MANAGING UNEVEN LEVELS OF KNOWLEDGE: A CHALLENGE FOR BUILDING-UP THE FIRST CORE CAPABILITIES IN 'LATECOMER' FIRMS[1]

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Abstract

This paper explores certain problems of knowledge management that latecomer firms have to consider when they are building-up their first core capabilities. This paper particularly analyses the characteristics of the firm's knowledge base and problems associated with an uneven depth of knowledge.

Two types of unevenness are analysed: (i) unevenness in the levels of knowledge between technological fields (see table 1), and (ii) uneven depths of knowledge between organizational units related to the same knowledge field (see table 2). Based on that, this paper argues that the type and level of unevenness hinders the integration of knowledge, the knowledge creation process and the building-up of initial core capabilities.

According to some scholars, the main constraint on the process of re-building of core capabilities for the most innovative firms is located at the level of the organization. In contrast, the main conclusion of this paper is that latecomer firms that are building up their first core capabilities still have problems related to lack of knowledge. This sets up specific issues for knowledge management in latecomer firms. A high degree of unevenness in knowledge depth between fields and organizational units is an important issue to be explicitly tackled in a knowledge management system by latecomer firms.

This research is based on a detailed case study about the role of knowledge management in the process of building-up technological capabilities in a Mexican group that competes in the international frontier and has subsidiaries in US and Latin America.

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[1] I wish to thank Vitro S.A. for being willing to open their doors to me. Any inaccuracies or errors in the text are, however, my own responsibility.

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1. INTRODUCTION

This paper discusses some problems faced by latecomer firms that are building-up their first core technological capabilities. This is a barely explored area between two different theoretical traditions based on firm-level empirical research. The first one is the tradition of research on technological capabilities accumulation in industrial latecomer firms, which has focused on studying the processes of accumulation of a minimum base of innovative technological capabilities. The second theoretical tradition refers to the studies about the process of building/re-building/renewing core technological capabilities in firms at the international frontier in advanced industrial countries.

However, there is no simple linear progression from the early stage of accumulation of the minimum levels of innovative capability to the management of knowledge as a strategic asset and the deployment of core capabilities. On the contrary, the transition process is complex and while the firms make that transition they have to build up deeper and broader stocks of knowledge and develop new types of knowledge management. Although recently an increasing amount of literature on the role and characteristics of knowledge management in the process of re-building of core capabilities has been developed, the challenges of knowledge management in firms that are in the process of building-up their first core capabilities require a more specific analysis.

The aim of this paper is to explore certain problems of knowledge management that latecomer firms have to consider when they are building-up their first core capabilities. Particularly this paper explores the characteristics of the firm's knowledge base and problems associated with an uneven depth of knowledge.[3]

The main results of this paper are the following ones: (i) there is a strong unevenness in the levels of knowledge between technological fields, and (ii) there are uneven depths of knowledge between organizational units related to the same knowledge field. Based on that, this paper argues that the type and level of unevenness hinders the integration of knowledge, the knowledge creation process and the building-up of initial core capabilities.

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[3] In this paper the concept of knowledge base is used in two ways: (i) to refer to the base of knowledge of the firm, and (ii) to refer to the specific knowledge in a technological field. In this last sense the firm has a set of knowledge bases.

According to some scholars, the main constraint of the process of re-building of core capabilities for the most innovative firms is located at the level of the organization. In contrast, the main conclusion of this presentation is that latecomer firms that are building up their first core capabilities still have problems related to lack of knowledge. This sets up specific issues for knowledge management in latecomer firms. A high degree of unevenness in knowledge depth between fields and organizational units is an important issue to be explicitly tackled in a knowledge management system by latecomer firms.

This research is based on a detailed case study about the role of knowledge management in the process of building-up of technological capabilities of a Mexican group that competes in the international frontier and has subsidiaries in US and Latin America. The case is 'Vitro Envases de Norteamérica', the glass containers division of Vitro S.A. The case study was developed in 1996 and 70 employees of the group were interviewed. This firm competes close to, but below, the technological frontier and is still in the process of building-up its first core technological capabilities.

This paper is organized in 5 sections. After this introduction, Section 2 presents a brief summary of the focus of attention of two theoretical bodies that tackle the issue of the building-up of technological capabilities: the literature on developing countries, and the literature on strategic management. Section 3 summarizes some issues discussed by the literature on knowledge management. Section 4 presents the case study and discusses the issue of unevenness by knowledge fields and by organizational units. Finally Section 5 contains the final reflections.

2. THEORETICAL BODIES ON THE BUILDING-UP OF TECHNOLOGICAL CAPABILITIES

The process of building-up technological capabilities has been a topic of attention in the literature on industrial firms in the last 20 years. On the one hand, the literature on strategic management, based on the most innovative firms in the advanced industrial countries, has focused on analysing the core technological capabilities. The concept of core technological capabilities refers to those abilities that competitively distinguish the firm and allow it to

create a sustained competitive advantage based on the technology in a changing context.[4] These core capabilities are based on the ability to create new knowledge and to integrate it with the existent base of knowledge. The process of knowledge creation is in the centre of attention, and problems about knowledge management play an important role in the explanation of the effectiveness of this process.

In this direction, several authors have addressed the role played by knowledge management in the building-up of core technological capabilities, or in other words to maintain, nurture and renew core technological capabilities already existent in firms that compete in the technological frontier.[5] However, this literature has paid little attention to explaining how these capabilities were initially accumulated, or in other words to the problem of the building-up of the first core capabilities.[6]

In contrast, the literature on the building-up of technological capabilities in industrial latecomer firms has focused on analysing the problem of the building-up of a minimum base of knowledge to survive in the market.[7] In this literature the technological capabilities are understood as the ability to use technological knowledge efficiently to assimilate, use, adapt and change existent technologies; and also as the ability to create new technologies and to develop new products and processes.[8]

The analysis of the processes of technological capability building-up in this literature has focused basically on studying the learning processes involved in the gradual building-up of a minimum base of technological knowledge to be able to carry out innovative activities.[9] This literature starts from the idea that firms are technologically immature, they learn over time, they accumulate knowledge and, on these bases, they are able to progressively carry out new activities and acquire new technological capabilities. The technological

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[4] See for instance Prahalad and Hamel (1990) and Leonard-Barton (1995).
[5] See for instance Leonard-Barton (1995) and Nonaka and Takeuchi (1995).
[6] See Teece and Pisano (1994). Henderson (1994) and Iansity and Clark (1994) suggest that the capability to integrate knowledge is a key capability for the building-up of initial core capabilities.
[7] A minimum base of knowledge to survive in the market is a stage of accumulation where the firm has built technological capabilities to reduce costs, improve the quality, and upgrade the equipment to achieve parity with competitors. It corresponds to have basic to intermediate innovative technological capabilities according to Bell and Pavitt's and Lall´s taxonomies. See Katz (1986), Lall (1992) and Bell and Pavitt (1995).
[8] Kim (1997).
[9] See for instance Katz (1986 and 1987), Lall (1987 and 1992), Bell and Pavitt (1995), Kim and Nelson (2000) and Dutrénit (2000a) for a critical review.

development is gradual, and it is possible to identify stages of the accumulation of technological capabilities. Based on the original taxonomy of Lall (1992), Bell and Pavitt (1995) identified four stages or levels of technological capabilities: one of routine production technological capabilities, and three levels of innovative technological capabilities –basic, intermediate and advanced.

When concentrating on the building-up of the minimum base of knowledge, this literature, particularly the one concerning the Latin American countries, has barely examined the last stage of accumulation–building-up of advanced innovative technological capabilities. Additionally it has paid little attention to the role played by the processes of knowledge management in the building-up of technological capabilities at any stage.

On the contrary, the research on the 'catching-up' processes of the new industrialized countries of the East Asia has paid attention to the building-up of advanced innovative technological capabilities by a set of firms that are successful in the international market. This literature has identified different stages of accumulation from the acquisition of foreign technology to the gradual building-up of innovative technological capabilities that allowed some firms to reach the technological frontier, and even develop technological leadership in certain areas.[10] The technological and commercial success of these firms was linked to a set of factors, amongst which stand out: the characteristics of the technological strategy followed by the firms, the processes of knowledge management inside the firms and the structure of the government's incentives. However, whilst focusing on the description of successful firms, this literature throws light on the problems faced by the firms in the process of building-up technological capabilities.

In general, little empirical evidence and theoretical reflection exist on the characteristics, problems and strategies of the building-up of technological capabilities of large firms that compete close to, but still below, the technological frontier, particularly in the Latin American context. The literature has paid inadequate attention to organizational and

[10] See for instance Amsden (1989), Hobday (1995 and 2000); Kim (1997); Kim and Nelson (2000). For instance, Hobday (1995) describes how a set of Taiwanese firms learned and moved along three stages: (i) manufacture of the original equipment, (ii) production of own designs, and (iii) creation of own brands.

managerial aspects of that stage of accumulation and has hardly examined the later stage as firms approach the international frontier and seek to build up core capabilities.

3. A KNOWLEDGE MANAGEMENT SYSTEM

Knowledge management refers to the set of decisions and systematic actions related to the firm's knowledge assets. From the perspective of academic research, Leonard-Barton (1995) has made an important contribution to the understanding of the role of knowledge in the creation of core technological capabilities, and the need for its management. In the analysis of the bases of differentiation of firms, Leonard-Barton (1992 and 1995) points out that a core technological capability is a system of interrelated and interdependent knowledge. This knowledge system is made up of four subsystems or interdependent dimensions: (i) the knowledge and skills of the employees, (ii) the physical technical system (e.g. the equipment, the software, etc.), (iii) the managerial systems (systems of education, rewards and incentives), and (iv) the values and norms. The first two dimensions are a dynamic knowledge reservoir, or a competence, and the last two are mechanisms for controlling or channelling knowledge. Due to the particular interrelation found among the four dimensions of knowledge, such systems are hard to imitate, and here can lay the base of the competitive advantage. Leonard-Barton (1995) states that knowledge management plays a key role on the operation of this knowledge system.

From the perspective of management consultancy, a set of works has focused on analysing the intrinsic characteristics of knowledge management. Knowledge management is perceived as a system that needs to balance out four dimensions: the knowledge content, the processes, the culture and the infrastructure.[11] The content of the knowledge management system refers to the idea that a base of strategic knowledge susceptible to being managed should exist. This knowledge should be clearly identified. The processes dimension is related to two levels: (i) the design of specific procedures and mechanisms to carry out the basic processes of knowledge management, such as to identify the needs, to create or acquire, to gather, to store and to share the knowledge; and (ii) the implementation of global processes of knowledge management, such as the conversion of

[11] Bock (1998), Probst (1998) and Chait (1998).

individual learning into organizational learning, the coordination of the learning processes within the firm, and the knowledge integration. The culture refers to the practices or the ways of doing things in the firms that affect the nature of the learning processes at the level of the individuals, groups and the organization as a whole. Finally, the infrastructure is concerned with the establishment of a structure for knowledge sharing, which should consider: material aspects - hardware, software, etc.– and human aspects–personnel to support the use of the system and the application of the knowledge management processes.

The management consultancy literature referred to focuses on defining the set of dimensions that need to be integrated to be able to create a knowledge management system, and they describe different aspects that may contribute to the functioning of such a system. On the contrary, Leonard-Barton (1995) focuses on identifying the subsystems of a core technological capability in order to understand the knowledge creation process. Beyond the difference in their focus of attention, the four dimensions of knowledge management show certain relations with the four subsystems of knowledge. The dimension of the content is related with the subsystem of knowledge and skills. The dimension of the processes, particularly the analysis of the basic processes of knowledge management, is partially related with the managerial systems, in the way in which these include procedures to carry out the basic processes of knowledge management and mechanisms to stimulate the setting up of the processes. The dimension of the culture is related with the subsystem of norms and values, and with those managerial systems linked with the reward of learning behaviours. The dimension of the infrastructure is partially related with the denominated physical technical systems, in the way that these include the computation and software equipments. The four dimensions of knowledge management include different interrelated aspects that when being integrated allow to create a knowledge management system that can contribute to the creation of knowledge and the building-up of core technological capabilities.

However, the academic literature on strategic management of technology has largely focused on analysing two dimensions of the knowledge management system: the processes and more recently the culture. In relation to the processes, this literature has devoted itself to analysing the set of global processes of knowledge management that are relevant to support the consolidation of the competitive advantages of firms and to build learning

organisations.[12] In the analysis of the global processes, a description of the basic processes, particularly creating, storing (based on codifying) and sharing of knowledge is included. The authors highlight the mechanisms and procedures established by successful firms to manage knowledge through these processes, and the routines or ways of doing things in successful firms. Some authors highlight the culture (values and beliefs) behind certain behaviours.[13]

These authors consider explicitly or implicitly that the main difficulty of firms to renew their core capabilities lies in the organization, not in the knowledge base. In this direction, Pavitt (1997) suggests that problems in the organization are crucial for the large innovative firms that are rebuilding their core capabilities. On the contrary, the dimension of the knowledge content - the existence of a relevant base of knowledge to be managed – is taken like a premise.

It is important to highlight that this literature analyses large innovative firms that have already concluded the stage of the building-up their minimum base of knowledge and have also built some core capabilities. However, the core capabilities have to be renewing in a changing environment, thus it is required to constantly create knowledge to renew the core capabilities. For this reason this literature have addressed the effect of the knowledge management on the processes of knowledge creation. The dimension of the infrastructure has also received little attention.

In the case of latecomers firms, the study of the characteristics of knowledge management and the specificities of their dimensions is still incipient. As opposed to the large innovative firms referred to above, latecomer firms that are in the process of building-up their initial core capabilities seem to have problems in the dimension of the knowledge content –in the knowledge base. As a result of uneven learning processes, with different directions, consistency and depth, the existing base of knowledge can show significant unevenness between technical functions, technological fields and organizational units, which can limit the functioning of a knowledge management system. This suggests

[12] Prahalad and Hamel (1990), Pavitt (1991), Teece and Pisano (1994), Leonard-Barton (1992 and 1995), Nonaka and Takeuchi (1995) and Garvin (1993).
[13] See for instance Leonard-Barton (1992 and 1995), Garvin (1993).

different challenges for the knowledge management in these firms. The following section analyses the case of a large Mexican firm that presents these characteristics and has observed difficulties to complete the process of building-up of initial core capabilities.[14]

4. THE CASE: UNEVEN LEVELS OF KNOWLEDGE

'Vitro Envases de Norteamérica' is the Glass Container division of Vitro S.A., an internationally competing and multinational Mexican group with subsidiaries in Latin America and the US, which made half of its sales abroad in 1996. It has its headquarters in Monterrey (Mexico) and came into being as a producer of bottles for the Cuauhtémoc brewery (now FEMSA). It was created in 1909 as a family owned firm with Mexican capital and is now a publicly held company listed on the Mexican Stock Market (1976) and on the New York Stock Exchange (1991). It became a multinational firm in the 1960s with acquisitions in Latin-America. In 1996 it was a 2.2 billions dollars/sales Mexican group in glass-related activities.

The group operated through six divisions in 1995: (i) Glass Containers, (ii) Flat Glass, (iii) Packaging (plastic, cans and machinery), (iv) Glassware, (v) Home Appliances, (vi) Chemicals, Fibres & Mining. Eighty four per cent of total sales were glass-related products. After the acquisition of Anchor Glass Container Corporation in the US, the glass containers operations in Mexico and the US generated 54% of Vitro's sales in 1995.

Vitro has traditionally used joint ventures as a core component of its strategy to develop new, fast-growing product lines, gain access to new markets, expand its distribution channels and acquire leading-edge technology. Vitro's major alliance in the glass containers business is with Owens-Illinois. The firm has always had a particular technological culture related to its own history. Its founders were strongly influenced by American entrepreneurs at the beginning of the 1900s. Since the earliest days they pushed the organisation to introduce state-of-the-art technology, which behaviour has continued until today. On average, Vitro spends 1.2% of the sales in technology-related activities (research,

[14] Dutrénit (2000a) analyses other characteristics of the processes and culture of the knowledge management system in this firm, such as the lack of routines to codify knowledge, the limited organizational learning and the difficulties for the knowledge integration.

development and engineering). Additionally it pays out around 0.6% of sales to its technology licensor in the case of the glass container business. In 1996 Vitro had 55 active patents and 19 applied for in the US in 1995 and also had 53 active and 25 applied for in Mexico. Thirty of these patents were in glass container related fields.

Vitro Envases -the Glass Containers Division- is the largest glass container manufacturer in Mexico. It has a long experience of technology transfer to Latin-American subsidiaries and other companies since 1964. With the purchase of Anchor Glass Container Corporation in 1989, it became the second largest player in the US glass container market and the third largest in the world.[15]

In 1996 Vitro Envases consisted of 8 plants in Mexico; 14 plants in the US; 1 plant in Bolivia, 2 associated firms with 3 plants in Guatemala, Costa Rica and Peru, 1 distributor company in the US and 2 other minor companies. It had around 8.000 employees in Mexico and 5.000 in the US. The Mexican plants were located strategically close to the largest towns, such as Mexico City, Monterrey, Guadalajara, Querétaro and Toluca. The Mexicali plant is located close to the US border.

The total sales in 1995 were around $1.6 billion, of which US$0.6 billion were generated by the glass container activities in Mexico and US$1.0 billion by the activities in the US. Sales in Latin America represent around 5% of the sales in Mexico. In 1996 the total sales of Vitro Envases were reduced to US$693 million, which included only the Mexican and Latin American operations. Exports have continually increased from 1981, following the reorientation of the industrial production towards the international market. By 1996, 70% of the production of the Mexican subsidiaries was sold in the domestic market, 25% in NAFTA markets and 5% in Latin America.

By 1970 Vitro Envases had built its minimum base of knowledge to be in the market. From the 1970s Vitro Envases began a transition process towards building core capabilities. During this process it built innovative technological capabilities in several technical-functions and created different bases of knowledge. It undertook activities in each

[15] This ranking changed in 1997 after the divestment of Anchor Glass Container Corporation.

technical-function that match with different stages of technological capability accumulation according to the taxonomies of Lall (1992) and Bell and Pavitt (1995). Many activities required to integrate knowledge bases located in different organisational units as analysed by Prahalad and Hamel (1990), Leonard-Barton (1995) and Iansiti and Clark (1994). Vitro Envases has also implemented several organisational arrangements to promote learning processes at individual and organisational levels as analysed by Nonaka and Takeuchi (1995). However, nearly 100 years after start-up Vitro Envases is still missing core capabilities. It is a firm that competes close to, but behind, the technological frontier. The firm has a limited organizational learning, co-ordination of learning and knowledge integration process, which characterises a limited knowledge management. Thus, it remains in a transition process from having the minimum base of technological knowledge toward the building-up of its initial core technological capabilities.

Difficulties in the company's technological strategy contribute to explain this result. The 1970s were a period of economic growth and the flourishing of the innovative technological capabilities for the firm. On one hand it made a great effort to find different sources of knowledge, stimulate more complex technological activities and implement new ways of doing things. This allowed to create some areas of specialization. At the same time, the firm re-defined its business strategy and proposed a market tactic aimed to increase exports and, particularly, help enter the American market. Such proposals required bringing up to date and improving the equipment technology, as well as increasing the operational efficiency.

In this context, the firm had different kind of technological demands, so it chose a single strategy incorporating two main components: (i) technological independence, aimed to strengthen the internal technological developments in certain areas in the long-term; (ii) fast follower of the technological leader, aimed to solve technical problems in the short-term. The technological strategy had to be unique, but with different articulated targets.

The technological independence strategy had the following characteristics:

1. The main event was the organization of the technological function in 1977, fruit of a process of knowledge specialization. An R&D unit at central-level was created, specialized in basic and applied research, and in development activities, oriented to

strategic projects; divisional centres of technology were established, oriented to minor improvements and adaptations and, thus, work jointly with the production function.

2. The creation of R&D capabilities.
3. The development of a set of patents in the 1980s.
4. The development of links with Mexican and American universities.
5. The creation of embryonic core capabilities in electronic control systems, glass composition, and investment projects management.

The strategy of the fast follower of the technological leader had the following characteristics:

1. In 1974, the main event was the signing of a technological agreement with one of the technological leaders.
2. The firm began exporting to the U.S. and had to solve some technical problems, improve the equipment technology and increase the quality and efficiency.
3. A gradual and slow incorporation of the leader's technology.
4. The creation of embryonic core technological capabilities in engineering to adapt the acquired technology and integrate the leader's technology with other operational technologies.[16]
5. A limited R&D in engineering, which was a field of knowledge provided by the technological leader. The embryonic technological capabilities in this area were based on applied work.

Two problems related with the technological strategy of the firm were found: (i) the strategy's duality, and (ii) the instability of the organizational support to each strategy.[17][18] As a result, the capabilities related to each strategy determined a different base of knowledge, relations of a different nature with suppliers, competitors, universities and consultancies, and a different kind of knowledge to be shared, codified and integrated.

[16] Embryonic core technological capabilities are those innovative technological capabilities that are still incipient; they are not used to distinguish the firm competitively, thus they have not been deployed to be core capabilities. They may include a deeper stock of knowledge accumulated more in some technical-functions, technical areas or knowledge fields than in others, and which can be the base on which to build core capabilities.

[17] El apoyo organizacional a cada estrategia fue inestable debido a la existencia de diferentes grupos de poder, una pugna entre criterios financieros vis a vis tecnológicos y presiones económicas, lo cual generó inconsistencia de los proyectos en marcha.

Moreover, the process of building-up of capabilities improved, but there were difficulties to complete the building-up of the first core capabilities.

As a result of this process, the knowledge accumulation process has been uneven. The accumulation was quicker in some technical-functions, knowledge fields and technical areas than in others. The existence of unevenness in the depth of knowledge is a fact of organisational life. However, the type, level and evolution of the unevenness reveal a weaknesses of the technological capabilities building process, in fact they have affected the scope of the knowledge management.

In the following sections two types of unevenness in the knowledge base of the firm are analysed, these are: (i) by technological knowledge fields, and (ii) by organizational units. The evaluation is carried out through the qualitative analysis of results of technological development projects and activities related with innovation. Thus the main point of attention is the level of knowledge for innovation.

4.1 Different levels of knowledge between technological fields

Firms need to combine different fields of technological knowledge (mechanical engineering, electronic, etc.) in order to develop their basic activities. According to different factors, such as the products, the industrial sector to which it belongs, the nature of the activities it develops (production, continuous improvement, research and development) and the technological strategy followed, the knowledge required in each technological field can have a different level of depth and degree of complexity. The knowledge that the firm possess in each technological field may come from different sources: internal (created) or external (acquired).

Three fields of technological knowledge have been particularly relevant for Vitro Envases: applied mechanical engineering, electronic control system and glass composition. The depth of knowledge in those technological fields has been uneven.

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[18] La evidencia empírica de estos aspectos está desarrollada ampliamente en Dutrénit (2000*a* y 2000*b*).

It is difficult to measure and compare levels of knowledge between different technological fields. For instance, patents can be a good measure of knowledge related to the electronic control system but not of the knowledge related to applied mechanical engineering or glass composition. These fields have lower propensities to patent because of the ease with which competitors can copy them. In other even more operative technical areas patents do not enter the equation. Hence, a qualitative assessment of the knowledge depth in those three fields was made.

The evaluation was based on two basic sources of information: (i) a questionnaire on the sources of knowledge, which was filled out by three managers of technology departments, where the internal I&D activities were assessed; and (ii) a number of interviews with project team members where the histories of development projects and innovation related activities were described in detail. This evaluation includes a variety of indicators of innovative performance that are ad-hoc for each technological field.

Three levels of knowledge were taken into account: (i) shallow, (ii) deep and (iii) very deep. Table 1 summarizes the evaluation of the knowledge depth of three technological fields relevant to the firm.

Table 1 illustrates the uneven depth of knowledge by technological fields in the organisation, from shallow knowledge in applied mechanical engineering to deep in glass composition and to very deep in electronic control systems. The evaluation was based on several considerations. With the strategy of technological independence, Vitro Envases carried out R&D activities for several years and was able to come close to the frontier of technological knowledge in electronic control systems and glass composition in the 1980s. The depth of knowledge was assessed as very deep in electronic control systems because of the firm having been granted a patent close to the first patent in the world and having the capability to apply this knowledge to other equipment. The depth of knowledge in glass composition was assessed as only deep because Vitro Envases achieved independence in this field and used its own formula from that time, but it did not nurture consistently this base of knowledge from that achievement.

Table 1. Different levels of knowledge by technological field: 1970-90s

Technological fields	Evidence of the level of knowledge	Evaluation
Applied mechanical engineering	• limited or no systematic R&D activities • several adaptations and improvements were carried out in the IS machine • there were still difficulties to master the principles of the machine mechanisms and to couple them with equipment technology	Shallow
Glass composition	• R&D activities for some years • the use of its own glass formula from the 1980s • the certification of the ISO-9001 in several plants, which reveals the use of good quality glass	Deep
Electronic control systems	• R&D activities for several years • a patent of an electronic control system in 1978, eight years after the first such patent in the world • other patents resulting from applying the knowledge in electronic to other equipment • the use of the Vitro electronic control system from 1990	Very deep

Source: Interviews in the firm.

However, in applied mechanical engineering the base of knowledge is only the basic level required to maintain the operation and upgrading of the equipment. Although the firm has carried out sporadic R&D activities (intense in some periods and almost absent in others) and has developed important practical knowledge along the years, a more formal base of knowledge is required to solve some of the practical problems that appear, such as the solution of technical problems in equipment to couple different technologies. Though the firm has made efforts to accumulate knowledge in mechanical engineering, those efforts have not been systematic over time. In certain periods, when the strategy of technological independence received more support, the firm accumulated knowledge in mechanical engineering and managed to design equipment, but in other, as a result of a follower strategy and a technical agreement with the supplier of equipment technology, the firm had little pressure to increase or maintain its innovative technological capabilities in mechanical design, or even to develop capabilities to describe its requirements or to negotiate the equipment. Since it is feasible, and even advisable, to acquire the knowledge

of certain technological fields from external sources, this process must be managed. But the technical agreement with the technology supplier limited the concern and systematic support from the firm's managers to develop and to systematize the knowledge in this technological field, which gave as a result shallow knowledge. In fact, the external and internal knowledge in this field was not managed consistently.

The uneven depth of knowledge between the three technological fields affected the evolution of the technological capability building process. For instance, the electronic control system was designed to control the glass forming process; the evolution in this knowledge field suggests that it could be an area of development of core capabilities in the firm.[19] To understand the mechanical sequence of the machine's mechanisms, knowledge in applied mechanical engineering is necessary. Therefore, a balance between the knowledge base in electronic control system and mechanical engineering is necessary to improve the operation of the electronic control system. The unevenness between the depth of knowledge in electronic control systems and mechanical engineering has affected the integration of knowledge and so the knowledge creation process in electronic control systems.

The difference between the depths of knowledge in the technological fields has affected several knowledge management processes, such as the knowledge integration, the coordination of the learning processes, and the process of knowledge creation in electronic control systems and other technological fields. The existence of different levels of knowledge in the technological fields has demanded challenges for those knowledge management processes that the most innovative firms do not confront, such as managing strong inequalities or imbalances of knowledge. Unfortunately this challenge was not approached directly by the firm.

4.2 Unevenness of knowledge between organizational units

Due to the processes of knowledge specialization at the firm, new organizational units have arisen, and specialized in certain technological knowledge fields and technological activities. Particularly in the 1970s the firm established an organization of the technological

[19] Dutrénit (2000a) analyses in detail the accumulation process in this technological knowledge field.

function. In 1977 Vitro-Tec (the central R&D unit) was created as a unit oriented to strategic projects, it dedicated 80% of its personnel's time to develop major innovations. Dirtec (the Technology Direction at divisional level) was established as a unit more guided to solving the plants' requirements, it dedicated 80% of its personnel's time to minor innovations and technical assistance. The plants had assigned the function of operation and undertaken continuous improvement. This organization of the technological function persisted up to 1989. From that date onwards Vitro-Tec was decentralized to the divisions and Dirtec assumed some of its functions.

The case of Vitro Envases shows that there is an uneven depth of knowledge between the organisational units related to the same technological field. Several authors from the strategic management literature asserted that, to be able to apply the existent knowledge and nurture the base of knowledge, firms are required to share some common knowledge between their organisational units.[20] In the case of Vitro Envases, even though both common and complementary knowledge between Vitro-Tec, Dirtec and the plants was required to assure the implementation, feedback and upgrading of the equipment, plants did not possess the basic knowledge required for that activity in all the technological fields. Based on the results of the development projects, Table 2 presents an assessment of the type of knowledge possessed by each unit and the extent to which plants had the required basic knowledge. Two levels of knowledge in the plants were considered: (i) insufficient, if the plants do not have the minimum base of knowledge required, thus if they lacked an adequate understanding of the technological fields, and (ii) sufficient, if the plants do have it. Table 2 summarises the evaluation of the depth of knowledge for the main technological knowledge fields used in the firm.

Table 2. Different levels of knowledge by organizational unit: 1970-90s

Technological fields	Vitro-Tec/Dirtec		Plants	
	Type of knowledge	**Evaluation of the level**	**Type of knowledge**	**Evaluation of the level**
Glass composition	Research, development and minor improvements	Deep	• the use of the glass formula to produce glass containers and carry out quality control • problems of lack of knowledge were not identified	Sufficient

[20] See for instance Iansiti and Clark (1994); Leonard-Barton (1995); Nonaka and Takeuchi (1995) and Pisano (1997).

Electronic control systems	Research, development and minor improvements	Very deep	• operation and maintenance of the electronic control system • the demand of changes generated by the plants was the result of their unfamiliarity with electronics and their lack of understanding of the operation of the electronic control system • the level knowledge among plants is uneven, while three plants have a basic knowledge, other plants are unable to solve some operational problems	Insufficient
Applied mechanical engineering	Only some developments and basically minor improvements	Shallow	• operation, maintenance and continuous improvements of the equipment • the plants are familiarized with the equipment and suggest changes • the plants lack knowledge in mechanical engineering and have difficulties to identify the problems generated by some improvements introduced to the global operation of the IS machine	Insufficient

Source: Interviews in the firm.

Table 2 illustrates that there was an asymmetrical depth of knowledge by the organisational units related to each knowledge field. Vitro-Tec and Dirtec, in different periods, were in charge of the strategic R&D activities and played a different role in the knowledge creation process to that played by the plants. However, the plants lacked the basic knowledge required to accurately undertake and implement projects give feedback to Vitro-Tec and contribute to the upgrading of the knowledge in electronic control systems and applied mechanical engineering. For instance, plants needed some basic knowledge in electronics to allow them to understand the functioning of the electronic control system; deal with its operation and obtain good performance; and be able to integrate their knowledge with Vitro-Tec and Dirtec and to suggest improvements. However, only few plants possessed this basic knowledge and even the more knowledgeable plants lacked an adequate understanding of the functioning. For this reason the assessment of the plants' depth of knowledge was insufficient.

Similarly, because plants were more knowledgeable about machine operation than applied mechanical engineering, they had difficulty in identifying the source of problems in the

line. Therefore, the assessment in applied mechanical engineering also shows an insufficient depth of knowledge at the plants. In contrast, in the case of glass composition no problems of lack of knowledge were identified during the fieldwork. This, alongside the production of good quality glass containers in all plants, suggests that in glass composition the plants had the necessary base of knowledge.

The evidence presented in Table 2 shows that in two of three technological fields the firm had an uneven depth of knowledge between the organizational units.

To sum up, the unevenness in the knowledge depth described above reveals that the firm had problems related to lack of knowledge in some technological fields and organisational units, and therefore imbalances between them. The imbalance of knowledge between the organisational units in electronic control systems and applied mechanical engineering affected the performance of the equipment, the effectiveness of the feedback to the units in charge of the R&D activities and therefore the knowledge creation process in those fields. This illustrates that even though the advantages of the knowledge specialisation in terms of the acceleration of the knowledge creation process, the unevenness between the organisational units makes it difficult the interaction between units, the flow of knowledge and therefore the knowledge integration and the knowledge creation process. The type and level of unevenness described above contributes to explain the problems in the knowledge content dimension, one of the weaknesses of the knowledge management system and one reason why the knowledge management was limited. It also provides insights to understand the difficulties to complete the building of the first core capabilities.

5. FINAL REFLECTIONS

1. Unevenness in the levels of knowledge between the technological fields and the organizational units reflects that the firm has problems of lack of knowledge in some fields and units. This is an imbalance in the base of knowledge. This suggests that the firm has problems in the content of the knowledge base. This arises two queries: Which levels of disparity between the knowledge bases are acceptable in the process of building-up of core capabilities? When do the disparities become a disequilibrium?

2. The problems in the knowledge content limited important processes associated with knowledge management, particularly the co-ordination of learning, the conversion of individual learning into organizational, the knowledge integration and the creation of knowledge. This determines that the knowledge management is limited and it hinders the process of building-up of initial core capabilities.
3. The literature about the most innovative firms focuses on two dimensions of the knowledge management system: the processes and the culture for strengthening the building-up of core capabilities. This focus seems to be limited in approaching the most important problems of 'latecomer' firms that are in the process of building-up their initial core capabilities. A knowledge management system in these firms should give greater importance to problems in the content of knowledge. The problem of the unevenness in the base of knowledge outlines challenges in terms of designing successful processes of knowledge management that are able to articulate unbalanced bases of knowledge. In this sense, the main problem in these firms does not fundamentally lay in the 'organization', but in a mixture of problems of the processes and content of knowledge. The case also presents other problems related to the processes of knowledge management and the culture. In particular difficulties were observed in designing appropriate mechanisms and procedures to the cultural characteristics of the firm,[21] and difficulties to change the way things are done inside the firm.[22]
4. Different kinds of problems associated with the building-up of initial core capabilities exist for large 'latecomer' firms. First, there is an intra-firm problem of how to change the organizational practices and manage the technological knowledge to contribute to the building-up of core capabilities, some of which aspects were analysed in this paper. Second, the strategies adopted by the firms are strongly affected by the macroeconomic stability, the competition conditions and the structure of incentives. Third, the process of core technological capability building-up of firms are affected by the characteristics of the National System of Innovation; the kind of articulations among the firms, universities and research centres, bridge institutions and government organisms; and the measure in which

[21] An analysis on the relationship between culture and technological behavior is found in Vera-Cruz (2000).
[22] A detailed analysis of the mechanisms is found in Dutrénit (2000a).

these agents play the role that corresponds them in the innovative activity.[23] This paper has focused on intra-firm processes, but the last two aspects require attention.

[23] For the characteristics of the Mexican National System of Innovation see Cimoli (ed.) (2000). In particular see Casalet (2000) for the role of the bridge institutions, Casas (2000) for the role of the universities, Gonsen (2000) and Dutrénit (2000b) for the processes of the building-up of technological capabilities of Mexican firms.

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