Globelics

Innovation capabilities accumulation using a lifecycle approach: The case of a Mexican Steel company

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Abstract

How are innovation capabilities created in a firm in an emerging economy, why does such a firm decide to start to innovate? These are two of the challenging questions that direct this study. A Mexican steel company, called "Steel Company", is the subject of study. This company started to operate with obsolete equipment, and thanks to a strong management commitment to innovation, it could develop its own processing technology becoming the world technological leader in its market. This study uses a single case study research design in order to start the academic discussion regarding both questions.

Capabilities life-cycles are identified, with a cluster of strategic capabilities evolving in a synergetic way, accumulating and diminishing innovation capabilities along the firm history. Strong context effects, shareholder and management support, and corporate strategy changes are among key factors that conducted this evolutionary process.

The need to consider spin outs from the firm when studying the dynamics of capabilities is identified as an interesting future research for regional development purposes, as innovation capabilities can be transferred crossing the boundaries of the firm.

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Introduction

How are innovation capabilities created in a firm in an emerging economy, why does such a firm decide to start to innovate? These are two of the challenging questions that direct this study. A Mexican steel company, called “Steel Company”, is the subject of study. This company started to operate with obsolete equipment, and with a strong management commitment to innovation, it could develop its own processing technology becoming the world leader in its market. This study uses a single case study research design in order to start the academic discussion regarding both questions.

Firms in emerging economies, in contrast to their competitors in developed countries, lack of necessary knowledge base to compete at the technological frontier (Dutrénit, 2000; Hobday et al, 2004); thus, they should start an accumulative process of capability development to catch-up their competitors in developed countries (Lall, 1992). In addition to this difficulty, external factors, such as government intervention, weak IPR, and macroeconomic cycles make it harder for these companies to develop a long-term strategy towards the creation of innovation abilities.

This paper draws on two approaches; the technological capabilities accumulation literature and the resource based view of the firm; and attempts to apply an integrative framework to the study of innovation capabilities accumulation processes in order to identify innovation activities drivers. This framework uses strategic capabilities, such as technological, marketing, market-linking, IT, and management capabilities (Desarbo et al, 2005), and includes the time dimension when studying innovation maturity stages using a lifecycle approach. As shown in Figure 02, and following Bell and Pavitt (1995), each capability increases its innovativeness level during its lifecycle, according to firm-contingent conditions.

This paper studies the evolution of innovation capabilities in “Steel Company” that has developed advanced innovation capabilities in some of its core areas.

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Theoretical Framework

There are two theoretical developments that attempt to explain the creation of innovation capabilities in firms in emerging economies. Lall (1992) and Bell and Pavitt (1995) developed the technological capabilities taxonomy, where they identified the accumulation of these capabilities through learning processes, from basic routines to advanced innovativeness levels. These levels are identified analyzing primary (investment and production) and supporting activities around technology development. This taxonomy has been extensively used in empirical studies to picture the level of Technological Capabilities achieved by firms in emerging economies (as Figueiredo, 2001; Dutrénit, 2000 and 2004) It has also received criticism because of its static characteristic (it is useful to identify current innovation position), but does not provide information about how the organization got to such a level of innovation maturity (Figuereido, 2001:25), and it is centered around technological innovations, not taking in account other kind of innovations (e.g. managerial, administrative, IT, or marketing innovations).

The other theoretical tradition studying this phenomenon is based on the Resource Based View (RBV) literature. The RBV considers a firm as a bundle of resources, competences, and capabilities, and states that its heterogeneity and competitive advantage are based on different combinations of these elements (Penrose, 1995; Teece, Pisano, and Shuen, 1997; Barney, 1991; Teece, Pissano, and Shuen, 1997; Prahalad and Hamel, 1990). The notion of firm capabilities is central under this approach.

Helfat and Peteraf (2003) go a step further than other scholars proposing the “Dynamic Resource Based View” (DRBV), stating that all organizational capabilities behave in a dynamic way, following a lifecycle model that can explain their emergence, development, and change (renewal, replication or retrenchment) (Figure 01).

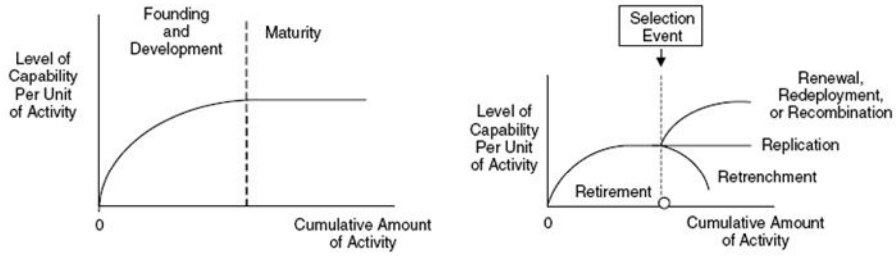

Figure 01. Capability Lifecycle (Helfat and Peteraf, 2003)

This paper develops an integrative framework conjoining both approaches to the study of innovation capabilities in order to identify how these capabilities evolve in time. Based on Desarbo et al (2005) strategic capabilities, this framework covers all firm capabilities and includes the time dimension when studying innovation maturity stages using a lifecycle approach. A variation of Bell and Pavitt (1995), based on Figuereido (2001) is used to qualify the innovativeness levels reached by each capability.

As shown in Figure 02 each strategic capability increases its innovativeness level during its lifecycle, according to firm-contingent conditions. It is expected that each capability will have different innovativeness levels. This capabilities lifecycle approach has not been used to analyze innovation capabilities.

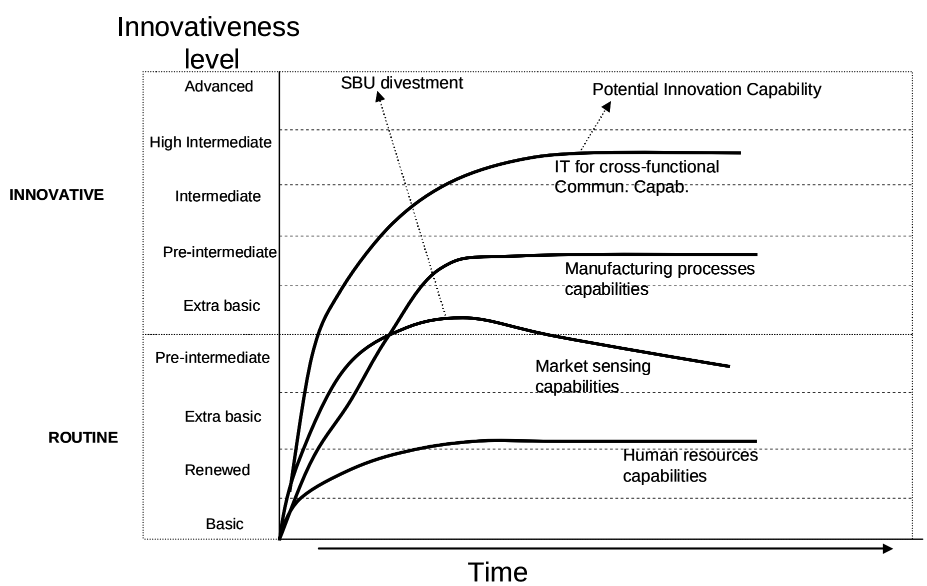

Figure 02. Capability lifecycle and Innovativeness level (Adapted from Helfat and Peteraf, 2003, and Figueiredo, 2004)

Methodology

Yin (2003) recommends the use of case studies when analyzing emergent areas of organizational inquiry with strong context effects on the phenomenon, and where the inquiry is motivated by how and why research questions. Also, Eisenhardt (1989) considers this research design suitable to inquiries where factors that affect the phenomenon are unknown.

The novelty of studies using DRBV and integrated approaches applied to innovation capabilities development recalls for case study research design. An embedded single case study is used (Yin, 2003).

The subject of study is a Mexican steel company, called "Steel Company". This company started to operate in 1943 with obsolete and used equipment, and thanks to a strong management commitment to innovation, it could develop its own steel processing technology becoming the world leader in this field. Steel Company becomes an exemplary case for this study. The study uses strategic capabilities and the "innovation outcomes" [3] as units of analysis.

This study is limited to the analysis of the Technology Division of Steel Company, and it covers its history from 1943 to 2008. It focuses on the activities, processes, and capabilities used to develop technological innovations and to commercialize them. It does not study the steel processing activity, but ir will be lightly touched as it is strongly related to the steel technology development.

The paper uses different sources of information to triangulate primary information obtained from open-ended interviews with key personnel from Steel Company. Some of the sources of information are:

- Steel Company Annual Reports
- Media and trade news obtained from Factiva digital database
- Previous studies and books regarding the Mexican steel industry and Steel Company

[3] Innovation outcomes are visible to all participants and also facilitate identification of activities, events and clarify the nature of capability interactions.

- Internal reports from Steel Company
- Interviews to retired personnel from Steel Company

As first step the study identified innovation outcomes reached by Steel Company along its history, as reported by senior executives and according to available media information. This provides a first insight of the innovativeness level reached by Steel Company. Later some key innovation projects are studied to discover the nature of the capabilities evolution process. The study uses different levels of newness[4] to consider a project as an "innovation" project. As the object of study is the accumulation of capabilities, even simple improvement projects or equipment acquisitions contribute to this process. The objective of this data collection strategy is to rebuild the history of each capability development.

With this data, strategic capabilities are identified in the first place, and using an innovativeness analysis for each capability they are classified using the Figuereido (2001) adaptation of Bell and Pavitt (1995) innovativeness maturity level. This task is developed in different years to visualize the trajectory developed for each capability when developing innovation abilities.

Case Development

The origin of Steel Company's proprietary Direct Reduced Iron (DRI) technology

Steel Company started to operate in 1943, caused by the shortage of steel because of World War II, and the requirement of its parent company of steel products. It started to operate with obsolete and used machinery acquired in the US (based on batch steel processing). Actually it had to buy three scrap equipments to build one operational unit, with foreign technical support. As it was new entrant it required foreign assistance to learn how to operate this equipment (Mendirichaga, 1978).

In its early years, Steel Company was not profitable and its products had low quality, and it was subsidized by its parent company. Since the beginning it had technological challenges for not closing operations, and the owners support became

[4] Johannessen et. al. (2001) identifies three newness dimensions: what is new, how new, and new to whom (to the company, to the market, and to the industry)

critical to start its technological trajectory. Soon the first technological learning process started, based on equipment acquisitions and technological dependence from the US, as the implementation of semi-continuous process, that was its second technological generation.

External factors were critical in Steel Company's technological developments. After World War II and with the restart of imports of American steel products the Mexican market demanded better quality products, and some years later Korean War created a shortage of scrap iron and the high costs of local iron ore pushed Steel Company to decide between closing operations or creating alternative processes to survive (Mendirichaga, 1978; Guzman, 2002; de Gortari and Santos, 2004). Management selected the second option, with the investigation of substitutions of scrap iron with virgin iron that conducted to the development of its own direct reduction iron processes. The first stage was developed with Canadian technical assistance, and later with its own research efforts that conducted to the first industrial scale and successful DRI plant in the world, in 1957 (Steel Company, 1997).

Steel Company's Innovation Milestones

When Steel Company started to operate, it was a strategic decision not to purchase technology (as paying royalties or licenses). They decided to buy equipment, and with them to learn how to repair, adapt, and put in operations through engineering capabilities. With this strategy, it could catch-up world-class steel technology leaders in DRI in few years. Table 01 shows Steel Company's technological innovations milestones, as reported in its web-site.

Steel Company became world leader in DRI technology early in its history. Many technological innovations milestones reported in Table 02 were the first implementations in the world of different incremental and radical technological innovations in DRI technology.

#	Year	Innovation milestone
1	1957	Start up of the first commercially successful gas-based direct reduction plant, using the proprietary Process.
2	1957	Production of flat products via the EAF, based on the use of DRI. 1958 Batch charging of DRI to the EAF at 600°C.
3	1965	Use of more than 30% DRI in an EAF charge, eventually increasing in stages up to 100% by 1972.
4	1968	Continuous feeding of DRI to the EAF.
5	1968	Computerized EAF process control system put into use.
6	1969	Use of Foamy Slag practices.
7	1970	Design of pellets for direct reduction.
8	1970	First full scale testing and use of DRI as a BF-BOF feed.
9	1972	Production of extra-deep drawing steels in EAF using DRI.
10	1980	Start up of the Proprietary III Process continuous shaft furnace
11	1988	Use of cement coating of pellet/lump ores for direct reduction.
12	1993	Pneumatic transportation system and hot DRI feeding to the EAF.
13	1994	Production of high carbon DRI (3.0-4.5%).
14	1995	Production of ultra thin (<1mm) hot rolled coils via continuous strip processing minimill in Monterrey.
15	1997	World's first dual-discharge (DRI and HBI) plant design put into operation, Vikram Ispat-Grasim, India.

Table 01. Steel Company's Innovation milestones (source: corporate website)

Discussion – key Strategic Capabilities at Steel Company

It is necessary to difference when Steel Company could develop these innovation outcomes and when it acquired significant levels of innovation capabilities. This study uses Heltfat (2003) capability definition: "an organizational ability to perform a coordinated task, utilizing organizational resources, for the purpose of achieving a particular end result." Thus, obtaining an outcome doesn't create a capability, it is necessary to generate routines that create organizational abilities during this process, and just then a strategic capability emerges. Following this tradition, innovation capabilities for this study is defined as a higher order "integration capability", it means that they have the ability to mould and manage different key strategic capabilities and resources that successfully stimulate the innovation activities (Lawson and Samson, 2001). In the same sense Henderson (1994) highlights that this kind of capabilities has the ability to integrate knowledge across boundaries inside a firm, creating sources of competitive advantage.

Also, as reported by Teece (2007) and Di Benedetto et al (2008), it is not sufficient that an organization is capable to develop innovations; it requires complementary capabilities that allow it to diffuse and commercialize its developed innovations (e.g. marketing, sales, and alliance capabilities). Without these capabilities a firm cannot generate value from its innovative activities. In this section the study analyzes the bundle of capabilities that are required to close the cycle of generating-commercializing innovations.

After that the paper analyzes the evolution of key strategic capabilities that have the potential to transform to innovation capabilities. As the RBV states, a bundle of capabilities (resources) define a firm orientation and sustains its competitiveness. Then this capabilities combination is firm specific contingent, according to its strategic intent and orientation[5].

Following Day (1994), DeSarbo (2995) and Di Benedetto (2008), this paper uses their strategic capabilities taxonomy. It is composed by marketing, market linking, IT, technological and management capabilities.

In the case of Steel Company, and based on interviews to key personnel, this study will analyze this bundle of strategic capabilities[6] that are considered as critical:

- *Marketing capabilities*: they allow a firm to better implement its marketing strategies.
- *IT capabilities*: they facilitate the diffusion of information (technological and marketing) throughout all the firm
- *Technology development capabilities*: they provide the ability to develop technological innovations
- *Manufacturing processes*: they operations on manufacturing plants to produce goods (or services)
- *Production facilities*: infrastructure that support operations
- *Project Management Capabilities*: ability to manage complex projects
- *Management Capabilities*: other capabilities that affects profitability and strategy implementation in a firm

Discussion – Innovativeness Levels

[5] See DeSarbo (2005) for a quantitative analysis relating strategic type, using Miles and Snow tipology, with strategic capabilities.
[6] Based on Di Benedetto (2008)

Steel Company followed the next distinctive innovation periods:

Period	Characteristics	Main indicators	Orientation to innovation
1943-1955	Founded using obsolete equipment	Sense crisis generates the creation of Steel Company, with strong technological dependence	Adopter
1955-1971	Develops proprietary DRI process	Beginning of R&D activities, succesful operation of 1st DRI plant in the world, patents registered, first alliances for commercializing its technology, Puebla plant starts operations	Adopter-Generator
1971-1977	Begins to commercialize DRI technology	First "purchase" of DRI plants from abroad by owner intervention, beginning of training in DRI technology, DRI II is developed	Generator
1978-1998	Organizing to commercialize	Stronger alliances (pasive sales); DRI III, pneumatic transportation system, and DRI feeding developed; pilot plant acquired; first "sales" of DRI plants	Generator
1998-2005	Best DRI plants in the world	"The most cost and energy efficient DRI plant in the world" starts operation, first implementations of radical innovations, international expansion of sales	Generator
2005-2008	Acquired by Global Steel Company	Deactivation of R&D operations; new strategy to adopt mature technology	Adopter

Table 02. Steel Company Innovation periods (based on Guzman, 2002; interviews and internal reports)

Analyzing these distinctive periods in the interviews, the study identified that these are supported by strategic capabilities at different innovativeness levels. Each capability followed its own development trajectory, with different paces when increasing its abilities and innovativeness capacities.

Marketing Capabilities

Steel Company was founded to satisfy a necessity of its parent company, not to commercialize its technological discoveries, and it was stated in this way by management. Then its marketing capabilities were null in the first two periods. A former executive related:

> *"our first DRI plants were not sales, instead of that they were 'purchases' from our customers: they came and knock our doors asking if we could replicate our DRI plants in their countries".*

These initial marketing efforts were developed by the owners themselves using international forums in coordination with owners of other steel companies. After this experience, initial marketing activities were developed, through alliance with mature technological and engineering companies based on developed countries. The "Mexican technology" could not sell easily in a global market, and this partnership was a step necessary. The first sales of Steel Company's commercial partners were sold as their technology, not as Steel Company's technology. In the fourth innovation period Steel Company could organize a whole division to commercialize their technological innovations. Even then it continued commercializing its DRI plants with foreign partners (developing passive sales). It could increase its marketing capabilities, developing new abilities, as knowledge of customers, post-sales services (training and support contracts), presence in forums, that allowed to locate it in "extra-basic innovative levels". Steel Company brand was consolidating thanks to these new marketing capabilities. Its participation in the amount of contracts when selling plants also increased.

IT Capabilities

Steel Company, for its "traditional operations" (steel processing) has been an IT leader in Mexico and Latin-America, but this IT capability was not reflected in the technology commercialization activities. Some interviewees reported that the first plants implementation projects did not have significant IT support (in the 80's), even complex calculations had to be developed using calculators. Since 1992 IT support was deployed supporting these activities. Nowadays it has reached "intermediate" levels of innovation, with integrated systems, workgroup applications and modern CAD/CAM applications. Steel Company was one of the first plants to adopt integrated SAP applications, and has appeared in various SAP promotional White Papers. Since 2005, when Steel Company was incorporated as part of Global Steel Company, it has reached "high-intermediate" innovation levels, with centralized applications to communicate department across all the corporation (covering operations in three countries), allowing to follow-up activities in a daily basis, and integrating operations with outsourcing partners using IT tools.

Technology Development Capabilities

This has been the first capability to develop innovative practice. In the first innovative period it was based on embedded technology transfer in purchased equipment, jumping rapidly from "basic routine" levels to start to obtain technological independence in 4 years (reaching "extra basic routine" levels), and to begin R&D activities in just 13 years since its foundation ("extra basic innovative" level).

It should be noticed that even it gained mature technological levels around 1957, its marketing capabilities were too weak to take commercial advantage of it. Interviewed executives explained that it was not the corporate strategic intent to develop technology to commercialize, but to satisfy internal technical requirements to reduce cost and energy usage. Since 1970 it developed patenting strategies, and since then Steel Company became the world technology leader in DRI processes, but not the market leader[7]. In the 90's it was already developing radical innovations in this field (as the pneumatic transportation technology), reaching "advanced" innovativeness levels. It has been the innovation capability until 2005 (the integrative capability that conducts the innovative activity of the company), when Steel Company became part of Global Steel Company. Then the R&D function disappeared, and a new function was created, the technology group, with a different approach, as reported by another interviewee:

> "*we were told that our new function was to look for emergent technological processes that can be beneficial to the corporation, not to develop it anymore*",

The company was transformed from an innovation generator to an adopter, retrenching this capability to "extra-basic" innovativeness level. It did not disappear, as it has remained as a competent "technology follower" in the market.

Manufacturing processes capabilities

In this case it represents the ability to implement DRI plants to their customers or own plants. It started with very basic levels, where they had low participation ("basic routine" levels) in the first implementations (as their new plant in 1952, with American experts support). Interviewees reported that because of continuous conflicts with these experts, they started to replace this kind of assistance in plant implementation with their own engineers.

The first in-house implementation was developed in 1957 (with little support from US), reaching "extra basic" innovative levels. Until the second stage of DRI plant implementations (1978) they did not developed higher levels of this capability (reaching

[7] Indeed it was the market leader for few years around 1970, but its competitor, with stronger marketing capabilities, soon took the market leadership, even being the technology follower (see guzman, 2002 for detailed tables with DRI market share)

"pre-intermediate innovative" level). This enhanced capability helped to develop strong local partners in construction and equipment building, obtaining independence from American partners in these activities.

In-house plant building and expansions allowed the development of "high intermediate" innovative levels when they built the DRI-4 plant. As this capability has evolved, time for implementing a DRI plant was reduced from 3-4 years in the first projects to less than one year. The next figure shows the different modules developed in Steel Company.

They developed high levels of innovative levels that allowed them to three-fold their participation in contracts with customers' plant implementations, compared with initial arrangement with partners. Since 2005, this capability has disappeared as the commercialization of technology was divested from Steel Company.

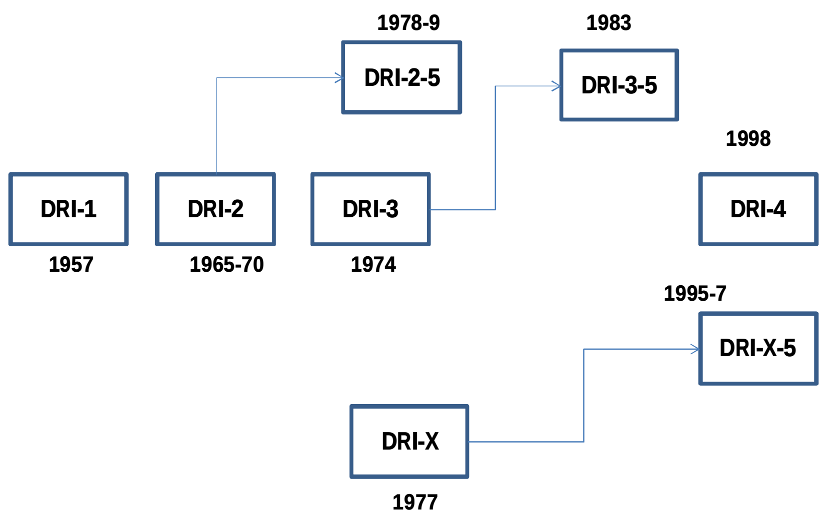

Figure 03. Steel Company's plants and expansions implementations (source: interviews and internal documents)

Production facilities capabilities

This capability is based on facilities that support the development of DRI technology and other commercial activities. It started with low levels (basic routine) in the first period, as they had to use external facilities for validating their technologies and scaling to industrial levels prototype solutions. This capability increased with their own modules (plants) that allowed them to make testing and scaling activities ("pre-intermediate routine" level). At late 70's Steel Company already had a pilot plant for these activities, with a permanent staff for operating this small plant, reaching a “pre-intermediate innovative” level. In 2005, Steel Company divested these activities as well as the pilot plant, thus it disappeared as a capability.

Project Management Capabilities

Steel Company, since its first operations, started to develop this capability based on the engineering department. When it started to commercialize (1971) it already had innovative levels (“extra-basic”). Interviewees report that it was noticeable the change in performance when Steel Company project managers replaced the ones assigned by their customers, reducing the time of implementation to ½ or 1/3 of expected time. Matrix project management was used very early in the company. In the last in-house plant implementation this capability reached “intermediate innovative” levels, with original methods to improve the efficiency of project management, as “post-mortem” meetings (mandatory meeting when finishing projects) and supported by IT applications.

Management Capabilities

Steel Company, even a technology leader in DRI process, did not prioritized its commercialization activity, implying low levels of managerial innovations for this activity. They did not have an organizational structure to support the first sales operations. In 1978 they created a division with this purpose. It maintained a medium level of managerial capabilities in the commercialization field, with some organizational improvements, as the creation of the “staff” approach to retain competitive researchers, but these initiatives were isolated, that did not create high levels of managerial innovations. Alliance capabilities, as exception, were quite strong since its foundation. Guzman (2002) reports an extensive list of technological partners (“cuadro 63”) that Steel Company had along all its operations. Another exception has been the development of innovative initiatives with universities to recruit new employees, including the technology division. Cooperative projects with universities were very few.

Figure 04 summarizes the evolution of the innovativeness levels for each of these strategic capabilities. It is noticeable the retrenchment of innovativeness levels of most capabilities after the incorporation to Global Steel Company.

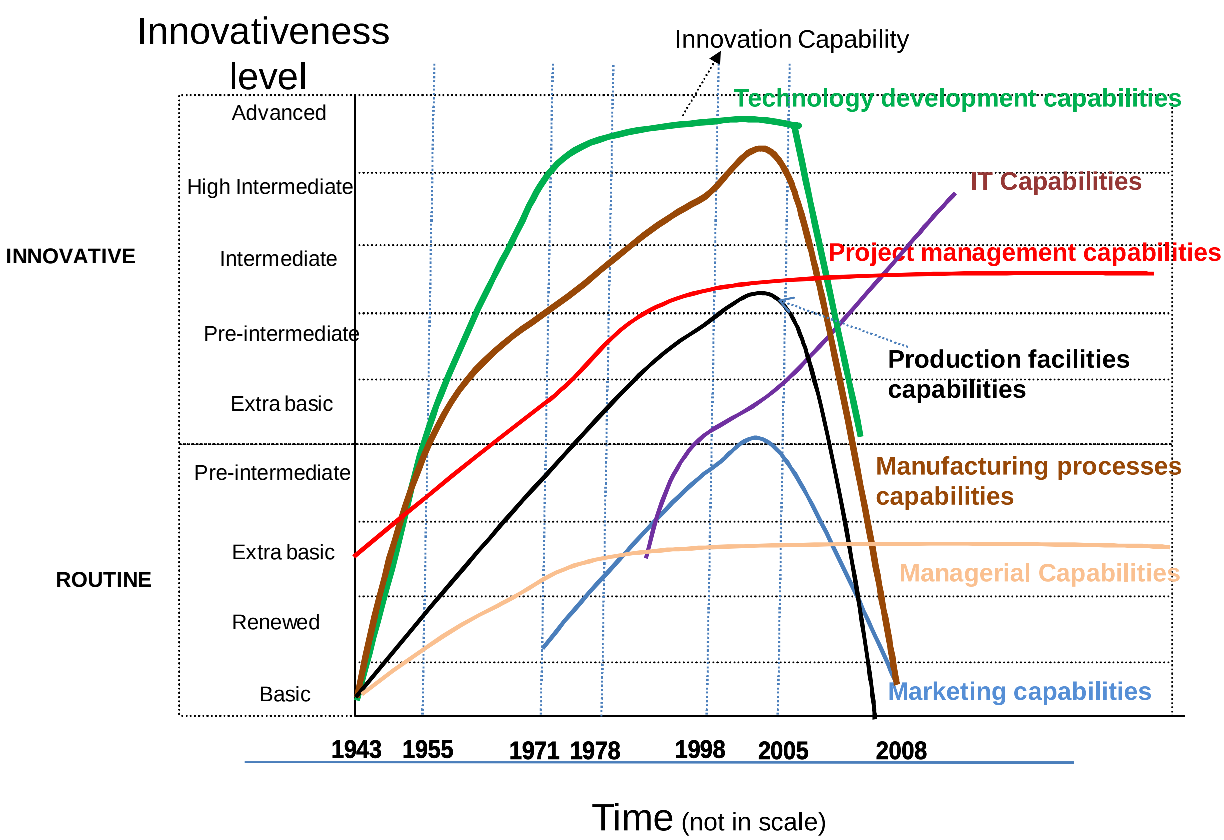

Figure 04. Steel Company: Strategic Capabilities Innovativeness Levels (based on interviews and internal documents)

The end of and era, or the beginning of a new age? Effects of acquisitions and divestitures on innovation capabilities

This study has identified that capability innovativeness grows at different paces and levels according to the strategic attempt adopted by an organization, expressed in the bundle of strategic capabilities that it prioritizes[8]. Steel Company reached the highest

[8] See how Prahalad and Hammel (1990) explains that an organization should prioritize some few capabilities in resource allocation, that create the firm core competences

innovative levels in technological capabilities, but sacrificing other ones such as marketing and managerial capabilities. Suddenly everything changes when it was taken over by Global Steel Company that decided to divest the Technology Division, retrenching almost all of these highly innovative capabilities. In the other side, some capabilities were benefited by corporate decisions, as IT capabilities and some managerial capabilities (such as integrated logistics capabilities), and others have remained in high innovative levels (such as project management capabilities).

During the research, the study tried to know what happened with all the tacit knowledge generated through over 60 years of innovative activity. Was it really lost as part of a corporate decision?

Investigating the destination of the human groups that had all this valuable knowledge, the study found that they became a spin out of Steel Company, and this new company was acquired by Global Technology Group. This new company continued commercializing DRI plants. It happened something unexpected: Global Technology Group is an international company specialized in technology commercialization, and the former Technology Division of Steel Company received renovated and stronger complementary capabilities that have created extraordinary results. Indeed, in just 3 years it has obtained results that took decades to the former division. Synergetic effects of stronger complementary capabilities were detected (in particular marketing and managerial capabilities). Further research is required to obtain more revealing conclusions.

Conclusions and Further Research

This paper has analyzed the evolution of innovative levels of a bundle of strategic capabilities using a life-cycle approach, based on a single case study research design. It was limited to the bundle of capabilities involved in the generation and commercialization of technological capabilities. A further research will cover all Steel Company's strategic capabilities.

Capabilities advances and retrenchments are identified, as well as the participation of not a single capability but a cluster of them in the innovation activity, which intervene in a synergetic way.

Previous to a critical innovation, technology transfer via international experts was developed in Steel Company[9], with strong human resources training and recruitment. Marketing and market-linking capabilities were created and improved in order to commercialize innovative products and services[10] that also support future innovation projects in the technological capabilities sphere. They create a Capability Cluster that interacts in continuous evolution with the other capabilities. Each capability develops its own transformation process accumulating knowledge, experience and obtains different levels in its ability to "create new knowledge from previous knowledge" (innovativeness ability).

Some specific capabilities emerge as leaders in these accumulation processes, which are called "innovation capabilities" (integrative firm capabilities that mould and coordinate other organizational capabilities that support innovative activities). In the case of Steel Company, the Technology Development, Manufacturing Processes and Project Management capabilities became innovation capabilities.

Strategic intents, resources availability, and management leadership emerge as main drivers for creating innovation capabilities. Steel Company's own creation (caused by steel shortage) provides an insight of this finding. The "crisis sense" is also identified in the capability development process at Steel Company.

Capabilities development trajectories are also identified, contingent to the firm. The differences on these trajectories create heterogeneity in innovativeness levels across the company's capabilities, with some of them emerging as leaders.

A new question emerges as result of the study. It studied the phenomenon inside the boundaries of Steel Company. Under this perspective, the most critical innovation capabilities have disappeared. Extending the analysis including spin outs from Steel Company, a richer analysis can be obtained, which can identify a discontinuity (for renewing or retrenching) of the former capabilities lifecycle. If a regional development approach is applied, the inclusion of spin-offs and spin-outs is necessary to analyze, as at

[9] An executive stated that when Steel Company was created, they realized that it was not sufficient the installation and use of steel equipments, but the technical assistance from foreign steel experts to be technically proficient and to be capable to develop their own innovation projects.
[10] In this industry, technical conferences and visits to key customer locations are preferred commercialization channels.

regional technological capabilities they have not been lost, but just transferred to another organization, and this was the case of the former innovation capabilities found at Steel Company.

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