



# The influence of manufacturing flexibility on the interplay between exploration and exploitation: The effects of organizational learning and the environment

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THE INFLUENCE OF MANUFACTURING FLEXIBILITY ON THE INTERPLAY  
BETWEEN EXPLORATION AND EXPLOITATION: THE EFFECTS OF  
ORGANIZATIONAL LEARNING AND THE ENVIRONMENT

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# **The influence of manufacturing flexibility on the interplay between exploration and exploitation: The effects of organizational learning and the environment**

## **Abstract**

This paper analyzes whether the firm can combine exploration and exploitation and seeks to determine whether implementing manufacturing flexibility will facilitate the development of either of these two terms or both simultaneously. This relationship was measured in 231 Spanish production firms. The results obtained show that: (1) firms develop exploration of new knowledge at the same time as they exploit their abilities; (2) manufacturing flexibility encourages the development of both exploration and exploitation; (3) this relationship is even more significant if we take into account dynamism of the environment and organizational learning.

Key words: manufacturing flexibility, exploration, exploitation.

## **1. Introduction**

Many new product development (NPD) companies today operate in uncertain and dynamic competitive environments (Kettunen, 2009). The changing nature of the environment, internationalization of markets, growing competitiveness and development of new technologies require managers to implement dynamic production systems (Das and Narasimham, 1999), in order to satisfy the customer's needs effectively and to achieve competitive advantage over competitors. As a result, manufacturing flexibility becomes a competitive key for all firms and their production systems (Wang *et al.*, 2006). Greater manufacturing flexibility, along with a competitive strategy appropriate to the sector, will enable adaptation to changes in the environment, or even the ability to anticipate changes that may arise, giving the firm a competitive advantage over its competitors (Beach *et al.*, 2000).

In order to achieve competitive advantage, organization managers seek to develop the new capacities and competences needed to adapt to variations in their environment, and thus obtain better margins than other

firms in the sector. There are two ways for firms to gain such knowledge: capturing information from the environment surrounding them and encouraging development of their own abilities, whether through interaction among their employees or through interaction with the hypercompetitive environment (Jansen *et al.*, 2006). We thus seek to analyze how the abilities of manufacturing flexibility, exploration, exploitation and organizational learning taken together enable the firm to respond to the environment and to obtain competitive advantages.

Recent changes in the environment present us the importance of this study. Such changes have made manufacturing flexibility one of the main aspects for firms to consider when making decisions about how to compete with other organizations. Although some literature on manufacturing flexibility does exist, there remain gaps to be filled. Our study is based on a theoretical review of the literature as well as previous literature reviews such as those conducted by Sethi and Sethi (1990) and Beach *et al.* (2000). We attempt to resolve contradictions in the literature and to develop the theoretical arguments supporting the relationship between manufacturing flexibility and the terms exploration and exploitation. Based on these theoretical foundations, we attempt to make an empirical contribution by proposing a model that considers how the implementation of manufacturing flexibility influences exploration of new knowledge or exploitation of the firm's abilities.

The scientific interest of this research exists, firstly, in the need to accept that production firm flexibility is a new current of knowledge in strategic management, one that can give the organization competitive advantages and facilitate the organization's process of change. Secondly, in the importance of understand the different behaviour that organizations manifest when developing their abilities.

This study has two goals. First, we seek to demonstrate whether exploration and exploitation can be developed simultaneously in the same firm (Debenham and Wilkinson, 2006; Li *et al.*, 2008) or whether they are incompatible due to the scarcity of resources, as March (1991) proposes. Second, we analyze how dynamism of the environment and organizational

learning moderate the relationship between manufacturing flexibility and strategic behaviour.

The rest of this paper is structured as follows: Sections 2 and 3 explore the background of and related work on exploration, exploitation and manufacturing flexibility, in order to help us to establish definitions of both concepts used in this research. Next, in Section 4, we suggest a series of hypotheses in a global model. Section 5 justifies the methodology and sample, including the design of the research instrument, the data collection procedures and the process of construct validation. Section 6 presents the results obtained. Finally, in Section 7, we analyse the main contribution of our research.

## 2. The balance between exploration and exploitation

The terms exploration and exploitation have evolved greatly since the publication of the study by March (1991). They have come to dominate the literature related to technological innovation in the organization, to the design of the organization, and its adaptation to the environment (both internal and external), to organizational learning and to the search for competitive advantage (Siggelkow and Levinthal, 2003; Taylor and Greve 2006). Competing in a dynamic market, firms today must perform different tasks, explore new possibilities for adapting to future changes in the environment, and exploit the abilities they have already developed in order to meet the current demands on the firm (Lavie and Rosenkopf, 2006).

March (1991) defined the term exploration as "search, variation, risk taking, experimentation, play, flexibility, discovery, innovation" and exploitation as "refinement, choice, production, efficiency, selection, implementation and execution", making an initial distinction between the two terms.

Both concepts have completely different objectives. While the main goal of exploration is achieving flexibility and developing new knowledge and new ways of solving the problems that arise in the firm, exploitation takes shorter term and more specific perspective (March, 1996).

Exploration is linked to and developed through different activities that increase organizational processes, activities such as complex searches, deep

research, greater risks for the firm and disruptions of bureaucratic tasks with many rules (Levinthal and March, 1993). Exploratory behaviours are those that seek to win the technological race in new niches and achieve competitive advantages in order to develop new products and technologies (Beckman, 2006).

In contrast, exploitation seeks to increase efficiency, reduce periods without sales, and increase the reliability or precision of all activities. It is performed through activities that seek to reduce changes in the organization's processes, or to establish standardized processes (March, 1996).

As these concepts evolve over the years, we see different points of view that relate these concepts to many topics of interest in the literature on the firm and its environment (Gupta *et al.*, 2006). Among these, we must mention the relation to *organizational learning*. If we relate the terms to the firm's search for knowledge, we find exploitation defined as the firm's learning via search for information, experimental refinement, choice, and reuse of existing routines; whereas exploration is defined as acquiring knowledge through changes in established firm processes, planned experiments, or different kinds of tests (Baum *et al.*, 2000).

From the study by March (1991), exploration and exploitation refer to two ways of learning of the company. But theory has evolved greatly over the years, and we can find different points of view that enable us to consider these two terms not only as two ways of learning for the firm (Li *et al.*, 2008). In fact, Calantone *et al.* (2007) believe that the two terms should be treated as basic concepts in defining entrepreneurial strategy.

In developing these terms, the literature makes continual reference to whether exploration and exploitation are two contrary and mutually exclusive terms or whether they are extremes on a *continuum* on which each firm should choose where it wishes to be situated, while developing both terms together.

March (1991), for example, argues that, despite exploration and exploitation are fundamental for the firm in the long term, they are basically incompatible to perform efficiently, due to the scarcity of resources. They will only cause an increase in costs and poor use of production time. This means that a larger quantity of resources for research (exploration) means

a smaller quantity of resources for the development of the capacities belonging to the organization's personnel (exploitation) and viceversa.

In contrast, other authors believe that firms should efficiently combine exploitation of ideas already developed with exploration of new needs with the intention of both satisfying customers' daily needs and anticipating changes in demand (Danneels, 2004; Boer and Laugen, 2008).

The literature thus presents the following question: "Is the interaction of the two terms possible?" (Hamel, 2006). This situation presents two possibilities: The first is the binary relation of the two concepts and the second is the possibility of dual organizations developing the concepts of exploration and exploitation in a perpendicular or synergic way, respectively. Many authors see the answer in ambidextrous organizations (Christensen, 1998; Benner and Tushman, 2002), which show the simultaneity of the two behaviours within one firm.

There are also authors who consider the possibility of a balance between exploration and exploitation (Burgelman, 2002) or cycles of time divided between long periods of exploitation of abilities and short periods of exploration of new knowledge (Boer and Laugen, 2008). Miller *et al.* (2006) in fact underscores the possibility that duality and specialization may exist in the same organization. That is, while the firm is developing duality in some specific departments, it is developing specialization successfully in one or the other.

### 3. Manufacturing flexibility

The term manufacturing flexibility is a complex, multidimensional concept that is difficult to define and that has been evolving over the years (Sethi and Sethi, 1990). It combines several factors, such as corporate culture, organizational structure, technology of processes, organizational design and/or information on the system (Beach *et al.*, 2000).

Throughout the literature, we find different definitions of the concept. Cox (1989) defines manufacturing flexibility as "the speed and facility with which manufacturing plants can respond to changes in market conditions." Sethi and Sethi (1990) consider manufacturing flexibility to be a set of elements that are designed as a whole and carefully related in order to



facilitate the adaptation of processes and equipment to all production tasks. A more comprehensive definition used generally by many authors is “the ability to change or react with the least time, cost, damage or performance” (Upton, 1994).

The term manufacturing flexibility is so important for authors that it has received attention from different perspectives. Beach *et al.* (2000) indicate that it can be used strategically in many different ways. They recommend that it must be one of the dimensions of a system's competitive strategy, along with price, quality and reliability.

If the company wants to solve customer’s desire, the organization must seek flexibility in the value chain (Zhang, 2001; Wang *et al.*, 2006). Flexibility in the value chain influences such areas as the development of products, manufacturing, and logistics, for example. It enables firms to introduce new products rapidly and to reduce manufacturing times and commercialization costs (Zhang, 2001).

There is one concept of manufacturing flexibility is generally accepted in the literature, it is its multidimensionality within the function of manufacturing. Researchers agree that it is a complex, multidimensional concept difficult to delimit (De Toni and Tonchia, 1998; Baykasoğlu, 2009), but they do not agree on the dimensions involved. The problem for organization managers is determining which dimension of manufacturing flexibility to develop in order to adapt to each kind of environment and its uncertainty (Van Hop and Ruengsak, 2005). With the hope of facilitating analysis of this problem, we have studied the most used dimensions, shown in the Appendix.

This study of the different dimensions of manufacturing flexibility has led us to choose six dimensions, which will enable us to analyze whether manufacturing flexibility influences exploration and/or exploitation. These dimensions are *routing flexibility*, *sequence*, *modification*, *material handling*, *machine* and *mix flexibility*. We have chosen these dimensions because they are the ones in the literature that articulate what can contribute the greatest significance (Zhang *et al.*, 2003).

#### 4. Model and hypotheses

Our model (Figure 1) presents two kinds of relationships in the firm. On the one hand, we attempt to confirm whether exploration and exploitation may be made compatible in a single production plant or organization (Li *et al.*, 2008). To achieve this, we will treat both concepts as *strategic behaviours* of the firm, by which we mean that they are the ways of acting that the organization seeks to develop, the way of learning and the basis for being able to develop new concepts (Levinthal and March, 1993).

On the other hand, we believe it is interesting to analyze whether the development of flexibility in production firms benefits the development of any of these strategic behaviours and whether dynamism of the environment and organizational learning moderate the relation between manufacturing flexibility and strategic behaviours. These relationships emerge from studies like those by Jansen *et al.* (2006), in which we find the importance of dynamism of the environment as a moderating variable in the relationship between both strategic behaviours and the organization's performance, and in studies like that of Dixon *et al.* (2007), which finds a close relation between learning and exploration and exploitation for the organization's workers.

Although our study does not focus exclusively on the firm's strategic behaviours but rather on the relation of manufacturing flexibility to these, we will begin by verifying the relation proposed in prior studies like those by Qian *et al.* (2007).

We thus present the following theoretical model (Figure 1), which will enable us to analyze different hypotheses:

#### Figure 1: Theoretical model

We wish to highlight the importance of strategic behaviour for the organizations' managers, since exploitation seeks to act rapidly and directly (March, 1991) and considers short-term results crucial, whereas exploration has long-term goals and occurs in firms that do not seek immediate results but instead propose projects that will take several years. As we know,

taking into account both the short and the long term are crucial tasks in the organization's strategy.

The continuous evolution of markets has changed the thinking of experts in this subject matter. During the 1990s, both behaviours were considered to be incompatible, primarily due to the scarcity of resources (March, 1991). However, over time researchers have developed the idea that it might be possible to combine these two strategic behaviours in the same firm, even in the same production plant.

Thus, most of the studies in this century refer to the facility or difficulty that firms have in implementing both concepts. These studies attempt to show whether one of these strategic behaviours depends on the other, or whether they should be treated as substitutable parts of organizational decisions (Gupta *et al.*, 2006; Debenham and Wilkinson, 2006; Li *et al.*, 2008).

Establishing a balance between exploration and exploitation is very complex for researchers because different results and even different models of implementation are obtained, depending on the place in the organization that they study. This possible point of balance has led some authors to present the idea of ambidextrous organizations, in which both concepts can be developed simultaneously (Christensen, 1998; Benner and Tushman, 2002). Other authors believe, however, that it may be useful to have a balance between exploration and exploitation, but one based on cycles of time divided between long periods of exploitation of abilities and short periods of exploration of new knowledge (Burgelman, 2002).

Taking all of this into account, we can propose the first of the hypotheses for our theoretical model:

**H1.** *Exploration and exploitation are compatible strategic behaviours in organizations.*

Exploration and exploitation are essentially strategic terms (March, 1991); they are options that those managing an organization should think about and carry out after an analysis of entrepreneurial possibilities. Debenham and Wilkinson (2006) indicate that the firm's strategic behaviours have a strong relation to the goals or specific strategy of the

organization. They emphasize the need to use one of the two behaviours to obtain the performance desired. We have thus found the first relationship between the firm's strategic behaviours and manufacturing flexibility, as it should form part of the entire organization's strategy, the strategy it wishes to establish in the competitive market.

Further, if we examine the definitions given by March (1991), we find exploration as "search, change, risk-taking, experimentation, play, flexibility, discovery and innovation." This definition stresses that one of the possibilities for strategic behaviour depends on the organization's flexibility. But exploration is not the only term for conceiving of the organization's flexibility. Baum *et al.* (2000) define exploitation as "learning in the firm through search, experimental refining, selection and reuse of existing routines in the firm," defining this reuse of routines as the firm's capacity to adapt its functioning to the needs of the moment, that is, to be flexible.

The main problem involves how to measure manufacturing flexibility. Like many other authors who analyze the concept, Sethi and Sethi (1990) refer to the possibility of measuring it by establishing a classification of the different dimensions of flexibility that can be developed in the organization (Koste and Malhotra, 2004; Wadhwa *et al.*, 2009). This means that they cannot establish a fixed measurement model, since each firm has its own characteristics and the dynamically evolving environment is developing new forms of action and new ways of measuring these movements (Chang *et al.*, 2006; Treville *et al.*, 2007). We can even find studies, like that by Anand and Ward (2004), in which the term is treated as a whole, using a set of items that measure the global character of the concept of manufacturing flexibility.

Exploration involves "finding new alternatives that improve what currently exists" (March, 1991), whereas the methods for applying exploitation in the firm appear to be "acting in the right way; adopting standard products; assuming a formal structure; defining and measuring performance, eliminating redundancies, creating routes, specializing...", (Levinthal and March, 1993). We can thus affirm that strategic behaviours seek new ways of adapting to the environment (Li *et al.*, 2008) and different ways to improve production in the organization. As we can see, one way a firm can adapt and improve the production process is by

searching for knowledge, whether through entrepreneurial innovations or through reorientation of its own abilities. That is, establishing new production routes in the firm—whether through the re-establishing some of the parts of the firm or through implementing a new process that enables it to change its production routing—will improve the firm’s strategic behaviour (Koste and Malhotra, 2004).

When we focus on manufacturing flexibility, we find references to the number of different tasks that a machine can perform (Barad and Hoang, 1996; Chen *et al.*, 1992), the cost that the firm incurs for changing to another machine due to periods of non-use (Gupta, 1993), and the cost of customizing machinery or explaining the different tasks to the workers (Petroni and Bevilacqua, 2002). If manufacturing flexibility seeks to reduce costs and waiting time, for example, strategic behaviours attempt to reduce these productions costs, whether in the short term through the exploitation of abilities, or in the long term through the exploration of new ideas and projects (Miller *et al.*, 2006).

Thus, following the suggestions of the most significant authors in the literature, we have chosen six dimensions of manufacturing flexibility and we will try to establish whether they can affect the firm’s strategic behaviour as a whole. These dimensions are modification flexibility, routing, sequence, material handling, machine and mix flexibility (Wahab, 2005; Ali and Wadhwa, 2009).

We thus propose the following global hypothesis:

**H2.** *Manufacturing Flexibility influences exploration and exploitation in the firm.*

Our model does not seek to determine only the relation between manufacturing flexibility and strategic behaviour. Rather, it shows whether the variables dynamism of environment and organizational learning moderate the relation between both of them.

We observe that the external environment of the firm as a contextual factor of the firm has been and continues to be an object of interest in the literature (Mintzberg, 1980; Nahm *et al.*, 2003). Having the right close relation between flexibility and dynamic of the environment is critical for

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2  
3 firms if they wish to achieve success (Liao and Hu, 2007). Anand and Ward  
4 (2004) show that a good fit between each kind of environment and the  
5 flexibility developed is associated with improvement in performance. The  
6 literature shows that the firm's production strategy will depend critically on  
7 the environment in which it operates (Hill, 2000). But studies like that by  
8 Eisenhardt and Schoonhoven (1990), in which we find organizational  
9 flexibility is the response to dynamism of the environment, explain why we  
10 consider that dynamism of the environment can be a variable moderating  
11 the relation between strategic behaviours.  
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20 Dynamism of the environment means that current products and services  
21 quickly become obsolete due to changes in technologies, change in  
22 customers' tastes, and the fluctuation of supply and demand of materials,  
23 leading to the development of new ones (Jansen *et al.*, 2005). To resolve  
24 this problem, firms should introduce innovations on the market, whether  
25 they are incremental or radical. In fact, Jansen *et al.* (2006) have already  
26 introduced dynamism of the environment as a moderating variable in the  
27 relation of strategic behaviours to entrepreneurial performance, enabling us  
28 to understand and extend the variable to our relation between  
29 manufacturing flexibility and the firm's strategic behaviour.  
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39 **H3.** *Dynamism of the environment moderates the relation between*  
40 *manufacturing flexibility and exploration and exploitation.*  
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43 **H3a.** *Dynamism of the environment moderates the relation between*  
44 *manufacturing flexibility and exploration in organizations.*  
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47 **H3b.** *Dynamism of the environment moderates the relation between*  
48 *manufacturing flexibility and exploitation in organizations.*  
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53 Organizations' absorption capacity determines their ability to learn, that  
54 is, "the ability to assimilate and apply new knowledge to adapt to new  
55 conditions" (Dixon *et al.*, 2007), whereas the concepts of exploration and  
56 exploitation that we consider are strategic options that the firm possesses to act in  
57 response to its competitors (Li et al., 2008). The concepts of exploratory and  
58 exploitative learning (March, 1991) have emerged as two premises of  
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organizational learning that enable the firm to adapt (Gupta *et al.*, 2006). Finally, organizations need to learn to adapt to their environment, such that learning constitutes the correct organizational response to existing uncertainty (Lei *et al.*, 1996).

García-Morales *et al.* (2007) believe that the fundamental role of learning mechanisms consists of modifying existing knowledge in order to adapt to the competitive environment. Within the process of regenerating organizational knowledge proposed by these authors, we can find that renovating organizational knowledge means combining the phases of *exploration* and *exploitation* of existing knowledge, which strengthens this relation.

According to Dixon, *et al.* (2007), exploratory learning facilitates strategic flexibility, as it enables development of new endogenous abilities, thereby encouraging development of sustainable competitive advantages. We thus believe that organizational learning is a variable moderating the relation between manufacturing flexibility and strategic behaviour in the firm.

**H4.** *Organizational learning in the firm moderates the relation between manufacturing flexibility and exploration and exploitation.*

**H4a.** *Organizational learning in the firm moderates the relation between manufacturing flexibility and exploration.*

**H4b.** *Organizational learning in the firm moderates the relation between manufacturing flexibility and exploitation.*

**5. Sample and methods**

**5.1. Sample**

To carry out the empirical study, we have used the SABI database to focus on firms in the Spanish production sector (without small companies). We obtained a population of 2000 firms, which is reduced through simple random sampling to 1850.



The information was obtained through a structured telephone questionnaire administered directly to the CEOs of the firms involved during June 2008. We obtained a total of 231 valid questionnaires, a global response rate of 12.46%. The sample error, taking an infinite population, is 6.1%, providing a confidence level of 95%. We compared the mean value of the size variables between all firms and those included in the sample and obtained similar values in both cases. We can thus affirm that firms that do not respond to the questionnaire do not introduce significant bias into the final results of the study and that there is no reason not to extrapolate from the results to the total population.

## 5.2. Measurement

To confirm that each group of indicators explains only one practice, we perform an exploratory factor analysis. From the exploratory factor analysis performed on each group of items, we see that each of the resulting indicators measures a single variable, enabling us to confirm the unidimensionality of the scales. We then performed a confirmatory factor analysis to analyze the significance of the factor loading to determine whether it is greater than 0.4 (Hair et al., 2004) and, finally, to determine whether the value of individual reliability ( $R^2$ ) is higher than 50%. In this case, we can see that all of the indicators fulfil the three conditions cited. Fulfilling these three requirements ensures the convergent validity of the indicators used.

Next, we examine the discriminant validity of the measurement scales. To do this, we compare the correlation value observed in the confirmatory factor analysis with the correlation value calculated for a perfect correlation. We can see that in no case does the correlation observed exceed the value calculated, thus ensuring discriminant validity.

### 5.2.1. Exploitation and exploration capacity

Our measures of exploration and exploitation capacity are based on the scale developed by Jansen, et al. (2006). To measure exploration, we used five items related to experimentation with ideas, technologies, strategies, and new knowledge. To measure exploitation, we used six items related to



ideas, technologies, strategies and existing knowledge. The Cronbach's alpha is 0.92, indicating the scale's reliability. To ensure unidimensionality, we checked that all items loaded on a single factor.

5.2.2. *Manufacturing flexibility*

To measure the flexibility variables, we reviewed the different studies that have developed scales to measure the dimensions of manufacturing flexibility. We have chosen six measurement scales from those proposed in the literature, the first five from Larso (2004), and the last from Koste and Malhotra (2004): modification flexibility, routing, sequence, material handling, machines and mix flexibility. To measure these dimensions, as well as the other variables, we asked the company CEOs to indicate on a Likert-type 1-7-point scale (1="totally disagree", 7="totally agree") their degree of agreement or disagreement with the items proposed.

The scale's internal consistency and reliability were studied. Factor analysis showed that the items loaded on a single factor, which provides proof of unidimensionality. The Cronbach's alpha values for internal consistency were modification flexibility (0.892), routing flexibility (0.832), sequence flexibility (0.739), material handling flexibility (0.863), machine flexibility (0.872) and mix flexibility (0.925).

5.2.3. *Organizational learning*

The capability of organizational learning has received much more theoretical attention than empirical. Dixon et al. (2007) defined it as "the ability to assimilate and apply new knowledge to adapt to new conditions". Additionally, previous measures have wide differences among their assumptions, procedures, and objectives. We chose the scale developed by Kale et al. (2000) due to the fact that there is a closer link with this research, that they reflected the different prior trends well and that the scale's validity was verified in detail. We used the first two items from this scale and added two additional items based on Edmondson's (1999) work to compose a multi-item scale of organizational learning. These items have been duly adapted to the present study. Its reliability was analyzed (0.912), as was the unidimensionality.

#### 5.2.4. Dynamism of the environment

There are different studies that synthesize the different dimensions of the environment (Aldrich, 1979; Sharfman and Dean, 1997). In these studies we find dimensions such as dynamism, complexity or munificence. We focus on dynamism, since it is the dimension that affects flexible environments directly (Sorensen and Stuart, 2000). We use the four items of the scale on dynamism of the environment proposed by Miller and Friesen (1983), which defines dynamism as the degree of instability of the factors that affect the environment of the firm. Unidimensionality was studied, as was the internal consistency (0.796).

## 6. Results

In order to test the hypotheses, we first analyze the contingency tables to determine the relation between the strategic behaviours, to establish whether both can occur in the firm. Second, we used hierarchical regression analysis to analyze the moderating effect of organizational learning and dynamism of the environment on the relation between manufacturing flexibility and the firm's strategies of exploration and exploitation. To confirm whether the moderating effects are significant, we first estimate the regression model, which includes dynamism of the environment and the firm's organizational learning as explanatory variables. We then introduce the dimensions of manufacturing flexibility. Finally, we introduce the terms of the interactions or moderating effects to estimate whether each inclusion causes a significant change in  $R^2$ .

The verification of Hypothesis 1 was performed using the contingency tables. The results of the  $X^2$  statistics are shown in Table 1. After relating each of the items, according to the recommendations of Hair *et al.* (2004), we can see that over 50% of the firms that believe the innovation of their products and services is high believe that the development of their intrinsic abilities is also high; that is, over 50% of the organizations that explore new knowledge also exploit their abilities. Through the study of the significance of  $X^2$  in each of the contingency tables, we confirm that we must reject the hypothesis that exploration and exploitation are independent, since in all of

the cases the value of  $p$  is less than 0.005. We can thus say that there is a relationship of dependence between exploration and exploitation. This enables us to confirm Hypothesis 1, which proposes the compatibility of the strategic behaviours in the framework of production firms.

**Table 1:  $X^2$  Statistic**

The three following hypotheses will be developed by studying a linear regression with moderating variables (George, 2003). We will perform the regression first on the dependent variable exploration (Table 2) and then on exploitation (Table 3). The descriptive analysis and the correlation are shown in the Appendix, which also provides the reliability of the different scales.

Hypothesis 2 suggests that production flexibility influences the firm's exploration and exploitation. In Table 2, we see that the change in  $R^2$  is significant, as there is an increase of 3% in the variance, with a significance level of 0.003, or 99%. Table 3 includes the effect of manufacturing flexibility on exploitation. We can see that the change in  $R^2$  is less, although still significant at 99%, with an increase of 1.2% in the variance. Through these results, we can confirm Hypothesis 2, which proposes the influence of the implementation of manufacturing flexibility on the development of exploration and/or exploitation.

The verification of this hypothesis strengthens the validity of Hypothesis 1, which treated the compatibility of strategic behaviour in the organization, as we can see that the implementation of manufacturing flexibility benefits the development of exploration and exploitation together, implying that these two behaviours can be developed simultaneously.

Table 2 in turn includes the moderating effects of dynamism of the environment and organizational learning on the exploration of new knowledge and abilities. When we introduce the moderating effects of learning and dynamism of the environment on the dimensions, we see that the data improve significantly, as adjusted  $R^2$  increases to 13.4% and the change as compared to the third model is 5.6%.

We should mention the importance that learning and dynamism of the environment possess in this relationship. In the three models, we find

significant data in the relation between dynamism of environment and the exploration of new knowledge and that favour as a moderating factor in the relation of routing and sequence flexibility with the exploration, -1.999 and 2.005, respectively (significant for a confidence level of 95%). This enables us to confirm some of our hypotheses, such as H3a and H4a.

## Table 2: Effect of MF on Exploration

In Table 3 we explain the relationships of the organizational learning and dynamism of the environment with exploitation and whether or not they affect as moderating variables the relationship between manufacturing flexibility and the exploitation of the firm's abilities.

We can see that the total increase in the  $R^2$  statistic is 5.9% from the initial model, in which we only introduced organizational learning and dynamism of the environment as explanatory variables, to the third model, in which we include these first two variables plus the dimensions of manufacturing flexibility and the moderating effects that the first two variables have on manufacturing flexibility.

Another significant data is that dynamism of the environment does not produce significant numbers, although the theory makes us expect that it would. In addition, we find significant results that show a moderating relation of dynamism to some of the dimensions of manufacturing flexibility and exploitation of workers' abilities, as in the case of manufacturing sequence and machine flexibility. Thus, the total effect (or regression coefficient) of machine flexibility on exploitation of abilities will be:  $0.017 + 0.148 \times D$  (according to Hair, *et al.*, 2004).

Among the nonsignificant results, we should mention the number of dimensions that have the opposite effect when we study the moderating effect of dynamism of the environment. We can see that modification, routing, material handling, and mix flexibility have a negative sign. This means that in dynamic environments, the development of these dimensions works against exploitation of the firm's abilities.

We can show the significance of organizational learning and its moderating effect on the relation of production process flexibility to

exploitation of new knowledge, confirming H4b, such that we can now verify the whole of H4.

**Table 3: Effect of MF on Exploitation**

**7. Discussion and conclusions**

*7.1. Discussion*

Theory shows us that in order to compete in the unstable environments of the twenty-first century, firms should both develop research in new knowledge and ideas and encourage their existing capacities. Our first hypothesis thus try to resolve the current debate in the literature concerning whether the two behaviours are compatible in the framework of a single firm.

The results of our study show that organizations that think they have a high level of innovation, whether in products or production methods, believe this success to be based on tasks such as the development of activities oriented to the search for new products, services, processes or markets, to the revision of these activities, and the firm’s adaptation to them.

The same firms believe profitable behaviours also include encouraging the development of each worker's abilities, the capacities that the firm can achieve by correct functioning, and achieving interaction between all of the firm’s internal parts.

Our results justify the proposals of Lavie and Rosenkopf, (2006) regarding the need for dual organizations or those of Birkinshaw and Gibson (2004) on ambidextrous organizations, as both theories advocate the development of both behaviours in the firm, that is, the development of exploration of new entrepreneurial knowledge and the exploitation of the firm’s common abilities.

With Hypothesis 2 we seek to determine whether manufacturing flexibility enables the development of exploration and exploitation in the firm. The first contribution we find in our analysis is that manufacturing flexibility encourages the development of both exploration and exploitation,

a fact that is understood by analyzing the goals of both behaviours. The main goal of exploration is "to find new alternatives that improve what exists" (March, 1991), taking a long-term perspective of the firm but without the urgent rush or need for performance (March, 1996). In contrast, among the variety of ways to conduct exploitation, we consider one of the main activities to be the search for new routes and the elimination of deficient tasks (Levinthal and March, 1993), identifying this as a short-term objective to obtain benefits for the organization.

Through the last two hypotheses, we have attempted to study whether the nature of the environment and organizational learning take part to block or to drive the implementation of manufacturing flexibility. This consideration comes from proposals found in the scientific literature, which explain that organizational learning and dynamism of the environment affect the implementation of manufacturing flexibility (Sorensen and Stuart, 2000; Nielsen, 2006).

Analysing the results, we can see that organizational learning influences both strategic behaviours positively and significantly. Baum *et al.* (2000) treat the concepts from this perspective, justifying the importance of exploration, through experiments planned by the firm for possible changes in processes, and of exploitation, through the refinement and reuse of routines. Further, Nielsen (2006) determined that the main knowledge management activities—such as the creation, integration and exploitation of the firm's knowledge—can generate flows that modify current knowledge of organizational resources and capacities. This enables adaptation to the conditions of the environment, which gives validity the relation we have found between learning and dynamism and entrepreneurial exploration and exploitation.

We can see in turn that the environment also affects the firm's strategic behaviour. Eisenhardt and Schoonhoven (1990) study the importance of the firm's structure and flexibility to adapt to the environment, understanding that the firm's characteristics will facilitate the different movements of information, the main source of a firm's nourishment (March, 1991). Within the dimensions of the environment that can be studied, we have seen that dynamism facilitates the exploration of new knowledge. This agrees with the results of Danneels (2002), who concludes that dynamic environments

enable greater flows of information between the different parts of the market, such that workers will have better sources of knowledge.

7.2. *Conclusions and implications for entrepreneurial management*

The conclusions obtained in this study should help organizations realize the imperative need to be flexible in markets in which fast and unexpected changes require adaptation and response capacity. To support these changes, firms need to develop a special internal ability to adapt to their customers' needs. This ability is known as manufacturing flexibility. We have also observed that organizations and their workers possess different ways of learning. We find that some firms seek knowledge outside themselves, investing in external research and development. Others give their managers and workers free rein to perfect their work methods using their own knowledge. And of course we find firms that develop both concepts and seek to improve by finding a balance between these two possibilities- exploration and exploitation of capacities.

The existence of flexibility in the firm's manufacturing and strategic behaviour has led us to propose two objectives. The first is to verify whether we can make the two behaviours compatible in the organization. The second is to contrast whether manufacturing flexibility benefits the development of these behaviours and whether the way in which the organization learns and the speed of change in the environment affect this relation. Hence, the main findings of this research can be outlined as follows:

We were able to establish through contrast that exploration and exploitation can be compatible in the same organization, as the firms that explore new external knowledge are those that exploit the abilities of their own workers to a greater extent.

As to the relationship to manufacturing flexibility, we can affirm that its implementation will enable the development of exploration and exploitation. If we analyze this relationship in greater depth, we see on the one hand that dynamism of the environment surrounding the firm will benefit the development of exploration, as there is more interaction with external agents. This means greater information flows through which to obtain



knowledge. On the other hand, stability of the environment and the organization's learning capacity will benefit the firm's efforts to exploit their workers' abilities.

In dynamic entrepreneurial environments with constant change, managers must be able to endow their organization with resources and capacities that enable the firm to adapt to changes in its customers' preferences and to exploit the firm's prior knowledge in order to satisfy demand. Thus, manufacturing flexibility is a basic variable to develop in all firms that have a transformation or production process. Those responsible for planning the manufacturing should structure their tasks in a way that the firm can adapt to changes in the environment.

Exploration is linked to and developed through different activities that increase the organizational processes and risks. In turn, the goal of exploitation is short term. From a practical point of view, analyzing the different objectives of exploration and exploitation, managers should keep in mind the advantages that they can achieve keeping production flexible in order to combine the two strategic behaviours and obtain the best performance possible. They obtain this performance through a balance between long and short term, that is, between exploration and exploitation. For this reason, our study should help to reinforce acceptance of the need to increase use of these activities in entrepreneurial environments.

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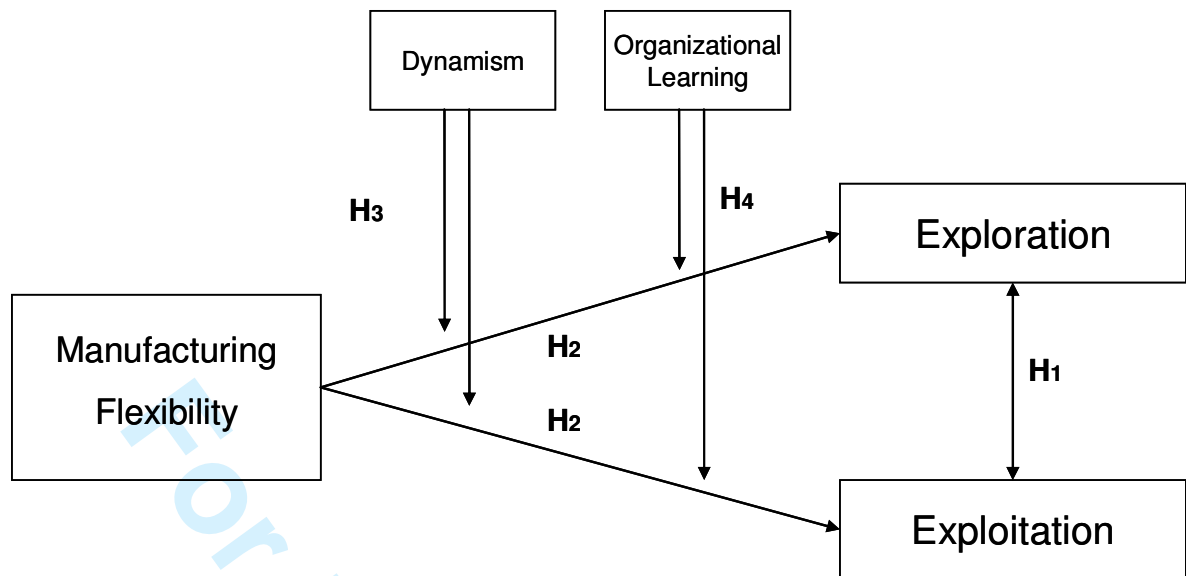


Figure 1: Theoretical model

Table 1:  $\chi^2$  statistic

	EXT 1		EXT 2		EXT 3		EXT 4		EXT 5		EXT 6	
EXR 1	82.212	0.000	96.875	0.000	68.962	0.001	78.636	0.000	93.260	0.000	69.120	0.001
EXR 2	100.783	0.000	131.242	0.000	114.791	0.000	78.871	0.000	107.514	0.000	68.269	0.001
EXR 3	84.974	0.000	99.547	0.000	108.819	0.000	74.140	0.000	73.653	0.000	65.523	0.002
EXR 4	83.736	0.000	90.843	0.000	92.093	0.000	107.587	0.000	102.157	0.000	80.465	0.000
EXR 5	80.596	0.000	101.460	0.000	100.292	0.000	104.091	0.000	111.884	0.000	72.486	0.000

Confidence interval 99%

Table 2: Effect of MF on Exploration

Variable	Model 1		Model 2		Model 3	
(Constant)	3.828***	(8.496)	2.829***	(5.227)	2.677***	(4.539)
DYN	0.165**	(2.331)	0.137**	(1.835)	0.170**	(2.200)
ORG LEAR	0.138**	(1.944)	0.087	(1.183)	0.171**	(2.051)
MOD			0.001	(0.009)	0.023	(0.298)
ROUT			0.150**	(1.950)	0.101	(1.279)
SEQ			0.040	(0.528)	-0.015	(-0.192)
MAT			0.124	(1.548)	0.129	(1.554)
MAC			-0.025	(-0.330)	-0.001	(-0.018)
MIX			0.044	(0.594)	-0.028	(-0.348)
MOD x OL					-0.065	(-0.716)
ROUT x OL					-0.105	(-1.145)
SEQ x OL					0.197**	(2.037)
MAT x OL					-0.114	(-1.148)
MAC x OL					-0.024	(-0.256)
MIX x OL					0.062	(0.656)
MOD x D					-0.054	(-0.655)
ROUT x D					-0.168**	(-1.999)
SEQ x D					0.176**	(2.005)
MAT x D					-0.044	(-0.480)
MAC x D					0.035	(0.432)
MIX x D					-0.069	(-0.853)
F	5.903***		3.101***		2.554***	
Adjusted R <sup>2</sup>	0.047		0.078		0.134	
Change in R <sup>2</sup>	0.047		0.031		0.056	

Dependent variable: Exploration

Shows regression coefficients and t-values.

\*p&lt;0.10 \*\*p&lt;0.05 \*\*\*p&lt;0.01



Table 3: Effect of MF on Exploitation

Variable	Model 1		Model 2		Model 3	
(Constant)	3.578***	(10.057)	2.985***	(6.893)	2.786***	(5.901)
ORG LEAR	0.331***	(4.842)	0.290***	(4.061)	0.311***	(3.820)
DYN	0.059	(0.863)	0.035	(0.487)	-0.010	(-0.127)
MOD			0.023	(0.302)	0.034	(0.437)
ROUT			0.153**	(2.052)	0.189**	(2.430)
SEQ			0.030	(0.410)	0.013	(0.166)
MAT			0.086	(1.100)	0.107	(1.320)
MAC			-0.014	(-0.189)	0.017	(0.226)
MIX			-0.041	(-0.569)	-0.072	(-0.914)
MOD x OL					0.117	(1.330)
ROUT x OL					0.119	(1.333)
SEQ x OL					-0.133	(-1.410)
MAT x OL					-0.061	(-0.629)
MAC x OL					0.054	(0.590)
MIX x OL					0.217**	(2.336)
MOD x D					-0.118	(-1.457)
ROUT x D					-0.094	(-1.146)
SEQ x D					0.216**	(2.517)
MAT x D					-0.088	(-0.980)
MAC x D					0.148*	(1.863)
MIX x D					-0.023	(-0.291)
F	13.697***		4.558***		3.075***	
Adjusted R <sup>2</sup>	0.113		0.125		0.172	
Change in R <sup>2</sup>	0.113		0.012		0.047	

Dependent variable: Exploitation

Shows regression coefficients and t-values.

\*p<0.10 \*\*p<0.05 p<0.01

## APPENDIX

## Appendix A: Dimensions of measurement scales for flexibility and manufacturing

Slack (1983)	Browne, <i>et al.</i> (1984)	Sethi and Sethi (1990)	Gupta and Somers (1992)	Hyun and Ahn (1992)	Gerwin (1993)	Upton (1994)	Koste (1999)	Braulia and Petroni (2000)	Vokurka and O'Leary-Kelly (2000)	Larso (2004)
Products	Machine	Machine	Machinery	Labour	Products	Machine	Labour	Machine	Labour	Machine
Volume	Sequence	Material Handling	Material Handling	Machine	Routing	Design	Machine	Mix	Machine	Material Handling
Mix	Process	Sequence	Sequence	Mix	Volume	Products	Material Handling	Products	Material Handling	Sequence
Delivery	Products	Process	Mix	Products	Mix	Routing	Sequence	Routing	Sequence	Products
Quality	Routing	Products	Routing	Routing	Materials	Volume	Products	Volume	Mix	Routing
	Volume	Routing	Volume	Volume		Expansion	Routing		Products	Volume
	Expansion	Volume	Program	Expansion		Program	Volume		Routing	Mix
	Production	Expansion	Market	Program		Mix	Expansion		Volume	Delivery
		Program					Mix		Expansion	
		Production							Program	
		Market							Production	
									Market	
									Delivery	

Appendix B. Correlations and descriptive statistics

Variable	Modification	Routing	Sequence	Material Handling	Machine	Mix	Exploitation	Exploration	Dynamism	Org. Learn.
Mean	3.8668	4.7062	3.6686	4.5018	4.9589	4.1880	5.0373	5.2957	4.3786	5.8274
SD	1.7940	1.4446	1.4031	1.2135	1.5683	1.7876	1.2716	1.0032	1.4934	1.1658
Modification		0.108	0.374	0.019	0.041	-0.004	0.115	0.096	0.351	0.174
Routing			0.215	0.383	0.305	0.196	0.240	0.239	0.122	0.181
Sequence				0.108	0.099	0.210	0.115	0.126	0.156	0.132
Material Handling					0.333	0.347	0.194	0.221	0.077	0.212
Machine						0.100	0.139	0.095	0.008	0.265
Mix							0.060	0.150	0.128	0.112
Exploitation								0.404	0.132	0.344
Exploration									0.196	0.174
Dynamism										0.222

Correlations greater than or equal to 0.16 are significant at  $p<0.05$ ; correlations greater than or equal to 0.23 are significant at  $p<0.01$

## Appendix C: Multicollinearity statistics

Effect of MF on Exploitation

Variable	Model 1		Model 2		Model 3	
	Tolerance	FIV	Tolerance	FIV	Tolerance	FIV
DYN	,951	1,052	,831	1,203	0.724	1.382
ORG LEAR	,951	1,052	,857	1,168	0.623	1.605
MOD			,754	1,327	0.702	1.424
ROUT			,783	1,276	0.688	1.453
SEQ			,795	1,258	0.722	1.386
MAT			,722	1,385	0.630	1.587
MAC			,813	1,230	0.734	1.362
MIX			,829	1,207	0.665	1.504
MOD x OL					0.533	1.877
ROUT x OL					0.518	1.932
SEQ x OL					0.463	2.160
MAT x OL					0.437	2.287
MAC x OL					0.492	2.031
MIX x OL					0.479	2.089
MOD x D					0.628	1.593
ROUT x D					0.616	1.622
SEQ x D					0.561	1.783
MAT x D					0.517	1.933
MAC x D					0.658	1.519
MIX x D					0.668	1.497

Effect of MF on Exploration

Variable	Model 1		Model 2		Model 3	
	Tolerance	FIV	Tolerance	FIV	Tolerance	FIV
DYN	0.951	1,052	0.831	1,203	0.724	1.382
ORG LEAR	0.951	1,052	0.857	1,168	0.623	1.605
MOD			0.754	1,327	0.702	1.424
ROUT			0.783	1,276	0.688	1.453
SEQ			0.795	1,258	0.722	1.386
MAT			0.722	1,385	0.630	1.587
MAC			0.813	1,230	0.734	1.362
MIX			0.829	1,207	0.665	1.504
MOD x OL					0.533	1.877
ROUT x OL					0.518	1.932
SEQ x OL					0.463	2.160
MAT x OL					0.437	2.287
MAC x OL					0.492	2.031
MIX x OL					0.479	2.089
MOD x D					0.628	1.593
ROUT x D					0.616	1.622
SEQ x D					0.561	1.783
MAT x D					0.517	1.933
MAC x D					0.658	1.519
MIX x D					0.668	1.497

Appendix D: Questionnaire.

PART I: MANUFACTURING FLEXIBILITY

Please indicate the degree you disagree or agree which each statemente regarding the flexibility of your manufacturing plant:

Strongly disagree	= 1	2	3	4	5	6	7=	Strongly agree
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Modification flexibility							
1. Existing products lines are frequently modified.	1	2	3	4	5	6	7
2. There are a large number of modified products produced each year.	1	2	3	4	5	6	7
3. The features of existing products are often modified.	1	2	3	4	5	6	7
4. Modified products can be made quickly.	1	2	3	4	5	6	7
Routing flexibility							
1. A route can process products/parts, which differ greatly to one another.	1	2	3	4	5	6	7
2. A route can process a variety of product/parts.	1	2	3	4	5	6	7
3. Route changes can be made quickly..	1	2	3	4	5	6	7
4. Alternate routes do not increase costs.	1	2	3	4	5	6	7
5. Alternate routes do not decrease quality of products/parts.	1	2	3	4	5	6	7
Sequence flexibility							
1. The ordering of several operations for a part/product type can be done in many different ways.	1	2	3	4	5	6	7
2. There are a large number of interchanges or substituions of operations.	1	2	3	4	5	6	7
3. There is a large variety of interchanges or substituions of operations.	1	2	3	4	5	6	7
4. Alternate sequencing plans do not increase costs.	1	2	3	4	5	6	7
Material handling flexibility							
1. The material handling system can transport materials of different sizes.	1	2	3	4	5	6	7
2. The materials handling system can transport a wide variety of materials.	1	2	3	4	5	6	7
3. Changing a material handling path is inexpensive.	1	2	3	4	5	6	7
4. Changing a material handling path is quick.	1	2	3	4	5	6	7
5. The choice of material handling path does not affect the material transfer time.	1	2	3	4	5	6	7
6. The choice of material handling path does not affect the efficiency of material transfer.	1	2	3	4	5	6	7
7. The choice of material handling path does not affect the material transfer cost (in €).	1	2	3	4	5	6	7
Machine flexibility							
1. Typical machines can use many different tools.	1	2	3	4	5	6	7
2. Machines can perform operations, which are not very similar to one another.	1	2	3	4	5	6	7
3. Machines can perform a high variety of operations.	1	2	3	4	5	6	7
4. Machines produce equal quality for all operations.	1	2	3	4	5	6	7
5. Machines are equally reliable for all operations.	1	2	3	4	5	6	7

Process flexibility							
1. The processing requirements for the products produced in the plant vary greatly from one product to another.	1	2	3	4	5	6	7
2. The material requirements for the products produced in the plant vary greatly from one product to another.	1	2	3	4	5	6	7
3. The product mix produced by the plant can be changed easily.	1	2	3	4	5	6	7
4. The manufacturing system can quickly changeover to a different product mix.	1	2	3	4	5	6	7
5. Productivity levels are not affected by changes in product mix.	1	2	3	4	5	6	7
6. The performance of the system is not affected by changes in product mix.	1	2	3	4	5	6	7

## PART II: EXPLORATION AND EXPLOITATION ACTIVITIES

Please indicate the degree you disagree or agree which the following steps the activities of your company last year:

Strongly disagree	= 1	2	3	4	5	6	7=	Strongly agree
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1. Our activities search for new possibilities with respect to products/services, processes or markets.	1	2	3	4	5	6	7
2. Our activities try to evaluate diverse options with respect to products/services, processes or markets.	1	2	3	4	5	6	7
3. Our activities are focused on strong renewal of products/services or processes.	1	2	3	4	5	6	7
4. Our activities require quite some adaptability of ourself.	1	2	3	4	5	6	7
5. Our activities require you to learn new skills or knowledge.	1	2	3	4	5	6	7
1. We develop activities of which a lot of experience has been accumulated by yourself.	1	2	3	4	5	6	7
2. We develop activities which serve existing (internal) customers with existing services/products.	1	2	3	4	5	6	7
3. We develop activities of which it is clear to us how to conduct them	1	2	3	4	5	6	7
4. We develop activities primarily focused on achieving short-term goals .	1	2	3	4	5	6	7
5. We develop activities which we can properly conduct by using our present knowledge..	1	2	3	4	5	6	7
6. We develop activities which clearly fit into existing company policy.	1	2	3	4	5	6	7

## PART III: ORGANIZATIONAL LEARNING

Please indicate the degree you disagree or agree which the following steps the activities of your company last year:

Strongly disagree	= 1	2	3	4	5	6	7=	Strongly agree
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1. The organization has learned or acquired much new and relevant knowledge over the last three years.	1	2	3	4	5	6	7
2. Organizational members have acquired critical capacities and skills over the last three years.	1	2	3	4	5	6	7
3. The organization's performance has been influenced by new learning it has acquired over the last three years.	1	2	3	4	5	6	7
4. The organization is a learning organization.	1	2	3	4	5	6	7

PART IV: ENVIRONMENT DYNAMISM

Please, indicate the rate of change of the environment of your company:

Slow	=1	2	3	4	5	6	7=	High
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Dynamism							
1. The rate at which your products and services become outdated is	1	2	3	4	5	6	7
2. The rate of innovation of new products and services is	1	2	3	4	5	6	7
3. The rate of innovation of new operating processes is	1	2	3	4	5	6	7
4. The tastes and preferences of customers in your industry are	1	2	3	4	5	6	7