Since a single response was solicited from each product development, single informant bias in data collection may stem as a result. However, the presence of common method bias was tested by following one of the procedures described in Podsakoff et al. (2003). More precisely, Harman's single factor procedure was applied, in such a way that all items from the main constructors were included into an exploratory factor analysis to determine whether the majority of the variance could be accounted for one general factor. In this analysis, no single factor emerged and no general factor accounted for the majority of the covariance among the measures. Therefore, common method bias do not seems to be a problem.

As a result, 80 products development managers provided responses. In terms of industry type, answers covered a wide number of industries. Table 1 summarizes respondents' characteristics in terms of total number of employees. Most of the respondents were product development managers from firms with less than 500 employees, i.e., small firms. To assess size bias, the influence of firm size on the constructs was controlled through an Anova tests. Results show that the null hypothesis of equal means could not been rejected and therefore firm size did not affect environmental dimensions or knowledge exploration and exploitation.

Table 1. Description of firms by total number of employees

Number of employees	Percentage
<= 499	65.8
500-999	9.6
1000-4999	12.3
5000-9999	6.8
>=10000	5.5
	100

Since it was a large survey, in this research, it was only chosen the questions that helped investigate the hypotheses detailed above. In our particular case, a first set of questions were related to define the environmental dimensions. The second set of items was associated to the knowledge strategy.

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.

2 See http://www.madrimasd.org

Table 2. Items used to measure analysis variables

Construct		Measurement item	Descriptive statistics: Mean	S.D.
Environment dimensions	Dynamism	Large of number of new product ideas has been made possible through technological breakthroughs in the industry	3.2	1.0
		The rate of technology change that your firm currently experiences is:	3.1	1.1
		Technological changes provided big opportunities in the industry	3.2	1.0
		Customers' preferences changed quite a bit over the time	3.5	0.9
	Complexity	Your firm's product complexity is:	3.8	0.7
		Your firm's process complexity is:	3.7	0.8
		Knowledge intensity of your product development process	3.7	0.8
Knowledge strategy	Knowledge Exploration	Product problem areas with which customer were dissatisfied were corrected	3.3	0.9
		Problem areas with which customer were dissatisfied were covered	3.2	1.0
		New knowledge, methods and inventions were introduced	3.6	0.8
		Many new novel and useful ideas were produced	3.5	0.9
	Knowledge Exploitation	The team was able to identify valuable knowledge elements, connect and combine them.	3.9	0.8
		It made use of existing competences related to products/services that are currently being offered.	3.9	0.8
		It was integrated new and existing ways of doing things without stifling their efficiency .	4.0	0.7
		Lessons learned in other areas of the organization were put in operation	3.9	0.9

Environment

Following previous studies, we have defined product development environment as a multidimensional construct where dynamisms and complexity are considered as representative dimensions. In order to measure environmental dynamism, four item was used: (1) the degree of the change technology; (2) the degree of new product ideas that have been made possible through technological breakthroughs in the industry; (3) the degree to which technical change provides big opportunities in the industry; and (4) the degree to which customers' preferences changed quite a bit over the time. This concept of dynamisms was previously proposed by Gupta and Wilemon (1990), Iansity (1995) and Soulder et al. (1998). Based on Germain et al. (2001) Clark and Fujimoto (1991) and Clark and Wheelwright (1995), we assessed complexity by (1) the level of complexity of firm's product; (2) the level of complexity of firm's process and (3) the degree of knowledge intensity of the product development.

Knowledge strategy

We have modelled the knowledge strategy 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 strategy 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 in which product development introduces new ideas, new knowledge, and the covering of problematic areas where customers were unsatisfied. The last four items measured the degree in which product development introduces lessons learnt in the past, existing competences, and the combination and integration of diverse knowledge.

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 the knowledge strategy items and other one for the environment dimensions items. Results were two factors that condense the original nominal variable information while providing continuous variables for each group of variables (Table 3). The internal consistency measures (Cronbach's alpha) were also obtained to assess the reliability of the measurement instruments.

Table 3. Definition of constructors and internal consistency measures

			Factorial analysis		
	Construct	**Measurement item**	**Loading factor***	**Variance extracted (%)**	**Reliability (Cronbach's alpha)**
Environment dimensions	**Dynamism**	Large of number of new product ideas has been made possible through technological breakthroughs in the industry	0.87	39.8	0.73
		The rate of technology change that your firm currently experiences is:	0.85		
		Technological changes provided big opportunities in the industry	0.83		
		Customers' preferences changed quite a bit over the time	0.67		
	Complexity	Your firm's product complexity is:	0.87	28.5	0.84
		Your firm's process complexity is:	0.82		
		Knowledge intensity of your product development process	0.67		
Knowledge strategy	**Knowledge Exploration**	Product problem areas with which customer were dissatisfied were corrected	0.87	33.55	0.83
		Problem areas with which customer were dissatisfied were covered	0.85		
		New knowledge, methods and inventions were introduced	0.75		
		Many new novel and useful ideas were produced	0.74		
	Knowledge Exploitation	The team was able to identify valuable knowledge elements, connect and combine them.	0.80	28.92	0.73
		It made use of existing competences related to products/services that are currently being offered.	0.76		
		It was integrated new and existing ways of doing things without stifling their efficiency .	0.70		
		Lessons learned in other areas of the organization were put in operation	0.67		

* Principal components

Second, we applied a cluster analysis to the environmental dimensions in order to define different environmental contexts in terms of dynamism and complexity. 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) to be used in a second K-means non hierarchical analysis that provided the final categorization of the firms. 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 4). The agglomeration coefficient shows quite large increases from clusters 5 to 4, from cluster 4 to 3, and from cluster 3 to 2, which in terms of the percentage change in the clustering coefficient, lead us to determine that the appropriate number of clusters was 4. This final result shows clear differences between clusters 1 and 2, and clusters 3 and 4, while the distance between centres of clusters 2 and 3 is quite smaller. Both context measures have discriminatory power. (See ANOVA test, Table 5).

Table 4: Analysis of agglomeration coefficients*

Number of cluster	Agglomeration Coefficient	Change in coefficient in the next level (%)
6	29.18	15,0%
5	33.56	17.3%
4	39.39	37.8%
3	54.28	69.2%
2	91.87	54.6%
1	142	

*Hierarchical cluster based on Ward method and Euclidean distance

Table 5. Results of Cluster Analysis of Context Dimensions (K-means)

	Cluster 1 Low-Low	Cluster 2 High-High	Cluster 3 High-Low	Cluster 4 Low-High	TOTAL	F (ANOVA)
Dynamism	2.36 (0.6)	3.79 (0.4)	4.16 (0.5)	1.96 (0.5)	2.75 (1.0)	54.87 (0,00)*
Complexity	2.06 (0.5)	3.75 (0.5)	2.38 (0.4)	3.81 (0.6)	2.94 (1.0)	52.81 (0.00)*
N	28	14	9	21	72	

In brackets standard deviation. *Significance level.

The characterization of clusters based on the final centres is the next (Table 5). Cluster 1 includes 28 product developments with low levels in both environmental dynamism and complexity. Cluster 2, which comprises 14 product developments, is characterized by high levels in both dynamism and complexity. Cluster 3 only includes 9 product development characterized by low levels in dynamism and the highest levels in complexity. Finally, Cluster 4, with 21 elements, is characterized by the highest levels in dynamism and the lowest levels in complexity.

Next, the relationship between the knowledge strategy and the environment in product development was analyzed within each group/cluster. Table 6 shows descriptive statistics (mean and deviation values) and ANOVA test for the segmented environments. These results confirm that exploitation and exploration are not mutually exclusive. In fact, product development may need to develop one area of knowledge while simultaneously exploiting another. As indicated by the ANOVA test, we can also observe that the knowledge strategy, significantly differs from variations in the environment of product development, especially in terms of exploitation ($p < 0.95$), and less significant in terms of exploration ($p < 0.93$). Then, our results confirm the differences that may exist in the knowledge strategy –in terms of exploration and exploitation- as a result of the differences existing in the environment of product development. These results are plenty consistent with the Hypothesis 1.

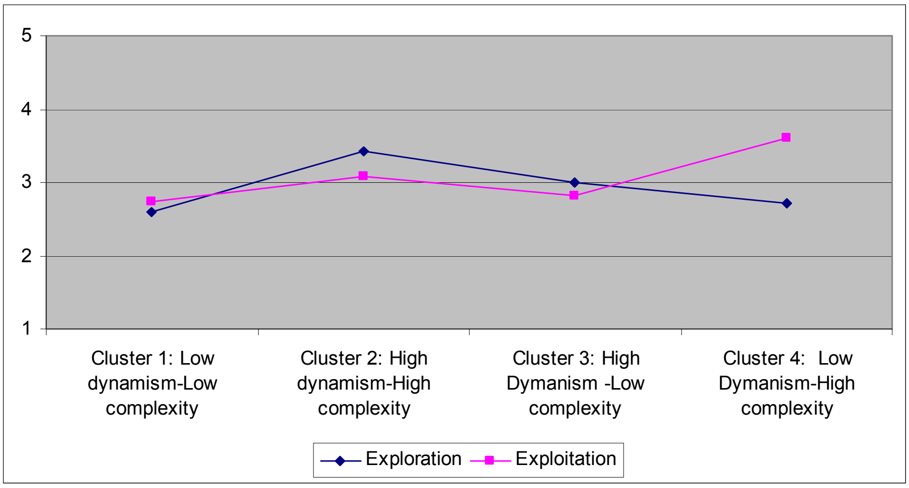
Table 6. ANOVA. Results for effects of environment dimensions on knowledge strategies

CLUSTERS	Exploration	Exploitation
Cluster 1: Low dynamism-Low complexity	2.59 (1.0)	2.74 (0.9)
Cluster 2: High dynamism-High complexity	3.41 (0.7)	3.08 (1.0)
Cluster 3: High dynamism-Low complexity	2.99 (1.3)	2.80 (0.9)
Cluster 4: Low dynamism-High complexity	2.72 (0.8)	3.60 (1.1)
Total	2.84 (1.0)	3.07 (1.0)
F (Signif.)	2.41 (0.07)**	3.53 (0.01)*
Main Group differences (Tuckey test)	(1-2)	(1-4)*
Homogenous groups (Duncan Test)	(1-4-3)(4-3-2)	(1-3-2)(2-4)*

In brackets standard deviation
*p<0.05; **p<0.1

To further analyze differences, we have plotted the mean values of both knowledge exploration and exploitation in Figure 1. The plot shows evidence in favour of hypothesis 2a and hypothesis 2b. Those environments with a higher level in dynamism (cluster 2 and 3) present the knowledge strategies with higher mean values in exploration, whereas cluster 2 and 4, which involve environments characterized by higher levels of complexity, exhibit the knowledge strategies with higher mean values of exploitation. Figure 1 also shows that the environments with a higher level in dynamism (cluster 2 and 3) leads product developments to follow an exploratory strategy, while the environments with lower levels of dynamisms (cluster 1 and 4), leads to a knowledge strategy which is mostly based on exploitation.

Figure 1. Mean Values of Knowledge strategies in four environmental contexts



In statistical terms, Tukey text clearly reveals significant differences in the knowledge strategy in terms of exploitation between clusters 1-4 (see Table 6). Thus, for the same level of dynamism, the growth of complexity leads to highest levels of exploitation in the knowledge strategy. This test also shows less significant differences in terms of exploration between groups 1 and 2. So, it is possible to presume that when the instability of the environment grows in terms of both dynamism and complexity, both exploration and (although not significant) exploitation are reinforced in the knowledge strategy of product development. Additionally, we observe that in stable environment – low dynamism and low complexity- the dominant knowledge strategy in product development is based on exploitation, while in more dynamic and complex environment, the knowledge strategy is mostly based on exploration.

5. DISCUSSION

Knowledge is the fundamental basis of competition. Successful competition requires aligning the knowledge strategy to the characteristic of the environment. Research on knowledge strategy based on the concepts of knowledge exploration and knowledge exploitation is quite emergent, but the understanding of the antecedents of both knowledge activities remains fairly unclear. Although prior research has suggested that the environmental antecedents have an important role in the choice of the knowledge strategy that sets the alignment of exploration and exploitation, empirical investigation has produced mixed resulted. Focusing on product development, this study extends the understanding of the environment-strategy framework and investigates the relative effect of two classical environmental variables, dynamism and complexity, on the knowledge strategy, in terms of exploration and exploitation.

First of all, this article shows that product development does not involve a trade off between exploration and exploitation, in such away that one would occurs at the expense of the other. On the contrary, product development efforts simultaneously develop both knowledge activities. Conversely, this study found strong evidence that exploration and exploitation should be understood in terms of duality, mutual interdependence, continual change, harmony, and balance.

It is not enough for a product development merely to engage in both exploitation and exploration. More importantly, those activities must be combined according to environmental factors. Because every firm competes in a particular environment, its knowledge strategy should be linked to the intellectual requirements of this environment. Our findings provide substantial support for this hypothesis and indicate that the environmental conditions influence the product development's strategy for developing and using knowledge. Results thus confirm that the knowledge strategy in product development is a managerial strategic choice that is related to environment. As such, this study corroborates the direct effects of dynamism and complexity on the knowledge strategy. Specially, our findings suggest that product development efforts operating in more dynamic environments pursue exploratory strategies. They resist the threat of the obsolescence of their knowledge base by generating new knowledge. Likewise, product developments functioning in less dynamic environments follow exploitative strategies. There is thus strategic value in using and combining existing knowledge for innovative solving problem activities. On the other hand, product development efforts facing high levels of complexity show the highest levels of exploitation. The higher the level of complexity, the higher the level of exploitation in the knowledge strategy is. So, we may conclude that product developments facing complex situations exhibit an experience effect that includes the application and integration of past experience and competences.

Our results also show that product developments operating in environment characterized by high levels of both dynamism and complexity pursue and reinforce both explorative and exploitative activities in their knowledge strategy. Although this is particularly significant in terms of exploration, the knowledge strategy concurrently looks for both exploration and exploitation to respond to different environmental demands. Anyway, it seems that environmental dynamism and complexity stimulate a higher level of knowledge generation.

In terms of managerial practice, this study suggests that, today, organizations and managers confront an increasingly contradictory word (Eisenhardt, 2000), and product development is not an exception. The traditional unitary approaches that emphasize extreme behaviours is not appropriate (Chae and Bloodgood, 2006). Managers should recognize and accept a paradoxical approach to management in product development practice and put their time and effort on sustaining it rather than avoiding it. Additionally, this study provides various managerial implications regarding how product development copes with different environmental conditions and selects certain strategic types. The findings of this study shed light on the importance of product development strategic flexibility. Since the importance of exploitation and/or exploration is different under different environmental conditions, it is important for product development to understand which knowledge strategies are most appropriated for each environmental conditions and to allow strategic flexibility enough to leverage knowledge in product development. Combinations of exploration and exploitation occur then in alignment with combinations of environmental factors to generate a powerful mechanism for competitive advantage. In conclusion, given that product development determines firm’s profits, growth, market share, and other key metrics, the knowledge strategy cannot be formulated in isolation of factors that characterize the environmental context.

Although this study has provided several new insights, it has several limitations. First, the scope of this study was limited to firms located in Madrid area. In addition, sample size was not large. Broadening the study to other geographic areas may lead to conceptual refinement and insight. Second, this study has tried to define their constructs as precisely as possible by drawing on relevant literature and through a careful process of item generation and refinement. Evidently, this measurement effort represents an advance for research but, nonetheless, the items are far for being perfect as long as they measure facts that are neither fully nor easily measurable. Third, this article opted to study product development function given its prominence in competitiveness and knowledge management literature. Future studies needs to examine other functions important to operation management (e.g., supply chain). Fifth, all data were collected from the same respondent using the same perceptual measurement technique. Although the presence of common method was tested and the results showed that common method bias should not be a problem, multiple respondents should be considered in future research on to rule out potential drawbacks. Finally, it is also important to note that this work is only a preliminary step towards a better understanding of the effects of two environmental dimensions on the knowledge strategy choice in product development and, on the basis of previous limitations, it naturally points out avenues for future research.

REFERENCES

Amit, R. and Schoemaker, P.J. (1993). Strategic Assets and organizational Rent. *Strategic Management Journal*, 14: 33-45

Ansoff, H.I. (1979). *Strategic Management*. London: The McMillan Press Ltd.

Astley, W.G. and Ban de Ven, A.H. (1983). "Central Perspectives and Debates in Organization Theory". *Administration Science Quarterly*, 28 (2),245-273.

Auh, S. and Menguc, S. (2005), "A Test of Strategic Orientation Formation vs. Strategic Orientation Implementation: The Influence of TMT Functional Diversity and Inter-functional Coordination," *Journal of Marketing Theory and Practice,* 13 (2): 4-19.

Benner, M.J. and Tushman, M.L. (2003). "Exploitation, Exploration and Process Management: The Productivity Dilemma Revisited". *Academy of Management Review*, 28 (2): 238-256.

Berdrow, I. and Lane, H. (2003). "International Joint Ventures: Creating Value Through Successful Knowledge Management". *Journal of World Business*, 38:15-30

Bierley, P. y Chakrabarti, A. (1996): "Generic Knowledge Strategies in the U.S. Pharmaceutical Industry". *Strategic Management Journal*, 17 (winter special issue): 123-135.

Chapman, R. and Hyland, P. (2004). "Complexity and Learning Behaviours in Product Innovation". *Technovation*, 24: 553-561.

Child, J. (1972). "Organizational Structure, Environment and Performance: The Role of Strategic Choice". *Sociology*, 6 (1):1-22.

Child, J. (1997). "Strategic Choice in the Analysis of Action, Structure, Organizations and Environment : Retrospect and Prospect". *Organizations Studies*, 18 (1): 43-76.

Clark, K.B. and Fujimoto, T. (1991). *Product Development Peformance*. Boston: Harvard Business School Press.

Clark, K.B. and Wheelwright, S.C. (1995). *Leading Product Development*. The free press, New York.

Crossan, M.M., Lane, H.W. and White, R.E. (1999). 'An Organizational Learning Framework: from Intuition to Institution'. *Academy of Management Review*, 24 (3): 522-537.

Cui, A. S.; Griffith, D.A. and Cavusgil, S. T. (2005). "The Influence of Competitive Intensity and Market Dynamism on Knowledge Management Capabilities of Multinational Corporation Subsidiaries". *Journal of International Marketing*, 13 (3): 32-53.

Dess, R. and Beard, D.W. (1984). "Dimensions of Organizational Task Environments". *Administrative Science Quarterly*, 29: 52-73.

Duncan, R.B. (1972). "Characteristics of Organizational Environments and Perceived Environments Uncertainty". *Administrative Science Quarterly*, 17: 313-327.

Eisenhardt, K. M. and Martin, J.K. (2000). "Dynamic Capabilities: What Are They?". *Strategic Management Journal*, 21: 1105-1121.

Floyd, S.W. and Lane, P.J. (2000). "Strategizing throughout the Organization: Managing Role Conflict in Strategic Renewal". *Academy of Management Review,* 25: 154-177

Fuentes-Fuentes, M.M., Albacete-Sáez, C.A. and Lloréis-Montes, F.J. (2004). “The Impact of Environmental Characteristics on TQM Principles and Organizational Performance”. *Omega*, 32: 425-442.

Ghemawat, P. and Costa, J.E. (1993). “The Organizational Tension Between Static and Dynamic Efficiency”. *Strategic Management Journal*, 14: 59-73.

Grewal, R. and Tansuhaj, P. (2001). “Building Organizational Capabilities for managing Economics Crisis: The Role of Market Orientation and Strategic Flexibility”. *Journal of Marketing*, 65 (April),67-80.

Gröge, C. and Claycomb, C. and Germain, R. (2003). “Does Knowledge Mediate the Effect of Context on Performance? Some Initial Evidence”. *Decision Science*, 34 (3): 541-568.

Gupta, A.K. and Wilemon, D.L. (1990). “Accelerating the Development of Technology-Based New Products”. *California Management Review*, 32 (2), 24-44.

Gupta, A.K., Smith, K.G. and Shalley, C.E. (2006). “The Interplay Between Exploration and Exploitation”. *Academy of Management Journal*, 49 (4): 693-706

Hart, S.L. (1995). “A Natural-Resources-Based View of the Firm”. *Academy of Management Review,* 20:874-907.

He, Z. and Wong, P. (2004). “Exploration vs. Exploitation: An Empirical Test of the Ambidexterity Hypothesis”. *Organization Science*, 15 (4): 481- 494.

Henderson, R. and Cockburn; I. (1994). “Measuring Competence: Exploring Firm Effects in Pharmaceutical Research”. *Strategic Management Journal*,15: 63-84.

Hitt, M., Hoskisson, R. and Nixon, R. 1993. “A Mid-Range Theory of Interfuncional Integration, its Antecedents and Outcomes”. *Journal of Engineering and Technology Management*,. 10: 161-185.

Hitt, M.A., Ireland, R.D. and Lee, H. (2000). “Technological learning, Knowledge Management , Firm Grow, and Performance: An Introductory Essay”. *Journal of Engineering and Technology Management*, 17 (3/4):231-246.

Iansity, M. (1995). “Shooting the rapids: managing product development in turbulent environments”. *California Management Review*, 38 (1), 37-58.

Jansen J., Van Den Bosch, F. and Volberda, H.W. (2006). “Exploratory Innovation, Exploitative Innovation, and Performance: Effects of Organizational Antecedents and Environmental Moderators”. *Decision Science* (Accepted for Publication).

Jap, S. D. (1999). “Pie-Expansion Efforts: Collaboration Processes in Buyer-Seller Relationship”. *Journal of Marketing Research*, 36 (November): 461-475.

Jaworski, B. j. and Kholi, A.K. (1993). “Market Orientation: Antecedents and Consequences”. *Journal of Marketing*, 57 (Julio):53-70.

Katila, R. and Ahuja, G. (2002). “Something Old, Something New: A Longitudinal Study of search Behaviour and New Product Introduction”. *Academy of Management Journal*, 45 (6): 1183-1194.

Koufteros, X and Vonderemse, M. and Jayaram, J. (2005). “Internal and External Integration for Product Development: The Contingency Effects of Uncertainty, Equivocality and Platform Strategy”. *Decision Science*, 36, (1): 97-133.

Lawrence, P.R. and Lorsch, J.W. (1967). *Organization and Environment*. Boston, Ma: Harvard Business School Press.

Lee, H. and Choi, B. (2003). “Knowledge Management Enablers, Processes, and Organizational Performance: An Integrative View and Empirical Examination”. *Journal of Management Information Systems*, 20 (1): 179-228.

Leonard Barton, D. (1992). “Core Capabilities and Core Rigidities: A Paradox in Managing New Product Development”. *Strategic Management Journal*, 13 (8): 111-125.

Levinthal, D.A. and March, J.G. (1993). “The Myopia of Learning”. *Strategic Management Journal*, 14: 95-112.

Luo, Y. and Park, S.H. (2001). “Strategic Alignment and Performance of Market-Seeking MNCs in China”. *Strategic Management Journal*, 22 (2):141-155.

Mallic, D.M. and Schroeder, R.G. (2005). “An Integrated Framework for Measuring Product Development Performance in High Technology Industries”. *Production and Operations Management*; 4, (2): 142-158.

March, J.G. (1991). “Exploration and Exploitation in Organizational Learning”. *Organization Science*, 2 (1), February: 71-87.

McDermott, R. (1999). “Why Information Technology Inspired but Cannot Deliver Knowledge Management”. *California Management Review*, 41(4): 103-117.

Miles, R. and Snow, C. (1978). *Organizational Strategy, Structure and Process*. McGraw-Hill:New York.

Miller, D. (1987). “The Structural and Environmental Correlates of Business Strategy”. *Strategy Management Journal*, 8: 55-76.

Mohrman, S.A. and Finegold, D. and Mohrman, A.M (2003): “An Empirical Model of the Organization Knowledge System in New Product Development Firms”. *Journal of Engineering and Technology Management*, 20: 7-38.

Nonaka, I. Toyama, R. and Nagata, A. 2000. “A Firm as a Knowledge-Creating Entity: A New Perspective on the Theory of the Firm”. *Industrial and Corporate Change*. 9 (1): 1-20.

Pisano, G.P. (1994). “Knowledge, Integration, and locus of Learning: An Emprirical Analysis of Process Development”. *Strategic Management Journal*, 15 (Winter):85-100.

Rothaermel, R.T. and Deeds, D.L. (2004). “Exploration and Exploitation Alliances in Biotechnology: A System of new Product Development”. *Strategic Management Journal,* 25: 201-221.

Smart, C. and Vertinsky, I. (1984). “Strategy and the Environment: An Study to corporate Responses to Crisis”. *Strategic Management Journal*, 5: 199-213.

Sorensen, J.B. and Stuart, T.E. (2000). “Aging, Obsolescence and Organizational Innovation”. *Administrative Science Quarterly*, 45: 81-113.

Teece, D. J.; Pisano, G. and Shuen, A. (1997). Dynamic Capabilities and Strategic Management”. *Strategic Management Journal*, 18 (7): 509-533.

Thompson, J.D. (1967). *Organization in Action*. McGraw-Hill: New York.

Tushman, Michael, and C. O'Reilly. (1996). “Ambidextrous Organizations: Managing Evolutionary and Revolutionary Change”. *California Management Review* 38 (4): 8-30.

Venkatraman, N. (1989). “The concept of fit in Strategy Research: Toward Verbal and Statistical Correspondence”. *Academy of Management Review*, 14 (3): 423-444.

Venkatraman, N. and Camillus, , J.C. (1984). "Exploring the Concept of 'Fit in Strategy Management". *Academy of Management Review*, 9 (3):513-525.

Vera, D. and Crossan, M. (2003). 'Organizational Learning and Knowledge Management: Toward an Integrative Framework'. In M. Easterby-Smith and M. Lyles (eds.) (2003): *Handbook of Organizational Learning and Knowledge Management*. Oxford: Blackwell: 123-141.

Zack, M.H. (1999). "Developing a Knowledge strategy". *California Management Review,* 41 (3): 125- 145.

Zahra, S.A. (1996). "Technology Strategy and Financial Performance: Examining the Moderating Role of the Firm's Competitive Environment". *Journal of Business Venturing*, 11:189-219.

Zahra, S.A. and Bogner, W.C. (1999). "Technology Strategy and Software New Venture's Performance: Exploring Effect of the Competitive Environment". *Journal of Business Venturing*, 15:135-173.

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