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Learning, R&D and Manufacturing Capabilities as Determinants of Technological Learning: Enhancing Innovation and Firm Performance

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Abstract

Facing the globally competitive environment characterized by uncertainty, dynamism and volatility, technological learning plays an important role in firms' competitive success, supporting their ability to develop maintain and exploit dynamic core competencies, besides leveraging firms to pursue technology based strategies. At this point, extending the resource based view (RBV) of the firm and basing technological innovation capabilities on dynamic capabilities view (DCV) these assets which enable firms to develop, acquire, assimilate and modify technologies to obtain new ones, are seen as critical sources of sustained competitive advantage. However, there is limited effort in the literature on the potential complementary relationship of technological learning with these TICs. In this study, by focusing on the complementary power of learning. manufacturing and R&D capabilities which build the basis for a systematic innovation strategy through establishing appropriate routines, accumulating skills internally and developing the ability to learn selectively, their influence on technological learning is investigated. Specifically, this study will enhance the theory on technological learning by operationalizing technological learning and its characteristics which have rarely been focused on in the literature. The conceptual model is comprised of five research propositions with six main constructs namely; i-) learning capability, ii-) manufacturing capability, iii-) R&D capability, iv-) technological learning, v-) innovation and vi-) firm performance. Concurrently, the managerial implications are discussed and the empirical testing of the propositions stated in the conceptual model is suggested for future research.

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1. Introduction

The research on technological innovation has become increasingly widespread since Schumpeter proposed this concept in his book "The theory of economic development" in 1912 (Bao, 2010). It is well recognized that in today's hypercompetitive environment seeking to respond the changes constantly arising in the environment does not rely on the static process of sole knowledge accumulation (Real et al.. 2006) or growth of technology assets through resource based view (Teece et al., 1997) rather it is dependent on the mutual relationship between firm's capabilities (e.g. effective coordination and adaptation of internal and external competencies), technology (e.g. timely responsiveness), and innovation (e.g. flexible innovations) (Teece and Pisano, 1994). Parallel to this, theories of the firm are further extending towards accommodating the dynamic, heterogeneous nature of the firm and its context (Carayannis, 2000) in order to survive in the contemporary competitiveness in globalised, knowledge-based economy. As implicitly suggested by Penrose (1959) and the expanded paradigm of Teece and Pisano (1994) which evaluates how competitive advantage is achieved, both internal and external firm-specific capabilities ought to be exploited and renewed in order to respond to the fluctuations in the business environment. Indeed, according to the dynamic capabilities theory, to achieve the outcome of sustained competitive advantage firms need to develop, unique, inimitable hard to replicate, hard to transfer and most importantly "modifiable" distinctive capabilities (Teece et al., 1997; Winter, 2003). Hence a definition of dynamic capabilities essentially focusing on its flexible nature suggests that "the capacity of an organization to purposefully create, extend or modify its resource base" (Helfat et al., 2007: 4) appear as the antecedents of organizational and strategic routines (i.e. repetitive and patterned behavior that is learned especially through learning by doing and embedded in tacit knowledge (Winter, 2003)) which enable the firm management to acquire new resources, integrate and recombine them to obtain a novel resource base (Yam et al., 2011).

Considering the technological innovation capability (TIC) from dynamic capabilities point of view there emerges the need to recognize TIC as organizational routines to capture firm-specific technological and operational knowledge (Real et al., 2006) which facilitate and support technological innovation strategies (Burgelman et al., 2004) through attentive tracking of the environmental changes and timely responses, exploitation of technology sources, development or adoption of new technologies, and modification of existing or newly adopted/developed technologies (Yam et al., 2004). Thus TIC comes into prominence as a critical factor in upgrading the firms' ability to generate technological knowledge, improving the way a firm allocates resources for innovation, developing alternatives to obtain new technologies and organizing its existing resources to assimilate and internalize new technologies (Cetindamar et al., 2009; Lin, 2003). Technological learning is defined as "the process by which technology driven firm creates, renews, and upgrades. its latent and enacted capabilities based on its stock of explicit and tacit resources" (Carayannis, 2000: 393). Although some studies suggest the interplay between TIC and technological learning (Carayannis, 2000; Carayannis and Alexander, 2002; Real et al., 2006; Huang, 2011) few studies to our knowledge have spent an effort to build a theoretical background regarding the particular interrelationship based on the dynamic capabilities theory. The literature on technology and innovation management (TIM) offers little insight on how TIC, especially its dimensions

namely; i-) learning. ii-) R&D and iii-) manufacturing capabilities which have the common functions of screening the external environment, adapting the internal structures/processes accordingly and the concurrent feedback mechanism which enables a continuous improvement, act in strengthening technological learning.

Amid this research aims to have a threefold contribution to the literature; i-) evaluating TICs from dynamic capabilities perspective to examine their relationship with technological learning, ii-) focusing specifically on learning, R&D, and manufacturing capabilities as the determinants of technological learning, and iii-) developing theoretical framework on the relationship between technological learning and innovation and firm performance. The article proceeds in the following manner. In the second section we briefly present the literature highlighting TIC; especially learning R&D and manufacturing capabilities and technological learning. Following, we develop related propositions concerning the conceptual model comprised of the interrelationships between the three TIC dimensions and technological learning, and the influence of technological learning on innovation and firm performance.

2. Theoretical Framework and Hypothesis Development

2.1. The Relationship between Learning, R&D and Manufacturing Capabilities and Technological Learning

TICs are considered the most important elements in achieving enhanced competitive advantage (Diaz- Diaz et al., 2008). Hence TICs are assets which facilitate the development of new products, application of new process technologies, and the ability to appropriately adapt to unexpected technological uncertainties (Adler and Shenbar, 1990). As one of the pioneers of the concept Burgelman et al., (2004) define TICs as a comprehensive set of organizational elements which through the tracking of technological development within the environment, and adaptation of the firm's systems and structures to the changing technologies and industrial progresses support organization's innovation strategies. Although different definitions of TICs are suggested throughout the literature a common view highlights that these resources (e.g. knowledge, skills, products, processes, technology, experience, and organization) not only incorporate internal elements of the firm (Guan and Ma, 2003) rather they embed the external determinants such as the inter-organizational interactive relationships in complementing their ability to create, transfer, organize and utilize technological knowledge, as well as the ability to integrate, coordinate, adapt and respond according to technological developments in order to establish successful commercialized innovations (Yam et al., 2011). The literature on firms' competitive sources has sought to highlight that to endorse ability to sustain advantages in the competitive market, a firm initiates by examining its resources, evaluating its strengths and weaknesses and completes the loop by analyzing how these resources can be combined or integrated into capabilities. Also, evidence suggests that firms need to acquire, generate and integrate and utilize knowledge in order to learn and manage technologies (Hitt et al., 2000). Hence firms require an established platform of capabilities as knowledge acquiring and exploiting assets, to build new capabilities, upgrade existing ones and exploit them (Mathews and Cho, 1999). Parallel, the definition of technological learning highlights that it is a process through which the technology-driven organization develops, improves and renovates existing capabilities (Carayannis, 1999). Contemporaneous, Teece and Pisano (1994: 545) suggest that "learning requires common codes of communication and coordinated search procedures" and underline that the output knowledge of these

coordinated practices (i.e. dynamic capabilities) are stored in new patterns of activity, routines or new mental models thus enabling the inter-organizational learning. The sources of technological innovation can be both internal and external. Internal sources are particularly driven by intrinsic motivation (Carayannis and Roy, 2000), R&D function and activities, manufacturing processes (Kim and Lee, 2002; Guo and Guo, 2011) and the external sources are controlled specifically by the acquisition of knowledge generated externally (Hitt et al., 2000; Matthews and Cho, 1999). Gaining access to other firms' technological know-how and skills through an organizational interdependence provided by a number of cooperative acts is yet not sufficient in the exploitation of that knowledge to integrate and transform it into innovative or performance outcome (Steensma and Corley, 2000). Although, exploration is essential for the knowledge acquisition, learning and capability building, it needs to be complemented with exploitation of new as well as existing resources, skills and capabilities (March, 1991). In order to establish both the exploration and the exploitation, dynamic capabilities play the role of stretch goals (i.e. organizational goals which have a probability of success but in order for its attainment current capabilities need to be modified) and establish a high degree of organizational interdependence with the technology sourcing firm increasing the richness of communication and interaction (Steensma and Corley, 2000). Yet, this study building the theoretical background on the dynamic capabilities perspective focuses on the three dimensions of TICs -learning (e.g. intrinsic motivation and leverage on external sources), R&D, and manufacturing capabilities which are the ones to mostly complement each other with the common objectives of i-) screening the external environment, ii-) adapting the internal structures/processes accordingly and iii-) leveraging a feedback mechanism which enables a continuous improvement occurring simultaneously in coordination.

Learning capability, indicates the tangible and intangible resources, characteristics and skills of the firm which facilitate or enable the learning process of the organization (Goh and Richards, 1997). Based on the learning organization and the organizational learning literatures there exist contextual variables that can promote and guide learning (Alegre and Chiva, 2008). Yam et al. (2004) regards learning capability from a TIC perspective and define it as the organization's ability to acquire, assimilate and exploit knowledge from the environment. Accordingly integrating the TICs view with the organizational learning and learning organization view proposed by Alegre and Chiva (2008) it appears that learning capability is both fed by internal and external environment through the complementary role of internal skills to absorb external knowledge. Learning capability enhances technological learning through its "pushing force" to acquire and internalize external technological knowledge which is established through the open-mindedness, experimentation and systems perspective (Jerez-Gomez et al., 2005). As the learning capability is built the different areas through which the organizations gain technological skills widens (Wang et al., 2008). Particularly, the technological knowledge which is encountered beyond the boundaries of the firm is more easily transferred within the firm and readily utilizable via the facilitation mechanisms learning capability provides (Hult and Ferrel, 1997). Hence the breadth of technological learning, since "firm's skills become outdated, its products obsolete and its future uncertain" if there is lack of interaction with the external environment (Zahra et al., 2000). Also, learning capability improves the depth of the technological learning through activating firm's previous experience and the ability to consolidate organizational technologies; design and manufacturing methods into competencies that improves the quality of the technological knowledge and skills the firm utilize (Lin, 2003). Moreover, the flexibility provided by learning capability leads organizations to be able to adapt faster to the technological changes and respond accordingly (Figueiredo, 2002). Thus learning

capability enhances the speed of the technological learning. Therefore we hypothesize that;

P1: Learning capability positively influences technological learning.

Parallel with the knowledge based view of the firm highlighting knowledge as the basis for the development of competitive advantage, dynamic capabilities theory also suggest that the capacity to acquire, generate and exploit technological knowledge assets is the medium through which a firm differentiates itself from its competitors and environment (Teece and Pisano, 1994; Diaz-Diaz et al., 2008). Building on the definition of organizational capabilities as "a high-level organizational routine or a collection of routines, that together with its implementing input flows, confers upon an organization's management a set of decision options for producing significant outputs of a particular type" (Winter, 2003), dynamic capabilities refer to the adjusted strategic responses according to the pace and nature of the environmental developments to adapt integrate and reconfigure internal and external skills (Teece and Pisano, 1994). Particular focus on R&D capabilities, has shown that a firm's ability to integrate R&D strategy with the organizational vision and mission, level of R&D investment, project implementation and portfolio management as the components of R&D capability result in the accumulation of new technological knowledge (Helfat, 1997). Firms rely on their R&D capability in order to access external as well as internal sources of knowledge (Lieberman and Asaba, 2006). According to a previous research which investigates the role of R&D in organizational learning, Cohen and Levinthal (1989) suggest that R&D is the main determinant of new knowledge acquisition, assimilation, transformation and utilization for firms which is conceptualized as the learning or the absorptive capacity of firms. Accordingly, R&D capability of firms lead to organizational knowledge creation in specific areas of science and technology through experimentation and exploration based learning, and facilitates the identification and association of the externally encountered knowledge with the firm's operations, products and processes (Lane, Koka and Pathak, 2006). Internal R&D activities equip the organizations for better absorption of externally generated knowledge (Murovec and Prodan, 2009). The repeated engagement in R&D activities leads to the accumulation of technological experience, which indicates gaining technological expertise in an iterative fashion (Ernst et al., 2011). Hence Ernst et al. (2011) claim that the accumulation of technological experience through R&D related efforts, contributes to the development of its absorptive capacity, more specifically to transformation and utilization of knowledge via its activation. Furthermore, Spithoven et al. (2011) indicates that the role of R&D personnel is to pass on technical and market information, monitoring the technology market and internalization of R&D and it outcomes. Researchers also agree that, internal R&D besides supporting external knowledge acquisition, provides firms to be better equipped for the transformation and utilization of external know-how in the innovation process (Nieto and Quevedo, 2005). Therefore building on the above argument we develop the following proposition.

P2: R&D capability positively influences technological learning.

Manufacturing capability is defined as the ability of a firm's production system to compete in the market through increased cost efficiency, flexibility, delivery and quality (Mukerji et al. 2010). Organizations increasingly become skilled in manufacturing products and services which enhance the existing knowledge regarding technologies, procedures, processes and market inputs through manufacturing capabilities (Benner and Tushman, 2003). Manufacturing capability which is embedded

in the technological systems of firms is often regarded as the ability to convert R&D outcome to commercialized products and services (Guan et al., 2006). Manufacturing capability, enhances both internal and external technological learning (Mukerji et al., 2010; Sapsed and Salter, 2008). Flexibility in particular leads to the enactment of the ability of transferring technology and technological know-how from the external environment (e.g. suppliers, competitors, customers) through establishing a suitable environment for the adaptation of the three technological learning elements i.e. human actors, processual containers and content. Authors argue that firms in order to engage in effective technological learning need to engage in both explorative and exploitative learning in the means that, besides the frequently experimenting R&D functions, firms need to reduce variability, increase efficiency and control in their process management efforts through strengthening manufacturing capabilities (Benner and Tushmen, 2003). For instance manufacturing capabilities improve technological learning such that; i-) the effort for increasing vendor quality contributes to the speed of production (Ferdows and De-Meyer, 1990), ii-) the strength of quality control activities enhance the success of pretesting new products and processes (Li, 2000), iii-) the availability of pre and post-sales services facilitate the customization of products and processes for local markets (Li, 2000), iv-) the increased level of manufacturing flexibility enables the new product flexibility (i.e. the ability to introduce new products to be manufactured) (Malhotra and Mackelprang, 2012), and v-) high quality, low cost and flexible production enhances the speed and volume of product/service introductions (Mukerji et al., 20 10).

P3: Manufacturing capability positively influences technological learning.

2.2. The Relationship between Technological Learning and Innovation

Innovation allows organizations to progress parallel with the changes flourishing in the environment. It's a strategic key in responding to the new challenges of an environment full of uncertainties (Llorens Montes et al., 2005). For an organization, innovation would denote the generation or adoption of novel ideas or behavior (Liao et al., 2008). In the literature the idea that innovation is essential for firms' long-term success and survival constituting a competitive instrument is widely recognized (Santos- Vijande and Alvarez Gonzalez, 2007). Authors reflect Nonaka and Yamanouchi's (1989) suggestions as; organizations fit to the changing conditions of the technology and the market by diversifying and adapting, and even rejuvenating or "reinventing" through innovation (Santos-Vijande and Alvarez-Gonzalez, 2007). Zahra et al. (2000: 931) claim that technological learning provides a base of knowledge upon which innovations can be developed." The degree of novelty is dependent on the situation and the individuals through which the technological learning emerges, thereby the breadth, depth and speed of technological learning leverages the ability to integrate organization specific technologies and technological skills that equip the actors in the technological learning process to adapt quickly to changing environment (Lin, 2003). Furthermore technological learning is considered as having impact on firm, innovation at three levels namely; instrumental, innovative and creative (Carayannis and Alexander, 2002). Instrumental impact drives incremental change in firm processes, outputs operations and performance, innovative impact results in radical change in firm processes, outputs, operations and performance and finally creative impact leads to architectural change in firm processes, outputs, operations and performance (Carayannis and Alexander, 2002).

P4: Technological learning positively influences innovation.

2.3. The Relationship between Technological Learning and Firm Performance

With the exploitation of organizational values, information processing behaviors, and organizational actions enterprises use organizational learning as a source of heterogeneity and of sustainable competitive advantage. Based on the theory of dynamic capabilities, technological learning performance is determined through the capability of firms to learn (Lin, 2003). Hereby firms need to strengthen the research and development activities in order to manage technological knowledge efficiently, to utilize it effectively and to acquire it continuously based on the need to distinctively meet customer requirements and seek market needs (Ussahawanitchakit, 2008). Technological learning is a source of improved firm performance since it provides the firm a non-transferable firm specific technological knowledge base (Lin, 2003). According to Smit et al. (2007) technological learning is "the process in which actors acquire knowledge in order to improve the performance of the technology-specific innovation system". Through the assimilation of the technology transferred from outside, and its integration within the firm the slope of the technological learning curve increases, the continuous creation of new languages of strategic thought is provided and novel organizational routines are created (Carayannis, 1999). Authors therefore regard technological learning as the driver of potential opportunities to be integrated with the corporate strategy. Moreover, the literature suggests that technological learning establish a mechanism through which technological knowledge is communicated between organizational members and integrated in the organizational strategy (i.e. management systems, policies, procedures, goals and objectives) resulting in the successful development of complex technological products as well as an increased quality offering higher value to customers (Hitt et al., 2000). Indeed, technological learning prevents the firm competencies to become outdated, and its products/services obsolete (Zahra et al., 2000). Furthermore, technological learning establishes a set of feedback mechanisms that through the continuous modification of an inclusive framework of technology-based strategies supports the expansion of firms' horizon of opportunities and increases their range of selection (Carayannis and Alexander, 2002).

P5: Technological learning positively influences firm performance.

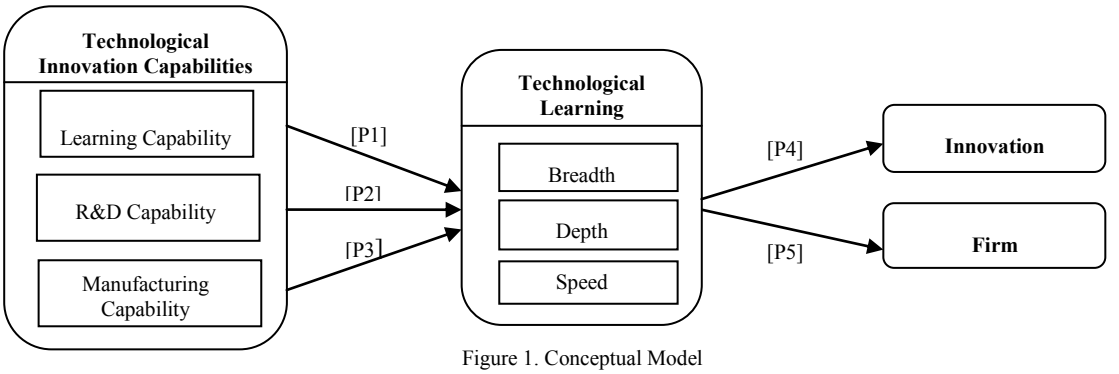

Figure 1. Conceptual Model

4. Discussion and implications

Along with the globalization and the beyond-boundary competition in the contemporary business environment, there emerge two limitations that prevent the persistence of competitive advantage and above normal returns which are the risk of imitation and substitution of competences (McEvily et al., 2000). Core competences in dynamic environments sometimes lead to core rigidities or competency traps

in firms whereas dynamic capabilities serve to exploit existing resources and technologies as well as exploring new ideas, skills, technology and resources for variation purposes (Benner and Tushman, 2003). In line with this concern organizations having dynamic capabilities which frame their strategies by intentionally creating, extending and modifying their resource base according to the changing environment (Eisenhardt and Martin, 2000), differentiate themselves from the competitors through exploiting the modularity attribute of the systems enabling the separation, coupling and reconfiguration of firm resources. But the idea here is that dynamic capabilities unlike operational/organizational static capabilities allow the firm to flexibly, uniquely, and urgently structure and restructure its processes, routines, skills and resources by establishing an adequate baseline for the synergistic specificity of the complementary components (Schilling, 2000). Hence this study suggests that through the ability of firms to leverage and reconfigure existing capabilities the imitability and substitutability of competences is suppressed. Therein, the three TICs simultaneously underlined by this study as the determinants of technological learning namely; learning, R&D and manufacturing capability open up a gate to prepare firms to be modular (i.e. the degree to which an organization's systems can be separated and recombined) in terms of the enhancement and transformation of existing capabilities and the development of new ones (Zahra et al., 2000). This research proposes a theoretical framework where besides the influence of the three TICs on technological innovations, the relationship between technological learning and innovation and firm performance is discussed. Hence managers would denote that an organizational focus on learning, production and R&D would enhance their ability to renew their technological knowledge bases and in turn i-) the ability to redesign products for ease of use, ii-) the range of customized options, iii-) radical changes in product definition and iv-) open up to new markets. Technological learning would lead firms to remain at the technological frontier of businesses by allowing management to recognize the organizational strength, invest in R&D in terms of labor force and capital and parallel with the explicit suggestions in the literature position the firm to improve performance (Carayannis and Alexander, 2002). This study is of interest from both theoretical and practical perspectives. Cultivating effective R&D capability can be used as a critical tool to exploration and exploitation of technological knowledge would be more successfully implemented resulting in enhanced firm performance, market share and customer satisfaction. Besides, the manufacturing capabilities establishing quality focused, cost effective, flexible and dependable (i.e. delivery success) organizational structure would be a key source of fast and deep technological knowledge accumulation and integration leading to the elimination of uncertainty, successful implementation of production routines and a larger variety of innovative outcome. Furthermore investing in learning capability promotes the ability of firms to track technological changes. retain tacit and explicit knowledge, absorb and integrate external technological knowledge leading to the development and implementation of new ideas, systems and technologies, communication of newly introduced procedures and techniques into the organizations technological base and the establishment of an organizational structure where the technological learning is resonated from the individual level to the organizational level collectively.

Our study has also some implications for future research such that the conceptual model can be empirically tested and the analysis of the hypotheses would shed light to the literature on technology and innovation management from a technological innovation capability perspective. Besides, the concept of TICs is not limited only to learning, manufacturing and R&D capabilities but involves also resource allocation, marketing, organization and strategic planning capabilities which trigger the opportunity for future research. For the purpose of expanding the research antecedents of this key variable; technological

learning which has a critical importance in the achievement of successful innovative outCome and firm performance additional TICs can be theoretically and empirically investigated. Finally the role of technological learning can also be examined as a mediating variable in the relationship between TICs and innovation and firm performance which would address a gap in the literature since the technological learning is up to our knowledge not empirically tested as a mediating variable besides its relationship with the TICs.

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