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Corporate knowledge diversification in the face of technological complexity: The case of industrial biotech☆

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ABSTRACT

In the course of late twentieth century, successive waves of molecular biological revolutions (recombinant proteins, monoclonal antibodies, genomics, proteomics, stem cells, tissue engineering, gene therapy) have emerged. As a result, technological knowledge base has become more complex. However, innovation and management studies have been ambivalent about this process. Part of the literature suggested that technological activity is highly industry-specific and accumulative. On the other hand, literature at the firm level has recognized that there has been corporate diversification. Such ambivalence reflects the tension between both micro process of technological diversification and technology convergence. One of the main empirical results of this paper is that inter-industrial convergence is localized covering some subsets of "industrial biotechnology" products. Secondly, patent data enable to distinguish between different kinds of corporate technology coherence: whereas health industry adopt conglomerate biotechnological diversification, industrial biotechnology corporations adopt a more coherent technology diversification enabling innovation and (dynamic) efficient growth.

1. Introduction

Towards the end of the 20th century, there were a series of revolutions in molecular biology (recombinant proteins, monoclonal antibodies, genomics, proteomics, etc.) that forced the major pharmaceutical, chemical, and agrifood groups to diversify their knowledge bases beyond their core capacities (Chesnais, 1981; Nightingale and Martin, 2004; Chandler, 2005; Ninghtingale and Mahdi, 2006). The dynamics of these technological revolutions have brought about a tension at the heart of neo-Schumpeterian approaches between an understanding of technological activity that is highly specific to each industry and the literature that analyzes groups' diversification strategies (Patel and Pavitt, 1997: 141; Patel, 1999: 8; Von Tunzelmann, 2006: 6).

This leads to the problem of complexity in the context of the theory of the firm. That is, how firms respond to the increasing complexity of their knowledge bases that results from the coexistence of different technologies. In light of this, the literature maintains, on the one hand, that firms can be understood as "adaptive complex systems" that can break down and specialize, simplifying their innovative activity so as to be manageable (Anderson, 1999). Other authors argue that when facing complexity, firms

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can diversify their knowledge base in a non-random fashion towards complementary technologies, thus ensuring a certain degree of coherence within themselves (Teece et al., 1992: 2).

Based on this discussion, this article asks whether the result of this tension between technological convergence and divergence is a single biotech paradigm that is shared by various industries, or if, in contrast, different paradigms that are highly specific (and complementary) to the pre-existing trajectories of each industry co-exist[1]. As such, a second question that arises is how firms respond to the increasing complexity of their knowledge bases, given the coexistence of different technologies. In particular, if large corporations have managed to consolidate a coherent knowledge base or have limited themselves to a conglomerate expansion in which different technologies become another asset in their financial portfolio.

To explore these questions, this paper is based on a methodological approach that uses patent data for a set of leading biotech firms to measure technological diversification. Section 2 contains a conceptual discussion of how the tension between specialization and diversification processes within large firms can explain the emergence of new technological paradigms. After the empirical framework has been presented, Section 4 considers how far there is a tendency for knowledge to converge into a single knowledge base that is shared by different industries. Section 5 analyzes whether this process is manifested in diversification strategies that are coherent with the knowledge base, or whether conglomerate diversification predominates among the different fields of biotech. It also considers how these strategies affect the pace of firms' biotech innovation. Finally, Section 6 presents conclusions and directions for future research.

2. Conceptual framework

Our starting point is the evolutionary theory of the firm, within which firms are understood as repertories of routines that define their own technological capabilities and their competitive performance (Nelson and Winter, 1982: 97). Through practice, repetition, and more or less incremental improvements, certain firms acquire capabilities in specific technologies. This allows the limits of the firm to be described above and beyond transaction costs, internalizing activities in which the firm has "core capabilities" that is, those innovation-, production-, and marketing-related activities for a limited set of products that the firm "knows how to do well" (Teece et al., 1992).

Although this perspective fills a theoretical void in neoclassical theory by explaining how firms innovate in a context of uncertainty, in certain circumstances when there is a change in the technological paradigm, firms must explore outside their prior knowledge base with greater intensity, seeking opportunities and orchestrating complementarities so as to create "new combinations." As Dosi argues (Dosi, 1988: 1133), in these circumstances, there is "a continuous tension between efforts to improve the capabilities of doing existing things, monitor existing contracts, and allocate given resources, on the one hand, and the development of capabilities for doing new things or old things in new ways."

In seminal literature of path dependency one technology is selected among a greater number of technologies.

This tension is expressed on both the theoretical and practical levels. In theoretical terms, two analytical perspectives can be identified in neo-Schumpeterian literature (Fai and Von Tunzelmann, 2001):

(i) First, studies that stress innovations as a *highly accumulative and stable pattern of technologies and activities* that are *specific to each industry* and that is the result of experimentation, experience, and interactions within firms or between the suppliers and users of new products (Patel and Pavitt, 1997: 141). From this point of view, innovation processes are *highly path dependent*, in that firms seek to solve their techno-economic problems in a way that is conditioned by their prior technological problem-solving experiences, giving rise to sector-specific knowledge bases. As a consequence firms (and industries) would show persistent and stable activities and technologies' portfolios.
(ii) Second, there are a wide range of studies that point out that the diversification of the knowledge base is a key feature of large firms' strategies (Fai, 2001; Fai and Mendonca, 2010). When unexploited scientific and technological opportunities and/or problems that cannot be solved using existing technology arise, firms broaden their knowledge base beyond the technologies that are specific to their products, resulting in a technological diversification that is greater than their productive diversification (Patel, 1999: 8; Tunzelmann, 2006: 6).

Several authors recently have acknowledge that even if path dependency has a constraining effect on firm's strategies, there are space to creativity and certain big corporations are able to influence the course of events, can generate new paths through technological diversification (Fai and Von Tunzelmann, 2001; Araujo and Harrison, 2002; Antonelli, 2009; Garud et al., 2010). Consequently, it's possible to admit the coexistence of multiple paths that can eventually converge (or not). For example some multi-propose technologies, such as biotechnology, have the potential to affect the potential of several paths and literature on industry convergence seems to suggest that a creative synthesis of several technological paths can generate new paths, e.g.: the emergence of "functional foods" and

[1] Dosi (1982: 147) defines a technological paradigm (a term based on Kuhn's concept of a scientific paradigm) as a techno-economic problem-solving "pattern" based on highly selective natural science principles, together with specific rules that are oriented towards acquiring new knowledge and safeguarding it from competitors wherever possible Technological paradigms define a knowledge base that has resulted from different scientific opportunities for future innovations, on the one hand, and on the other, from a limited set of heuristics or search procedures regarding how to take advantage of these opportunities and ensure that they are appropriated.