Editorial: Technology and innovation management: past research, present findings and future directions

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The management of technological innovation has become one of the most attractive and promising fields within the management. Three data confirm this fact as follows:

- A growing number of scholars have focused their research activities in this field of study. This is shown by the fact that the Technology and Innovation Management Division of the Academy of Management is one of the most numerous and had 2128 registered members in July 2005.
- New academic journals specialising in the study of innovation phenomena appear every year. Currently, more than 50 are published, five of which, like *IJTM*, are listed in the ISI Journal of Citation Report.
- Several international academic associations engaged in the study of technological innovation processes and innovation management have been consolidated: ALTEC (Asociación Latino-Iberoamericana de Gestión Tecnológica), IAMOT (The International Association for Management of Technology), ISPIM (The International Society for Professional Innovation Management), PICMET (Portland International Conference on Management of Engineering and Technology) and the International Conference on Technology Policy and Innovation.

However, for the time being there is no solid theoretical basis in our academic community for the study of the innovation management. This shortage is especially shown by the coexistence of radically different methods of approach and the absence of a precise and commonly accepted terminology. Innovation and technology management, just as other research fields within the management scope (for instance, strategic management or organisational behaviour), is now still in an early stage of development.

As Khun (1962) said in young disciplines still in a pre-paradigmatic stage, "research processes are typically chaotic – there are high levels of disagreement regarding both theory and methods and the quality of research output is usually weak".

However, the field of innovation and technology management has been developed substantially in both theory and empirical research over the last 40 years. It largely evolved from work primarily based on case studies that were theoretical to a field that is now largely populated by theory-driven empirical research.

The evolvement of Technology Management (TM) studies – just as that of other management fields – has been influenced by the progress achieved by other disciplines in the knowledge of the nature of innovative phenomena. Since the 1960s, when the first works on TM appeared, scholars and advisors have been studying the process of technological innovation in firms, applying radically different methods of approach. It is easy to identify such methods by means of:

1 the aspects picked up for study

2 the analysis of methodologies employed and

3 the hypothesis on the nature

   a of the technological innovation process and

   b its principal product, technology.

This first works on TM, focus on solving problems posed by R&D activities in big manufacturing concerns. With a clear operational method of approach, a series of tools are developed that ease the work of managers of R&D departments and projects. They assume in advance that the success of the process of innovation is certain, if resources are efficiently assigned to R&D operations.

Essentially, at this stage, models and tools are developed to support decision making on management of R&D operations (Archibald, 1976; Francis, 1977; Twiss, 1974). Sophisticated methods of approach are proposed for the performance of technological forecasts and to assess R&D investments. Techniques are developed for programming and overseeing R&D projects (Davies, 1970). The empirical grounds of most of the works are very weak and offer no consistent explanations on the nature of the innovation process in organisations. From the theoretical point of view, only some research efforts deserve reporting; they deal with the problems of communication and transfer of scientific information in R&D departments, and are due to Allen (1977) of the MIT.

Works carried out at that time have significant limitations. On the one hand, they present a mechanical and linear vision of the innovation process where scientific advance and R&D activities are the main feeding sources of the innovation process. At this point they are influenced by certain high-impact research efforts in the field of innovation economics (Freeman, 1974; Mansfield, 1968).

On the other hand, the analyses of methodologies they employ are oriented to the study of the conditions of equilibrium, and static models are designed that only permit the representation of a temporal phenomenon. As for these models, the decision to adopt a certain technology is not subject to past decisions and the first stages of dissemination of an innovation that do not affect its future evolvement: the innovation process is independent on the path it followed in the past.

Owing to neoclassical influence, all such works treat the innovation process in an exogenous way. Agents, in this case firms, play a passive role and have no capacity

whatsoever to influence the innovation process. The intensity and direction of the process are determined by a combination of multiple forces beyond control. Organisations may only adapt to the pace of the innovation process and try to improve the management of their internal resources.

At this stage, most papers take a restrictive view of innovation limited to the activities performed by the R&D department, and do not take into account other sources of innovation related to the learning capacity – by use, by practice, by error, etc. – of organisations. Underlying all these is the idea according to which technology is information, which implies ignoring other forms of technological knowledge. This consideration comes from the impact of the work of Arrow (1962), which examined the problem posed by the efficient assignation of resources to inventive activities, which are inherent to information-intensive public assets.

In 1980s, under the influence of the industrial economy, efforts were addressed to identify the structural factors that condition innovative efforts in organisations. Operational aspects of the management of R&D projects are forgotten and a series of analytical models are proposed articulating the most significant decisions for the strategic management of technology. The core aspect is the formulation of the innovation strategy most adequate for the characteristics of the industry. So, they assume that success in the innovation process is ensured if:

1 the structural features of the industry are identified

2 the technology portfolio is arranged and

3 the time (when?) and the most adequate way (how?) to access the new technologies are chosen.

New and diverse tools have been developed intending to set a pattern for such decisions and to help in the analysis and formulation of technological strategies: portfolio models (Roberts and Berry, 1985), S curves (Foster, 1986), technological typologies according to their maturity and competitive impact (Roussel et al., 1991) and many others. These models are aimed at finding answers to questions such as: How should technology improve our competitive positions? (Quinn, 1985), How should we integrate technology in corporate strategy? (Katteringham and White, 1984), When should we innovate: be a leader or a follower? (Ansoff and Stewart, 1967) or How to innovate: acquisition of licences, technological cooperation and internal R&D? (Ford, 1988).

At this stage, some works are concerned with setting the theoretical basis for the technological strategy according to the characteristics of the industry involved (Porter, 1983). Similarly, some empirical research examines the relations between R&D efforts made by firms and the structure of the industries (Clark and Hayes, 1985).

Such contributions, as far as they take into account the effect of contextual factors, represent remarkable progress with regard to preceding studies. They acknowledge that with an adequate technological strategy, firms may improve their competitive position. However, in such models of strategic management of technology, a static vision of the technological innovation process persists. As they are based on the traditional analyses of the industrial economy – as for instance that of Dasgupta and Stigliz (1980) – influenced in turn by the neoclassical orthodoxy, they are oriented towards the analysis of the conditions of equilibrium in one or several moments of time.

Just as the strategic management models having a 'Porterian' root represent technological competition as a comparatively static exercise (Hill and Deeds, 1996), they are useful for the analysis of a given situation at a given moment of time and for the prescription of the most adequate strategy for the achievement of a desired situation of equilibrium in the future. On the other hand, they cannot reflect the process that leads from one situation to another. This means ignoring that innovation is a dynamic process where success is determined by the competition between firms and technologies. Identification of the causes that determine the stock of resources and technological capacities of firms at a specific time has been considered more important than knowledge of how such resources are accumulated over time.

In the majority of such works, the process of innovation is deemed to be 'partially' endogenous. The firm has a limited capacity of control over the innovation process. It may orient the innovation process (but its actions are limited by the structure of the industry). Like the works of the preceding stage, they have a restrictive conception of the sources of innovation in firms. They emphasise the role of R&D activities and they underestimate other forms of technological knowledge (learning by use, learning by practice and learning by error).

Since 1990s, the central aspect consists of the formulation of the strategy of innovation that allows the firm to exploit internal technological resources and capacities and to develop new products on the basis of such resources. Currently, the influence of evolutionists' approaches and resource theory has contributed to the enrichment of studies on the management of business technology. Technological evolution is conceived of as a continuous and dynamic process that combines technological resources to generate new technological capabilities (Christensen and Foss, 1996; Hamel and Heene, 1994). This has oriented research in this field towards the consideration of the internal factors of the organisation. The firm is characterised as a combination of technologies, that is, as a depositary of knowledge applied to problem solving (Spender, 1996). Under such a perspective, technological strategy acquired a central role and became integrated, conflated, with corporate strategy (as far as technology is the main factor to be exploited by firms for their development).

Long-term competitive success is presupposed to be based on the capacity of the firms (Hill and Deeds, 1996):

1 to generate knowledge and materialise it into valuable innovations

2 to protect their essential technological competences from the action of imitators, creating efficient barriers to imitation and

3 to beat organisational inertia and rapidly imitate the valuable innovations of competitors.

Models of congruence concerning the organisation of innovation have been presented and a number of design recommendations have been made aiming at overcoming organisational inertia (Tushman and O'Reilly, 1997). In addition, measures have been proposed for the promotion of creativity in organisations and intended to encourage the creation of new technological knowledge (Nonaka and Tekeuchi, 1995).

At this stage, most works pay greater attention to empirical evidence. Within a consistent block of research efforts having their origin on the seminal work of Abernathy and Utterback (1978) and referred to innovation patterns, similar explanatory models

of the dynamics of the innovation process have been developed (Abernathy and Clark, 1985; Anderson and Tushman, 1990; Clark, 1985; Utterback, 1994). All of them emphasise the significance of the appearance of dominant designs in the evolvement of industries. Likewise, in other research work related to the above it has been verified that certain types of innovation – that of an architectural nature – may have a very strong competitive impact (Henderson and Clark, 1990).

Other works have focused on the study of learning mechanisms and the characteristics of technological knowledge. The learning-by-use process has been studied (Leonard-Barton, 1995; Von Hippel, 1988), as well as learning by error (Maidique and Zirguer, 1985). That the acquisition and assimilation of new knowledge occurs by accumulation and consequently requires time and availability of a certain absorption capacity is an acknowledged fact (Cohen and Levhintal, 1990). In addition, several dimensions of technological knowledge have been described, especially the one that refers to its tacit components (Winter, 1987), while the problems presented by its transfer have been examined (Zander and Kogut, 1995).

On the other hand, the efficiency and the employment level of different mechanisms available to firms for the protection of their innovation achievements have been subject to investigation (Levin et al., 1987). Explanations have been given on how the degree of appropriation of the income that may be generated by an innovation will be dependent on the control that the firm exerts over supplementary assets (Teece, 1987).

Research efforts at the time were oriented towards the study of the historical process in which competition between technologies and firms was present and a situation of stability was never achieved. They believe that the evolvement of technology fundamentally depends on the path it followed in the past (path dependency). In their opinion, the innovation and dissemination of a given technology is subject to an essentially dynamic process where through a number of self-reinforcing mechanisms – different modes of learning, the appearance of net and scale economies, the development of supplementary technologies – the technology gradually improves its performance.

According to these papers, firms play an active role in the changes of the technological environment and have a strong ability to become involved in the innovation process. The innovation process has a dynamic nature where success is determined by the competition between firms and technologies. The firm plays an active role in the innovation process and is able to orient it to modify the structure of the industry where competition takes place.

These works assume that the principal component of technology is not information but knowledge. Therefore, they take into account the different dimensions of knowledge: tacit dimension, complexity degree, dependency degree, degree of observability, teachability, etc. This notion is consistent with a broad-ranging conception of innovation sources where the various learning modes are taken into account: learning by use, by practice, by error and so on.

The research effort of scholars and consultants within the field of innovation management was first oriented towards the development of tools of an operational nature for the improvement of R&D management. Subsequently, interest focused on the elaboration of methodologies for the strategic management of innovation. Parallel to this, the level of theoretical and empirical grounding of research efforts increases (or its increase is intended).

The methodologies and the assumptions set forth in the studies have gradually evolved. From assuming that the technological innovation process had a static (exogenous) nature, they have come to consider that its nature is dynamic (endogenous). This change has been accompanied by a change in the perception of the technology characteristics. From assuming that the fundamental component of technology was information, they now consider that the fundamental component is knowledge.

Our knowledge on innovation has been enriched in recent years with all such contributions. However, one of the reasons for its slow advance is that many researchers have ignored the contributions made by other areas of knowledge. If a conceptual reference frame is to be established that permits the study of the technological at firm level, the methodological and conceptual barriers that separate these disciplines must be removed. As far as research on the field of the strategic management of technology is concerned, it is necessary to overcome the difficulties inherent to gathering data on internal resources of the firm and to base these works on strict empirical evidence.

The set of works included in this special issue is intended to contribute to the understanding of the innovation process and to the creation of knowledge in organisations. Pursuant to the background and aims of the 'Strategies for Innovation and Technological Knowledge-Creation', papers have been grouped by blocks. The first block contains works that analyse several issues on TM and innovation, and range from basic aspects relative to determinant innovation factors to other topics such as the appropriation of the results of innovation, the influence of technological effort on corporate strategies, the creation of technological alliances and the use of new technologies.

The second block contains works related to technological knowledge-creation strategies and is within the frame of the knowledge-based view approach of the firm. This block of papers examines several topics, such as the factors determining organisational learning and knowledge-creation, complexity management, causal ambiguity and the influence of knowledge on the formation of technological joint ventures.

All the works included have a similar structure with regard to their content. In addition to the introduction, where the goals to be achieved are described, the discussion covers background issues, theoretical models, design hypotheses, testing of such hypotheses, results and pertinent conclusions. The fact that in every case an empirical research effort is made to match hypotheses with recent data should be emphasised.

The most widely discussed topic is that of the determinant factors of innovation, which has already merited four proposals. Firstly, by Professors Pérez Cano and Quevedo Cano, deals with the influence of human resources management at the levels of innovation through promotion and remuneration policies, the organisation of work teams, the creation of a common language and the experience of employees, with pay policies seemingly having greater significance.

The paper by Professors Díaz-Díaz, Aguiar-Diaz and de Saá-Pérez deals with the influence of technological knowledge assets at innovation levels, and finds that the assets with a tacit nature and the capabilities formed by complex combinations of resources are the most important factors, as against other technological assets.

Cooperation between the marketing and R&D departments is studied by Professors Cordón-Pozo Aragón-Correa and García-Morales, to find out the degree of innovation as

measured by success in the development of new products. To this end, they use organisational structure, organisational climate and context variables, suggesting that the two latter have a stronger influence.

Finally, within the factors that determine innovation, the work of Professors Cabello-Medine, Carmona-Lavado and Valle-Cabrera identifies the variables that lead to each of the basic innovation types: radical versus incremental. With this purpose, they select variables relating to the strategic flexibility inherent to virtual organisations, the fluency and rapidity of information flows, the degree of vertical and horizontal differentiation of tasks and the degree of dynamism of the environment.

Other works regarding technology and innovation management touch on very diverse topics. For instance, Professor Galende investigated the factors that determine the reasons why firms choose between the different methods of appropriation of the results of technological activity, making a distinction between patents, industrial secrets, imitation costs and timing, continued innovation and supplementary resources.

Technological potential is the independent variable used by Professors López-Sánchez, Minguela-Rata, Rodríguez-Duarte and Sandulli when dealing with the degree of diversification within the Neo-schumpeterian line of research. In this case, the availability of patents as a measure of the output of technological innovation is used for explaining the degree of diversification of firms, both direct and indirect through subsidiaries, as well as the management of diversification.

The work of Professors Montoro-Sanchez, Mora-Valentin and Guerras-Martin deals with the reasons that lead firms to enter into R&D cooperation agreements with research organisations according to the characteristics of the partners: firms, universities and research organisations. In this connection they classify agreements according to various criteria such as investment levels, government aid, type and number of partners and duration of the agreement.

The final paper of this block – by Professors Fernández and Nieto – refers to the use of new technologies by firms. In this case, it is the use of the internet that serves to explain the creation of organisational capabilities and to define the limits of the firm. The work finds positive relationships between the use of the internet and the differentiation of products and the introduction of organisational changes, while modifying the limits of the firm, according to the vertical integration degree.

The second block, devoted to the strategies of creation and management of technological knowledge, opens with two methodological proposals, which are, respectively, due to Professors Pérez López, Montes Peón and Vázquez Ordás on the one hand and to Professors García-Muiña, Martín de Castro, López Sáez and Navas López on the other hand. The former deals with factors that benefit organisational learning, that is, decentralised strategic planning, organisational structure, corporate culture regarding cooperation, leadership for change and human resources practices. The latter considers a theoretical model of definition, measurement and description of the complexity of technological capabilities.

The next three papers have one thing in common: the consideration of variables that determine the creation of technological knowledge. So, the work of Professors Wha Sawng, Ho Kim, Doug Rah and Han tries to identify the relationship between the characteristics of R&D groups and the management of knowledge activities as well as to analyse the differences of such relationships according to firm type and size. The results show that the degree of knowledge creation is high when the groups are small, the percentage of women is high and the degree of cohesion of the group is equally high.

The paper of Professors Quintana-García and Benavides-Velasco deals that the combined effect of localisation and cooperation agreements on the access to scientific and technological knowledge and the creation of competencies. The conclusions reached by these authors show that forming part of a cluster and performing vertical alliances positively influences the transmission of information and tacit knowledge as well as the creation of productive and marketing capabilities. In turn, nearby localisation favours the creation of alliances.

On the other hand, Professors Carlos Real, Leal and Luis Roldán study the influence of organisational learning on the creation of different technological competencies. The orientation of the firm and the orientation of learning and information technologies are key factors of organisational learning that decisively contribute to the creation of technologic competences.

The role played by the causal ambiguity of technological knowledge in the success of a firm is discussed by Professors González-Álvarez and Muñoz-Doyague from a twofold standpoint: the negative internal effect in the transmission of knowledge within the organisation and the positive external effect of protection of the competitive advantage over competitors. The results show that although the internal effect is higher than the external effect, adequate human resources policies may favourably contribute to performance.

Finally, the work of Professors Revilla, Acosta and Sarkis deals with how Knowledge Management and learning processes may function to support a successful research and development collaboration. For this purpose, they introduce a typology to help categorise various collaborative efforts within a Research Joint Venture (RJV) environment, based on two dimensions: the locus of the RJV knowledge and the Knowledge Management approach.

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