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Mapping Innovation Strategies Through Patent Data

Technology Development In The Bio-Pharmaceutical Industry

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***Abstract*— Our research comes within the studies concerning innovation strategies. The aim of the paper is to define a set of innovation behaviors, by analyzing patent data. The work contributes to the current literature on innovation management by providing an integrated framework which detects four dimensions of innovation processes (core vs. non-core, exploitation vs. exploration, closed vs. open, incremental vs. radical) and describes how companies manage technological evolution and organize R&D activities from a quantitative point of view. The methodology is tested on a sample of 98 R&D intense companies from the bio-pharmaceutical industry, by analyzing 10,983 patents applied in 2012.**

Keywords*— innovation strategies, exploitation vs. exploration, closed vs. open innovation, incremental vs. radical innovation, patent data analysis, bio-pharmaceutical industry.*

I. Introduction

Patent data are the only formally and publicly verified output of inventive activities and are widely accepted as a measure of innovation. In the scientific literature, patent data are used to investigate technological innovation strategies implemented by innovative firms. Our research question is: how can innovation strategies of companies be analyzed through patent statistics? The research is based on data detected from PATSTAT database which will be used to map the innovation strategies of companies. In particular, *exploitation* vs. *exploration* activities, *closed* vs. *open* processes and *incremental* vs. *radical* outputs are studied. The methodology is tested on a sample of 98 R&D intense companies from the bio-pharmaceutical industry, by analyzing their patents applied in 2012, validating both the framework applicability and its explicative power and usefulness. From the analysis of the behaviors of companies, *exploitation* strategies that lead to *radical* outputs seem to be the most relevant within the sample. We also detected a widespread adoption of *open innovation* and a relevant concentration of R&D efforts on *core* technology fields.

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In what follows, after a brief literature review on patent-based metrics for innovation, the measurement framework is presented and then applied to the sample. Results are discussed and conclusions will close the work.

II. Literature Review

Patent data are used for analyzing both innovative activity [1] [2] and its output [3] [4] and are widely accepted as a measure of innovation [5] [6]. Data provided by patents offer a valuable source of information, useful to both keep track of the technological strategy evolution of companies and make comparisons, as they contain standardized data, stored for a long period of time and continuously updated [7].

We propose an integrated framework based on the combination of variables already acknowledged in scientific literature concerning *exploitative* vs. *explorative* activities, *closed* vs. *open* processes and *incremental* vs. *radical* outputs. In what follows, a deepening of the operationalization of each dimension under investigation is reported.

Since March's [8] work, a wide debate has raged over the need for balance between exploiting the knowledge an organization already holds and exploring for knowledge that is different and new to the organization. *Exploitation* is associated with current viability and thus leads to more capability at current activities, while *exploration* is related to the acquisition of diverse and novel body of knowledge that will serve as the seed for future technological developments. In order to assess how companies manage their learning activities, scientific literature investigates International Patent Classification (IPC) codes to define the technology field on which the patent impacts. A patent may be assigned one or more IPC codes, depending largely upon the patent's breadth of coverage. Each code can be considered as a proxy of skills developed by the firm in a specific technology domain. A patent is considered as an explorative one when it is situated in a technology domain that is new or unfamiliar to the firm, i.e. the firm did not patent in the technology domain in the past five years [9]. On the contrary, exploitative technological processes are acts of creation in technological domains where the firm has already patented technology in the previous five years. Such approach is widely diffused among scholars.

Regarding the organizational dimension of R&D, firms can either invest on their own resources and efforts, developing *closed innovation* processes, or open up their R&D processes through pooling of collaborative activities and/or trading of intellectual property rights [10] [11]. Patents can be viewed as a result of the collaboration with third parties: Al-Ashaab et al. [12] propose the number of patents deriving from

collaborative projects as a proxy of *open innovation*. Consequently, co-patents seem to be a relevant indicator for signaling the occurrence of *open innovation* strategies [13]. By analyzing the assignee field of a patent application, information about the ownership of innovation can be detected and it is possible to understand whether the patent is the result of collaborative activities. Such operationalization is widely diffused and many scholars, using joint-patenting information, reported a growing *open innovation* adoption [14].

As regards *incremental* vs. *radical* outputs, the former are minor improvements or simple adjustments in current technology [15], while the latter are based on a different set of engineering and scientific principles and often open up whole new markets and potential applications [16] [17]. According to literature, the radicalness of an innovation can be detected through the analysis of backward citations, which trace out knowledge flows and technological learning: a citation from patent Y to patent X indicates that inventors on Y knew about and used X in developing Y, therefore patents without backward citations to prior technical art can be considered 'pioneering' [18], determining an innovation based on a different set of engineering and scientific principles, i.e. a *radical* innovation. On the contrary, the existence of backwards citations may be a proxy of *incremental* innovations, enhancing the firm's competencies in a specific industry.

Even if in scientific literature patent data are widely used to investigate technological innovation strategies implemented by innovative firms, most attention has been devoted to only one dimension of R&D processes at time and only a limited number of contributions analyze the mix of concepts related to innovation activities, e.g. evaluating the impact of *open innovation* on exploitative and explorative processes through patent statistics [9] [19]. Further, although many contributions aimed at identifying the innovative behaviors of companies, they show only a partial overview of the innovation strategies pursued. Therefore, an integrated patent-based map of innovation capabilities, processes and competencies seems to be lacking. In this paper we aim at investigating patent data after a multidimensional point of view, in order to 1) analyze the whole innovation process in terms of capabilities, activities and competencies and 2) mapping the innovation strategies of companies.

III. Methodological Framework

Starting from the literature review, we designed a framework that combines all the aforementioned variables with the aim of defining the innovation strategies adopted by companies after a multidimensional perspective. By simulating innovation through an input-process-output model, we believe that innovation strategies are pursued through management choices on capabilities, activities and competencies. In particular, capabilities are considered as the input of our model and can be related to *exploitation* and *exploration* strategies on each technological field in which the firm is involved. Activities are linked to the organization of R&D efforts and are here summarized by the choice of collaborating or not with other firms. Finally, the patent, which is the concrete manifestation of competencies developed by the company at the end of the innovation process, can be considered as a proxy of *radical* or *incremental* innovation, depending on the potential pioneering of the output. A fourth dimension is added to the input-process-output model: the *relevance* of the process, that can be defined high if the capabilities which gave raise to the process are *core*, low otherwise (Fig. 1).

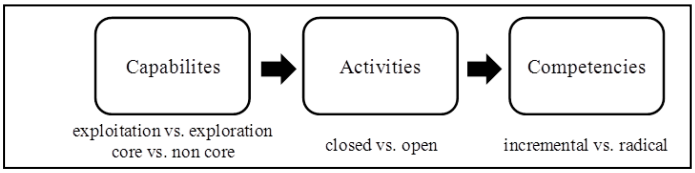

Figure 1. Input-process-output model for innovation

The starting point of our work is the extraction of patents from PATSTAT database: for each analyzed company we considered all its patents applied in the investigated time interval, and recorded patent classification codes, number of applicants and number of backward citations, in order to examine capabilities, activities and competencies respectively.

As suggested by scientific literature, technology fields can be analyzed by detecting IPCs recorded in patent applications. In our framework, we used Cooperative Patent Classification (CPC) system, a new patent classification system that has been jointly developed by the European Patent Office (EPO) and the United States Patent and Trademark Office (USPTO) which can be considered as an evolution of IPC, since it is more specific and detailed. At least one CPC is related to a patent application, in order to define the technological areas on which patents have impact. CPC categorizes technological field into a five-level hierarchical system, from the broadest to the very specific: *section*, *class*, *subclass*, *main group* and *subgroup*. In order to identify the technology field, we decided to cut the code to the main group, since the operationalization of the variable *capability* clearly requires more generalization.

After data extraction, for each company we have a list of all the CPCs detected in the patents it filed in the selected time horizon. CPCs can be labelled as *core* or *non-core* and *exploitative* or *explorative*. In particular, each CPC is defined *core* if it is declared in at least 10% of the patents filed in the previous five years, *non-core* otherwise; *exploitative* if the company filed patents in such technology domain in the past five years, *explorative* otherwise. Obviously, from these two definitions, no *core* and *explorative* CPCs can be found. In Table 1 the methodology for CPCs labelling is provided.

TABLE 1. CPCS LABELLING

CPC label	If
core exploitative	the company filed more than 10% of its patents of the previous five years in the technology domain described by the CPC
non-core exploitative	the company filed some patents, but less than 10% of those registered in the previous five years, in the technology domain described by the CPC
non-core explorative	the company did not file any patent in the previous five years in the technology domain described by the CPC

Further, by analyzing patents that declare the specific technological field and detecting the number of owners and backward citations, we can define their nature as (Tab. 2):

- *closed* if only one applicant is found, *open* otherwise;
- *incremental* if at least one backward citation is detected, *radical* otherwise.

TABLE 2. PATENTS LABELLING

		No. of applicants of the patent	
		one	*two or more*
The patent has backward citations	*yes*	closed incremental	open incremental
	no	closed radical	open radical

Given that a CPC can be detected in more than one patent for each company, both *closed* and *open* patents, as well as both *incremental* and *radical* ones, can be found, i.e. the competencies can be used by companies in both their *closed* and their *open innovation* processes and can give raise to both *incremental* and *radical* outputs.

Thus, our framework describes the innovation processes adopted for each CPC through four dimensions. Each patent that contains the analyzed CPC is described with four different labels, the first two inherited from the belonging CPC, and associated to only one of the twelve available different behaviors in R&D processes explained in Figure 2.

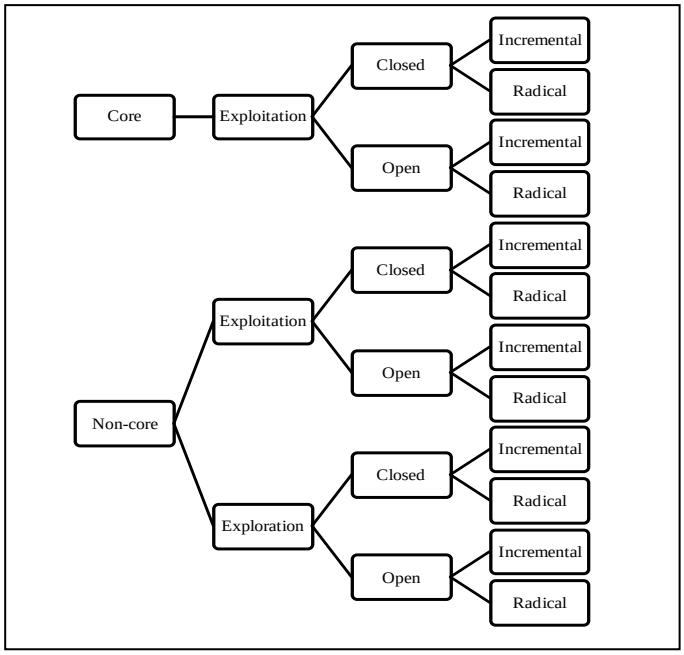

Figure 2. Twelve different behaviors in R&D processes

At the end of the analysis of documents containing the specific CPC, we obtain the number of patents related to each configuration. The combination of behaviors describes the innovation strategy pursued in such technology domain.

The individual information collected for each technological class is used to study the overall behavior of a firm, summing the results obtained from all the CPCs.

Therefore, our framework can evaluate the weight of a single behavior on the mix of innovation strategies of companies in a specific time interval, i.e. the map of innovation processes. A share indicator that summarizes the impact of a specific combination on the overall innovation strategy describes each behavior.

As the framework is built, we can potentially make partial analysis, considering only one to three labels and excluding the others, obtaining:

- 8 cumulative share indicators by considering one label (*core*, *non-core*, *exploitation*, *exploration*, *closed*, *open*, *incremental*, *radical*);
- 23 share indicators by considering the combination of two labels (e.g. 4 indicators deriving from the combination of *closed* vs. *open* with *radical* vs. *incremental* innovation);
- 22 indicators deriving from the combination of three labels.

Adding the previous 12 behaviors, 65 indicators can be defined in our framework.

Of course, two of the most discussed trade-offs in the scientific literature are *exploration* vs. *exploitation* and *radical* vs. *incremental* innovation strategies. Through our framework, we can evaluate the adoption of such strategies, or their mix. Table 3 defines the capabilities-competencies matrix.

TABLE 3. CAPABILITIES-COMPETENCIES MATRIX

		capabilities	
		exploitation	*exploration*
competencies	*incremental*	strengthening	expansion
	radical	advancement	explosion

Companies that exploit their capabilities in order to obtain *incremental* innovations pursue a *strengthening* innovation strategy, related to continuous improvement and evolution on already known technologies; otherwise, if their outputs are *radical* they carry on an *advancement* strategy, based on the development of potential revolutionary innovations and the exploitation of capabilities already owned. Firms may also explore new unknown technological fields, through the *expansion* in new technology domains of innovations already available, or obtain *radical* innovation through activities trespassing knowledge boundaries and leading to new concepts that depart from past practices, carrying on an *explosion* innovation strategy. As they are defined, the four strategies are complementary and considering their four share indicators we can summarize the overall innovation strategy of the company.

Starting from the behaviors described through the capabilities-competencies matrix, by adding the information about relevance and process organization, we can define a simple nomenclature for the twelve different combinations (Tab. 4).

TABLE 4. BEHAVIORS FOR INNOVATION STRATEGIES

Label	Behavior
Core - Exploitation - Closed - Incremental	Core closed strengthening
Non-core - Exploitation - Closed - Incremental	Non-core closed strengthening
Core - Exploitation - Open - Incremental	Core open strengthening
Non-core - Exploitation - Open - Incremental	Non-core open strengthening
Non-core - Exploitation - Closed - Radical	Core closed advancement
Core - Exploitation - Closed - Radical	Non-core closed advancement
Core - Exploitation - Open - Radical	Core open advancement
Non-core - Exploitation - Open - Radical	Non-core open advancement
Non-core - Exploration - Closed - Incremental	Closed expansion
Non-core - Exploration - Open - Incremental	Open expansion
Non-core - Exploration - Closed - Radical	Closed explosion
Non-core - Exploration - Open - Radical	Open explosion

Therefore, our framework supports us in identifying innovation strategies of firms in a specific time interval and provides a useful instrument for benchmarking. As already explained, even singular or partial analysis can be conducted, e.g. we can evaluate the role of *exploration* activities or the *open innovation* adoption simply analyzing the *exploration* and *open* share indicators.

IV. Findings

The framework was applied to a sample of 98 R&D intense companies from the bio-pharmaceutical industry ranked by their investment in R&D, according to *The 2012 EU Industrial R&D Investment Scoreboard*, excluding firms whose 2012 annual reports were not available and those for which the list of subsidiaries was not found in such documents. We choose this industry because it is the first for R&D investments, uses patents as a means of appropriation of innovation [20] and shows a greater propensity in the adoption of *open innovation* [21] [22]. In order to consider the impact of R&D activities on the corporate group, we searched patents developed by both the parent company and its subsidiaries disclosed in annual reports, also taking into account patents related to acquired companies and applied after the acquisition. We analyzed patents applied in 2012 and gathered data from PATSTAT database, examining 10,983 documents. We downloaded all patent applications of companies, including documents related to their subsidiaries, identifying the CPCs registered and verifying if they were *core*/*non-core* and *exploitative*/*explorative* by analyzing 153,807 patents from 2007 to 2011 and recording information about number of applicants and backward citations. We applied our framework in order to estimate the overall innovation strategy of each company. Then we cumulated the results obtained for each firm, evaluating the behavior of the whole sample. Table 5 reports the share of the twelve configurations for the whole sample, while Table 6 shows the capabilities-competencies matrix for patents applied in 2012.

TABLE 5. INNOVATIVE BEHAVIORS OF THE SAMPLE

Behavior	Share
Core closed strengthening	4.93%
Non-core closed strengthening	9.36%
Core open strengthening	7.63%
Non-core open strengthening	16.20%
Core closed advancement	16.30%
Non-core closed advancement	35.62%
Core open advancement	2.16%
Non-core open advancement	4.75%
Closed expansion	0.39%
Open expansion	1.45%
Closed explosion	0.93%
Open explosion	0.27%

TABLE 6. CAPABILITIES-COMPETENCIES MATRIX FOR PATENTS ANALYZED

competencies \ *capabilities*	**exploitation**	**exploration**
incremental	38.12% strengthening	1.85% expansion
radical	58.83% advancement	1.20% explosion

The *non-core closed advancement* is detected in over one third of innovative activities, with companies obtaining *radical* outputs starting from capabilities that currently are less relevant for their business. A similar behavior was found in *core* activities, with *core closed advancement* representing the most pursued strategy for relevant technology fields. Regarding *open innovation* adoption, in general, it is detected in about 32% of the patent applications and companies seem to prefer such behavior in *strengthening* activities, exploiting the capabilities of partners in order to achieve improvements on already known technologies. As a matter of fact, in the analyzed industry no single firm possesses all the knowledge, skills and techniques required, therefore collaboration strategies for technology acquisition are frequently adopted. *Strengthening* and *advancement* strategies are the most relevant ones, and in particular, the latter was detected in over half of the patent applications. In the bio-pharmaceutical industry - where 1) the technology is complex and expanding, 2) future revenue streams originate from current R&D, and 3) R&D is time-consuming, uncertain and costly - *exploitation* strategies are strongly preferred. As to *exploration* activities, their impact is less relevant and it seems to be in accordance with the characteristics of the industry, which requires the possession of specific skills and experience to produce highly scientific outputs. Furthermore, *radical* innovation seems to strongly characterize this industry, with about 60% of R&D activities leading to a *radical* output and patents without backward citations.

v. Conclusions

We suggest a methodology for mapping innovation strategies based on patent applications, that are a direct outcome of the inventive process and, more specifically, of those inventions which are expected to have a commercial impact. Patents are the only formally and publicly verified outputs of inventive activities [23]. Some limitations of the study can be defined. First, the use of patenting information as a proxy of technological activities might underestimate the phenomenon, since not all R&D efforts will result in an application for a patent. Second, the research is limited to only one industry. Third, the use of patent data for investigating the adoption of *open innovation* could be questionable, since not all collaborations will be captured by co-patenting activities [24].

In addition, the capabilities-competencies matrix may contribute to the literature on innovation, pointing out the differences between *exploitation* vs. *exploration* strategies and *incremental* vs. *radical* outputs. As a matter of fact, these concepts are often treated alternatively in current literature but they can be evaluated separately since they describe two different dimensions of innovation activities.

The results found in the analysis are affected by our definition of *core* and *non-core* activities - CPCs are considered *core* if they are declared in at least 10% of the patents filed in the previous five years - and in particular by the decision of cutting CPCs without considering the subgroup number, in order to avoid excessive detail on the definition of the capabilities of firms. Another questionable approach is related to the definition of *exploitative* activities: companies may not lose experience if they did not patent in the previous five years in a specific technology domain, since in the bio-pharmaceutical industry R&D processes are time-consuming and may generate outputs after ten or more years. We preferred to follow the approach already acknowledged in scientific literature but our consideration suggests a deepening of the operationalization of *exploration* and *exploitation* variables.

The paper addresses the need for operative, practical instruments, which can help managers to monitor and control their innovation activities. Given the availability and objectivity of patent documents, studying continuous innovation through the analysis of patent data can help decision-makers to assess the status of their own strategies and compare it over time and space, also allowing the benchmarking with competitors.

Further research will be addressed to widening our sample of investigation, by analyzing different industries, making comparisons among innovation strategies of companies with different features and detecting the evolution of technological patterns considering a larger time interval. Correlations between strategic behaviors detected through our framework, context features (e.g., firm's age and dimension) and financial performance indicators are under investigation. Finally, we are trying to match the openness indicator provided by this framework with the openness ratios measuring the pecuniary dimension of *open innovation* [25].

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