ARTICLES

Submitted 01.23.2021 Approved 06.07.2021

Evaluated through a double-blind review process. Guest Scientific Editor: Fernanda Reichert

Original version | DOI: http://dx.doi.org/10.1590/S0034-759020220206

DOES ACQUISITIONS IMPACT THE FIRM'S TECHNOLOGICAL DEVELOPMENT? A STUDY USING KNOWLEDGE BASE IN THE PHARMACEUTICAL INDUSTRY

As aquisições impactam o desenvolvimento tecnológico das empresas? Um estudo sobre bases de conhecimento na indústria farmacêutica

¿Tienen las adquisiciones un impacto en el desarrollo tecnológico de las empresas? Un estudio centrado en la industria farmacéutica

Murilo Montanari de Matos[1] | murilo.montanari@sp.senai.br | ORCID: 0000-0003-4141-4958

Ana Paula Macedo de Avellar[2] | anaavellar@ufu.br | ORCID: 0000-0001-8455-9458

[1]Serviço Nacional de Aprendizagem Industrial, Supervisão de Inteligência de Mercado, São Paulo, SP, Brazil

[2]Universidade Federal de Uberlândia, Instituto de Economia e Relações Internacionais, Uberlândia, MG, Brazil

ABSTRACT

This article focuses on the acquisition of small pharmaceutical firms (SPHF) by large pharmaceutical firms (LPHF). LPHFs enlarge their own knowledge base by incorporating their target's knowledge base. Given this scenario we pose the question: Is it possible to link knowledge acquired via an acquisition to technological development? In order to answer this question we developed an approach that allows the impact of a target's knowledge base to be observed in the acquirer's own knowledge base. This objective was achieved qualitatively, based on a sample of 8 LPHFs and 51 SPHFs. Our main conclusions were: (i) the dissemination of biotechnologies is boosted by acquisition; (ii) acquisitions have allowed the knowledge bases of LPHFs to assimilate their target's knowledge bases; (iii) the target's patents offer a great potential for developing technologies that are already dominated by the LPHF; and (iv) the "incorporation" of scientists from target companies allows LPHFs to internalize research lines. Our main contribution is to link knowledge base characteristics to potential directions taken in the technological development process.

KEYWORDS | Pharmaceutical industry, mergers and acquisitions, knowledge base, patents, inventors.

RESUMO

A aquisição permite que grandes empresas farmacêuticas incrementem sua base de conhecimento ao incorporar partes das bases de conhecimento das empresas adquiridas. Com fundamento nesse processo, propomos a seguinte questão como objetivo: é possível relacionar o conhecimento adquirido, via aquisições, ao desenvolvimento tecnológico? A fim de responder a essa questão, foi desenvolvida uma abordagem capaz de evidenciar o impacto da base de conhecimento da empresa adquirida na grande empresa que a adquiriu. Esse objetivo foi atingido qualitativamente com base em uma amostra de oito grandes empresas e 51 pequenas empresas adquiridas. As principais conclusões foram: (i) a disseminação de biotecnologias foi impulsionada pelas aquisições; (ii) as aquisições permitiram que a base de conhecimento das grandes empresas se tornasse semelhante à das pequenas empresas; (iii) as patentes das empresas adquiridas oferecem grande potencial para desenvolver tecnologias em áreas já dominadas pelas grandes empresas e (iv) a incorporação dos cientistas das pequenas empresas permite que as grandes empresas internalizem linhas de pesquisa. A maior contribuição deste artigo é relacionar bases de conhecimento a possíveis direções tomadas, como resultado de aquisições, no processo de desenvolvimento tecnológico.

PALAVRAS-CHAVE */ Indústria farmacêutica, fusões e aquisições, base de conhecimento, patentes, inventores.*

RESUMEN

Este artículo se centra en las adquisiciones de pequeñas empresas farmacéuticas (SPHF) por parte de Grandes empresas farmacéuticas (LPHF). En este artículo, la LPHF amplía su base de conocimientos incorporando parte de las bases de conocimientos de la pequeña empresa. En base a eso proponemos una pregunta orientadora: ¿es posible vincular el conocimiento adquirido a través de adquisiciones con el desarrollo tecnológico? Para responder a esta pregunta, desarrollamos un enfoque que permite observar el impacto de la base de conocimientos de la pequeña empresa en la base de conocimientos del adquirente. Este objetivo se alcanzó cualitativamente con base en una muestra de 8 LPHF y 51 SPHF. Nuestras principales conclusiones fueron: (i) la difusión de biotecnologías fue impulsada por adquisiciones; (ii) como resultado de adquisiciones, algunas bases de conocimiento de LPHF se volvieron más similares a las bases de conocimiento de sus destinatarios; (iii) las patentes del objetivo ofrecen un gran potencial para el desarrollo de tecnologías ya dominadas por la LPHF y (iv) la incorporación de científicos de los objetivos permite que las LPHF internalicen las líneas de investigación. Nuestra principal contribución es vincular las características de la base de conocimientos con las posibles direcciones tomadas en el proceso de desarrollo tecnológico.

PALABRAS CLAVE */ Indústria farmacéutica, fusion y adquisición, base de conocimientos, patentes, inventores.*

INTRODUCTION

Studies that focus on big-pharma have been discussing an apparent paradox; pharmaceutical companies have been substantially increasing their patent numbers, while new chemical entities (NCE)- is a drug that contains part of an active molecule approved by any regulatory office- remain stable. Regardless of the causes, the pharmaceutical industry has been trying to address this crisis by diversifying its capabilities to include biotechnologies (Nightingale, 2000 & Quéré, 2004). This process began in the late 1970s and early 1980s (Sharp, 1996), and has been recently boosted by acquisitions (Desyllas & Hughes, 2010). Nowadays, all large pharmaceutical firms (LPHF) have some kind of scouting team looking for promising new technologies that are being developed by small pharmaceutical firms (SPHF). This strategy has led to the well-established behavior of incorporating biotechnologies through acquisition (Matos, 2016, 2020; Andersson & Xiao; 2016; Eliasson, Hasson, & Lindvert, 2017; Lange & Wagner, 2019). Nowadays, as much as 50% of the new technologies of large pharmaceutical firms used to be SPHF projects (Matos, 2016).

The literature is not yet addressing properly the relationship between small and large firms. Some studies have focused on mergers and acquisitions (M&A) driven by technological interests, but ignored company size (e.g., Ahuja & Katila, 2001; Ahuja & Lampert, 2001; Cloodt; Hagedoorn & Kranenburg, 2006; Gerpott, 1995; Hagedoorn & Duysters, 2002). Even fewer studies concentrate on the interactions between small and large firms (e.g., Andersson & Xiao, 2016; Desyllas & Hughes, 2010; Eliasson *et al.*, 2017; Lange & Wagner, 2019; Norbäck; Persson; Täg, 2014; Xiao, 2015). Currently, many studies highly focus on post-acquisition performance.

The approach adopted by these studies has two limitations. First, productivity issues are not a patenting activity problem; this specific point is beyond the scope of this study. Second, the post-acquisition performance approach does not deal with the knowledge flow between small and large firms. In short, these studies treat firms as black boxes, in which acquisitions are inputs and patents are outputs, thus the problem is only a matter of correlating acquisitions with the increase or decrease in patenting activity.

In an attempt to overcome this black box problem, we pose an important question: Is it possible to link the knowledge acquired through acquisitions to technological development? To answer this question, we developed an approach that focused on the concept of the analytical knowledge base and that enables us to observe and track the impact of the analytical knowledge base of small firms on large firms.

We achieve this objective qualitatively, based on a sample of 8 LPHFs and the 51 SPHFs they acquired between 2005 and 2012. Our analyses focus on the impact of the target enterprise's (here represented by SPHFs) knowledge base on the acquiring firm's (here represented by LPHFs) knowledge base.

This study does not focus on the outcomes of the acquisitions, which has been discussed in other studies, many of which are referenced here. We deliberately focus on the acquisitions of SPHFs by LPHFs, because the latter are driven by technological interests; the knowledge of the SPHF is the condition for the acquisition, and small firms are seen as a relevant source of new knowledge for large firms (Andersson & Xiao, 2016; Eliasson *et al.*, 2017; Lange & Wagner, 2019).

The main contribution of this article is to propose an approach that overcomes the black box problem, which enables the knowledge base building blocks to be linked to the technological development of the enterprise.

Therefore evidence that the knowledge bases of small firms have an impact on the technological development of LPHFs in different ways. While technologies show the evolution of the enterprise's knowledge base by increasing advances in knowledge that is already dominated, the "incorporation" of scientists is evidence of the creation of new knowledge for the firm.

This article proceeds as follows. The next section discusses acquisitions driven by technological interests, in which the knowledge bases of firms are incorporated. The third section discusses the methodology. The fourth section presents and discusses the results, and the final section concludes the article.

LITERATURE REVIEW

M&As and innovation

Chakrabarti, Hauschildt and Sürverkrüp (1994) and Gerpott (1995) were among the first to turn their attention to acquisitions in which the main driver was technological interests. In line with these pioneering studies, literature shows that any new knowledge that is incorporated into a firm will increase its innovativeness (Ahuja & Katila, 2001; Desyllas & Hughes, 2010; Xiao, 2015).

The acquisition of small firms by large firms is a subgroup of the M&As that are driven by technological interests (Desyllas & Hughes, 2007; Hussinger, 2010). This type of acquisition is a typical high-tech sector phenomenon (Andersson & Xiao, 2016; Hussinger, 2010), which drivers depend negatively on the acquirer's commitment to internal R&D, and positively on low R&D productivity and a large body of knowledge (Desyllas & Hughes, 2007). These acquisitions have no short-term effects on the acquirer's sales figures or employment (Xiao, 2015), but they increase the large enterprise's innovative output (Andersson & Xiao, 2016; Desyllas & Hughes, 2010; Szücs, 2014). Therefore, this type of acquisition is fundamental for understanding the impacts of incorporating knowledge bases (Lange & Wagner, 2019; Matos, 2020).

The impact of the knowledge base on technological development

To understand the impact of a small enterprise's knowledge base on the acquirer's technology, we first start by defining the concept of knowledge base, that is: "the information, knowledge, and capabilities that inventors draw on when looking for innovative solutions" (Dosi, 1988, p. 1126). Firms with more diverse knowledge bases lead to more and different innovative solutions (Ahuja & Katila, 2001) and greater rates of growth (Grillitsch, Schubert, & Srholec, 2019). In addition to the concept of knowledge base, we must consider the industry specificities that bring different features to the search for innovative solutions, which implies typical sectorial knowledge bases (Fernandes, Farinha, Ferreira, Asheim, & Rutten, 2020).

The pharmaceutical industry encompasses an analytical knowledge base, in which scientific knowledge–the knowledge produced by applying the Baconian methods of research (Mokyr, 2002; Shapin, 2018)–highly important, and where knowledge creation is often based on formal models, codified science and rational process (Asheim & Gertler, 2005, p. 310, author's highlight). By applying this concept to firms, we can state that in analytical knowledge bases " [...] knowledge creation is based on cognitive and rational processes (e.g. formal models)" (Asheim, Coenen, & Vang, 2007, p. 144). These are the building blocks of analytical knowledge bases that are responsible for growth in the enterprise (Grillitsch, Schubert, & Srholec 2019). Based on Nightingale (1998), therefore, we consider technology in the form of patents as rational processes, and scientists as cognitive processes.

Patents are specific technologies that are classified according to the purpose for which they were developed. Each patent class addresses the patent's technological field (Hall, Jaffe, & Trajtenberg, 2001; Lerner, 1994; Novelli, 2015), and the patent classes describe the basic knowledge necessary to produce a patent (Strumsky

& Lobo, 2015; Verhoeven, Bakker, & Veugelers, 2016). Nelson and Winter's (1982) point of view is that a patent class and its subclass encompass a knowledge neighborhood, which is much closer to the results of research activities than the patent alone. According to Strumsy and Lobo (2015);Verhoeven *et al.* (2016), therefore, we consider that all patent classes for which firms have been granted patents are part of the firms' analytical knowledge base (Matos, 2016).

Nevertheless acquisitions prove difficult when it comes to the efficient incorporation of external knowledge bases, because they demand the acquirer's understanding of the target company's knowledge (Makri, Hitt, & Lane, 2010). Firms that engage in successful horizontal and vertical acquisitions, therefore, should have some technological relatedness with their target (Hagedoorn & Duysters, 2002).

Several studies have attempted to create concepts and measures of knowledge-base relatedness, and these concepts help clarify how relatedness affects the firms' technological outputs. All these ideas are based on Cohen and Levinthal's (1989) concept of absorptive capacity, which is "the firm's ability to identify, assimilate, and exploit knowledge from the environment" (Cohen & Levinthal, 1989, p. 569). In essence, Cohen and Levinthal (1989) are stressing that firms become better able to understand, search, identify and use external knowledge bases the more research they conduct.

Firms with larger and less specialist knowledge bases are more likely to boost their R&D productivity (Desyllas & Hughes, 2007). Furthermore, the difference in the technological and scientific knowledge between companies is an important factor in the process of technical change and in constructing the necessary capabilities for R&D (Hagedoorn & Duyster, 2002; Makri *et al.*, 2010). In a recent study Shkolnykova and Kudic (2021) found that in biotechnology, partner firms that focus on different technological fields can benefit more from the other companies' radical innovation than firms that focus on the same area. This conclusion increases the importance of existing differences in the firms' knowledge bases. For instance, the merger of firms that are very similar would only lead to duplication. Therefore, there must be differences in the knowledge bases of firms to provide the opportunities needed for learning and developing absorptive capabilities (Makri *et al.*, 2010). When companies are very different in terms of their knowledge bases, however, the M&A process becomes highly complex and incorporating the other firms' knowledge bases is almost impossible, therefore disabling any effect on the innovation rate (Makri *et al.*, 2010). In other words, the differences in the knowledge bases of acquisition targets must provide learning opportunities, which the acquirer can translate into new products and may even generate new technological trajectories (Cloodt *et al.*, 2006; Makri *et al.*, 2010). The relatedness of the firms' knowledge bases and their innovative output have an inverted U-shaped relationship (Ahuja & Katila, 2001). Along the same lines, Edjemo and Örtqvist (2020) found that increasing differences between firms (measured by way of patent classes) lead to diminishing returns in innovative entrepreneurial output. It is as if an optimal degree of difference maximizes innovative output.

The way in which firms combine and incorporate external knowledge bases enables firms to create new products, and in some cases to create new technological trajectories (Hagedoorn & Duysters, 2002). Arguably, the contribution of small firms to large firms' innovative output depends on the degree of relatedness of their knowledge bases (Edjemo & Örtqvist, 2020).

Therefore, it is necessary to establish a method that considers similarities (relatedness) between the firms' knowledge bases in order to link the knowledge acquired by acquisition to technological development (Ahuja & Katila, 2001; Hagedoorn & Duyster, 2002). We believe that relatedness works as a mediator in knowledge transfer processes.

Scientists' impact on an enterprise's knowledge base

For this study, the role of relatedness can be observed in technology. But the analytical knowledge base has another important building block linked to cognitive processes; the workforce. Arguably, all employees in an enterprise compose and alter its knowledge base. In an attempt to reduce this scope, we follow Asheim and Hansen (2009), Grillitsch *et al.* (2019), who state that chemists, science professionals and university teaching professionals are typical occupations responsible for constructing and expanding analytical knowledge bases, i.e., these occupations are responsible for the innovation process in firms that are characterized by such structures. In line with these studies the Matos (2020) uses inventors, who are described in the patent information as proxies for the main traceable occupation in the innovation processes of analytical knowledge bases.

This human resource is pivotal, especially in already formalized ventures, like those we are focusing on here. The inventors' background and training are distinguished in small innovative firms, with many of them having a PhD and being linked to university research (Malerba & McKelvey, 2016;2020). Therefore, the research by inventors in SPHFs enables firms to create (Colombo & Piva, 2012). More importantly, a firm's survival may depend on the outcomes of the research undertaken by these inventors, especially in biotechnology (Colombo & Grilli, 2005; Colombo & Piva, 2012).

They are the main agents responsible for high-tech entrepreneurship, and they mold its innovative characteristics (Colombo & Piva, 2012; Malerba & Mckelvey, 2020). Individually, a prestigious scientist is known and, at the same time, tied to their research, because it is what distinguishes them. Consequently, there is a lock-in effect between the researcher and the research agenda, regardless of their workplace (Hohberger, 2016). If scientists move from one firm to other because of the promising research they are doing, they will continue with the same line of research in the new firm . Therefore, researchers bring with them the same "successful" trajectory that drove the acquisition (Hohberger, 2016).

Many large firms select their targets based on the skills of their labor force, and so adopt a "cherry-picking" strategy in their acquisitions (Eliasson *et al.*, 2017). Many acquisitions are also one way of firms catching up with their competitors (Chen, Hsu, Officer, & Wang, 2020). As a result, acquisitions are used by large firms to access the knowledge base of a small firm. They are an equity base mode for sourcing external knowledge, which demands great commitment on the part of the acquirer, and leads to a more complete process of knowledge incorporation (Lange & Wagner, 2019).

We suppose that knowledge transfer is a consequence of acquisitions mediated by relatedness, which is one way of dealing with this process. As knowledge is transferred, it impacts the acquirer's analytical knowledge base. On the one hand, this impact through technology in the form of patents, but dependent on the relatedness between knowledge bases for technological development (Lange & Wagner, 2019), while on the other, inventors bring their abilities to the new firm, and through their research agenda they expand the acquiring firm's analytical knowledge base. Therefore, each of these building blocks should be considered when observing the knowledge base impacts resulting from acquisitions.. This is how we think the main concepts presented in this article interplay. Some recent studies have discussed related ideas, e.g. the impact of knowledge bases on company growth (Grillitsch *et al.*, 2019), and the impact of relatedness on entrepreneurial activity and innovativeness (Edjemo & Örtqvist, 2020).

METHODOLOGY

This study is based on acquisitions from 2005 to 2012 conducted by eight LPHFs: (i) Pfizer, (ii) Johnson & Johnson(We compiled patent information from Johnson & Johnson and Janssen together), (iii) Roche, (iv) Sanofi, (v) Astra-Zeneca, (vi) Abbott-Laboratories, (vii) Glaxo SmithKline (GSK), and (viii) Merck. These 8 firms acquired 51 SPHFs. Based on these 51 SPHFs' patents we identify three ways in which the external analytical knowledge base (target enterprise's knowledge base) had an impact. To do so we use three sources of data, two of them used to select the sample and one to compile the firms' analytical knowledge base.

The first source of data was the "HBM PHARMA/BIOTECH M&A REPORT 2013", which compiles M&A information for LPHFs (acquirer) and SPHFs (target) between 2005 and 2012. This report contains: (i) the target companies; (ii) the acquiring companies; and (iii) the amount paid. Based on this report, we can extract the most active acquirers and the companies that spent most on M&As. Another important data source was Forbes 2013 list of the 2000 largest companies in the world, which we used to determine the largest firms. Finally, we collected patent data from the free-access Patent Full-Text and Image Database (PatFT) published by the United States Patents and Trademarks Office (USPTO) in order to compile the firms' analytical knowledge bases.

Sample

To present the sample and show its relevance in the pharmaceutical industry, we compared financial and effort data (the share of R&D over Revenues), such as: revenues, R&D, and the relationship between revenue and R&D. We also compared M&A expenditure with these variables and reported it all in Table 1 (all values in the table refer to 2012, with the exception of patent count).

Table 1. **Sample information (data in US$ billions)**

Enterprise (sample)	Capital Origin	Number of Employees	Patents granted by USPTO*	Total Revenue US$	R&D US$	Total expenditure on M&A (from 2005 to 2012) US$	Average expenditure on M&A (from 2005 to 2013) US$	R&D/ Revenue	M&A average/ Revenue	M&A average /R&D
Pfizer	USA	91.500	4,279	51	6.6	76.5	9.5	13%	18.6%	1.44
Novartis	CH	112.461	4,000	32.1	6.7	70.9	8.8	21%	27.4%	1.31
Johnson & Johnson**	USA	128.000	9365	25.35***	5.3	0.4	0.5	21%	2.0%	0.09
Merck&Co	USA	83.000	2,166	47.2	8.1	44.9	0.5	17%	1.1%	0.06
Roche	CH	82.089	3,286	40.96	14.16	48.3	6	35%	14.6%	0.42
Astra-Zeneca	UK	51.700	1024	27.9	4.4	18.3	2.2	16%	7.9%	0.50
Sanofi	FR	111.974	2,024	43	5	26	3.25	12%	8%	0.65
GSK	UK	99.488	3,413	16	2	8.3	1	13%	6.3%	0.50
Abbott-Laboratories	USA	92.939	4,044	39.8	4.3	4.1	0.5	11%	1.3%	0.11

Source: Prepared by the authors.

Note: *Patents between 1976 and 2019 | **Patent information of J&J include the patents granted for Janssen | ***Revenues for only the pharmaceutical branch.Table 1 presents the M&A behavior of the firms, showing its relevance among the main technological activities conducted by the sample companies.

The LPHFs in the sample account for 37% of all R&D expenditure of the Pharmaceutical Research and Manufacturers of America (PhaRMA) members, and have an R&D/revenue ratio of at least 10% for each enterprise. With regard to acquisitions, eight firms account for 32% of all M&A expenditure in the pharmaceutical industry. The samples' share of R&D and acquisitions strongly supports their relevance in terms of technological effort and M&As.

The total expenditure on M&A indicates that firms behaved differently. A relevant share of the sample spent half of their R&D on M&As, but some firms spent more. To sum up, some firms engaged much more in M&A than in R&D, and *vice-versa*; therefore, the sample encompasses different behaviors and strategies and is relevant in the pharmaceutical industry.

An approach for observing the impact of the knowledge base on the acquirer's technological development

Based on the concept of the analytical knowledge base and its building blocks, we used patents as the main source of data for compiling the firms' analytical knowledge bases. A similar approach involving knowledge base notions was used by Lange and Wagner (2019), Edjemo and Örtqvist (2020). We understand that patents have three main proxies that allow us to observe the impact of knowledge bases: (i) patent class, which shows which firms are capable of encompassing rational processes (Strumsy & Lobo, 2015; Verhoeven *et al.*, 2016); (ii) patent citations, which shows the application of a specific piece of knowledge (patent) as input for producing a specific piece of *new* knowledge (patent) (Bryan, Ozcan, & Sampat, 2020; Hall *et al.*, 2001), but still encompassing rational processes; and (iii) inventors, meaning the cognitive side of formal models, and are responsible for producing, understanding and adapting the knowledge (in our case patents) they or others create (Nightingale, 1998; Matos, 2020).

Therefore, we propose three ways of observing how the targets' analytical knowledge bases can impact the analytical knowledge bases of LPHFs:

I. Indirect impact of an external analytical knowledge base: This process will enable us to draw an evolutionary picture that compares knowledge base relatedness. In this regard we track when the LPHF had its patent granted in the same patent classes as its target enterprise. This comparison offers a time-perspective observation of the construction of the knowledge base. Here we choose to focus on biotechnology only, because it follows the technological category classifications developed by Hall *et al.* (2001), which define Classes 435 and 800 of the United States Patent Classification (USPC) in the USPTO as biotechnologies. We must stress that with regard to the indirect use of external knowledge bases, we consider only the subclasses of Classes 435 and 800.

II. Direct impact of an external knowledge base: This process allows us to observe the impact of a target's patents on the new patents produced by the acquiring LPHF. This idea is mainly based on the work of: Hall *et al.* (2001); Trajtenberg, Henderson and Jaffe (1997). Here we observe which patents of the target firms were cited by the acquiring LPHF. We also use citation lags, calculated by Hall *et al.* (2001) to show the potential impact of each patent.

III. Utilization of inventors: this concept was used and further explored by Matos (2020). This process allows us to observe the "incorporation" of inventors by the LPHF. To do so we compiled all target firm inventors who had had at least one patent issued for the SPHF. In order to corroborate our choice, Asheim and Hansen (2009) show a significant statistical correlation between analytical knowledge base occupations and patent indices.

The next section will enable us to observe the impact of an SPHF's analytical knowledge base on the LPHF's analytical knowledge base, according to our categories of analysis.

DATA ANALYSES AND RESULTS

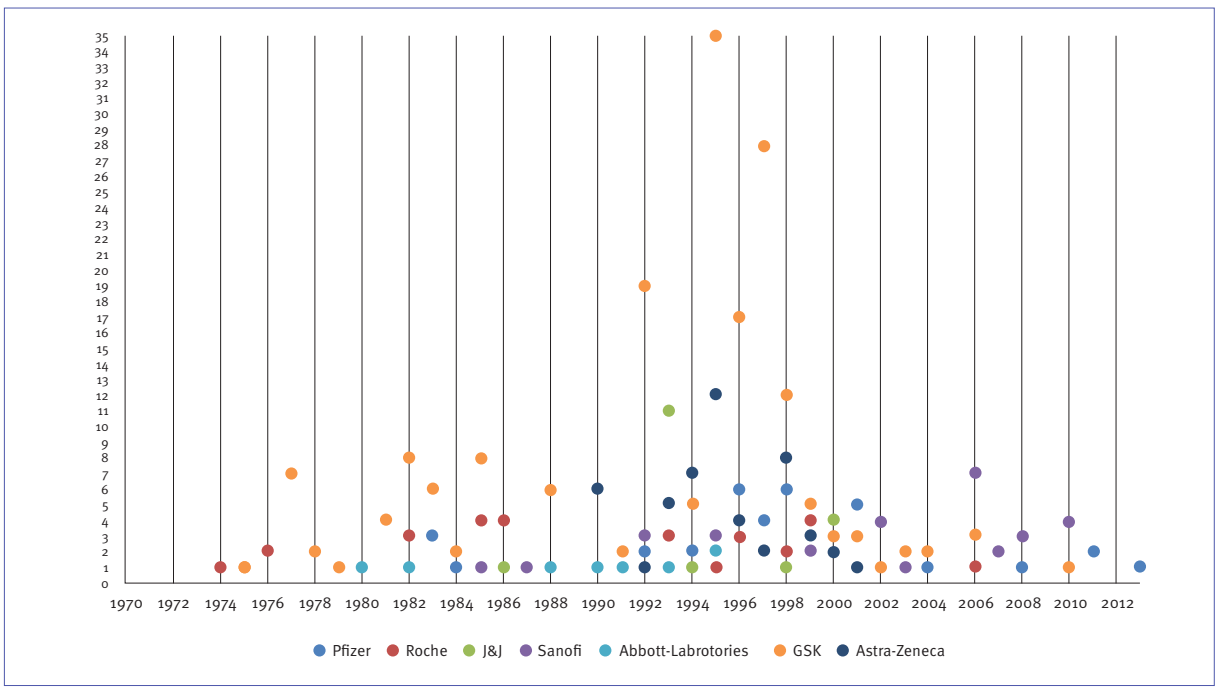
Analytical knowledge base: the indirect and direct impact of an SPHF's knowledge base

The process of patenting in different patent classes is a process of creating absorptive capabilities. In doing so, firms become aware of new technological developments and can to understand new knowledge (Cohen & Levinthal, 1990). In this process, LPHFs and SPHFs may develop patents pertaining to the same patent classes, thereby increasing their analytical knowledge base relatedness over time.

Figure 1 illustrates knowledge base relatedness in all subclasses of Classes 435 and 800 (biotechnologies) in a time perspective. To arrive at this result, we first determined the analytical knowledge bases of the small firms, following we searched for the first patent granted for each LPHF in the same patent classes as its target(s). Therefore, this figure presents the development of the LPHFs' knowledge bases over time.

The Y axis shows the number of new classes developed. A new class is considered when a patent is first granted to the large enterprise in a patent subclass. The X axis indicates the years. For example, in 1994, GSK started to patent in five new classes.

Figure 1. **Indirect use of external knowledge base**



Source: Prepared by the authors.

This figure can be divided into three main areas: (i) from 1974 to 1988, (ii) from 1988 to 2004, and (iii) from 2004 onwards. From 1974 to 1988, a few firms developed a few new classes. This period resembles an early period

in the development of biotechnology, as Sharp (1996) proposes. From 1988 to 2004, this process became more intensive as more classes and more firms started to develop new classes. The 1990s were distinguished by new biotechnologies, such as High Throughput Screening, the results of which appeared at the end of the 1990s and the beginning of the 2000s (Houston & Banks, 1997; Pereira & Williams, 2007); this is evident in the increasing number of new classes. Finally, the development of new classes slowed down from 2004 onwards.

Figure 1 summarizes the arguments of Sharp (1996) and Malerba and Orsenigo (2015), who point to the scattered and slow development of biotechnologies in large firms. Over time, and as collaboration between large and small firms increased (Organization for Economic Cooperation and Development [OECD], 2013; Sharp, 1996), so did the development of biotechnologies. Another important element was the Bayh-Dole Act of 1980, which allowed researchers and universities to own and commercialize their research outputs, thus increasing the number of biotechnology patents (Hall, 2004).

From Figure 1, we can clearly see that LPHFs slowly start developing similar knowledge bases as their targets, and this process accelerated between 1990 and 2000. The acquisitions we looked at (2005 to 2012) occurred in the same period as the development of new classes started to slow down (from 2004 to 2012); first we observe a growth in knowledge bases, then acquisitions take place. Similarly, Desyllas and Hughes (2007, 2010) showed the propensity of firms with a large body of knowledge to acquire high-tech companies.

In short, the figure shows an evolutionary perspective indicating that biotechnology "follows a well-established, historical pattern of slow and incremental technological diffusion" (Nightingale & Martin, 2004, p. 564), in which large pharmaceutical firms gradually incorporate new technology (Zucker & Darby, 1997).

We can further develop our analyses to observe the degree of relatedness between the LPHF and its targets. The idea is very simple; the incorporation of SPHFs allows LPHFs to develop similar analytical knowledge bases, but as the process continues the possibility of creating new patent classes decreases. Thus, the expansion of knowledge bases based on acquired knowledge slows down over time. The opposite is also true; a certain degree of differences between knowledge bases, may lead to more opportunities for the large enterprise to develop innovations (Ahuja e Katila, 2001). Therefore, in the acquisition process, the LPHF's indirect use is linked to the patent classes that are not developed by the acquiring firm (Matos, 2016), in other words, this firm has more opportunities to develop new knowledge in the form of patent classes.

In order to observe this potential, Table 2 outlines the classes not developed.

Table 2. **The portion of technical knowledge not developed**

Enterprise	Percentage of classes not developed
J&J+Jansen	66%
Astra-Zeneca	32%
Abbott-Laboratories	27%
GSK	14%
Pfizer	12%
Roche	10%
Sanofi	6%

Source: Prepared by the authors.

Table 2 shows different degrees of relatedness. J&J + Jansen has a very different knowledge base from those of the firms they acquired. Even Astra-Zeneca and Abbott-Laboratories have an intermediate degree of relatedness, but all other firms are extremely similar. Therefore, the data indicate that company knowledge bases start with a degree of relatedness that may grow over time as acquisitions become more frequent. The process of increasing similarity between company knowledge bases is in line with Boschma's (2005) arguments.

Similar knowledge bases, however, have an important aspect, which possibly indicates that SPHFs contribute towards improvements in already developed patent classes. Firms may understand the same piece of knowledge, but the innovative solution to the problems differs from one enterprise to another, i.e., firms have different routines for coping with the same problem (Nelson & Winter, 1982). The different technologies (innovative solutions) developed by each enterprise are forms of developing broad pieces of knowledge in specific solutions; in other words, the development of the same piece of knowledge by two different firms leads to different technologies (Nelson & Winter, 1982). We capture this behavior when firms start to produce several patents in the same patent class, because these firms are further developing broad categories of knowledge (patent classes), and creating specific technological solutions (inventions). Thus, the production of patents within classes shows that an enterprise is improving the knowledge of a patent class by adding new pieces of knowledge to a broader category.

The knowledge base of these firms may be used for specific technological solutions in already developed classes. It means, in terms of technologies, small firms are much more prominent in improving knowledge that has already been explored by LPHFs.

As explained in the methodology, the further development of patent classes is captured by patent production. When the LPHF references its targets' patents it is using the small firms' knowledge bases to further develop existing knowledge. In Table 3 we show this process by observing the acquired firms that had at least one of their patents referenced by their acquirers. Table 3 also shows the number of patents of each acquired enterprise, the number of patents used as a reference in new patents, and the patents generated using the referenced patents.

Table 3. **Direct use of external knowledge base**

Large Firms	Target Firms	Number of Small Firms' Patents (A)	Patents Used as Reference (small firms' patents used) (B)	Patents Generated
Astra-Zeneca	Kudos	30	5	3
	Medimmune	347	1	4
	Novexel	6	3	1
Sanofi	Fovea	5	1	1
	VaxDesign	24	3	1
GSK	Human Genome Science	711	14	9
	ID Biomedical	48	3	5
	Corixa	50	33	20
	Praecis	44	3	2
	Sirtris	14	9	5

Continue

Table 3. **Direct use of external knowledge base** Concludes

Large Firms	Target Firms	Number of Small Firms' Patents (A)	Patents Used as Reference (small firms' patents used) (B)	Patents Generated
Pfizer	Idun Pharmaceuticals	39	1	1
	Rinat Neuroscience	27	2	3
	Coley	56	34	7
	Covx	8	1	3
	Incagen	91	2	1
J&J + Jansen	Transform-Pharma	28	1	10
	Omrix	26	6	12
Merck	Sirna (Ribozyme)	192	35	32
	Glycofi	40	26	9
	Abmaxis	6	5	1
	Inspire	96	1	1
Roche	Piramed	4	4	13
	Arius	35	5	11
	Mirus-bio	37	12	7

Source: Prepared by the authors.

The third column from the left in Table 3 shows the total number of patents of each target firm. The fourth column presents the number of patents used as a reference, and the final column gives the number of patents that have at least one small enterprise's patent as a reference.

The table above shows that the eight LPHFs had cited the patents of 24 of their targets. Approximately 44(%) of the SPHFs had at least one patent cited by the LPHF, then showing their impact on the technology production of the large firms. As discussed by Hall, Jaffe, & Trajtenberg (2005), these small firms' patents can yield value for the large firms and become an important asset for the acquiring LPHF.

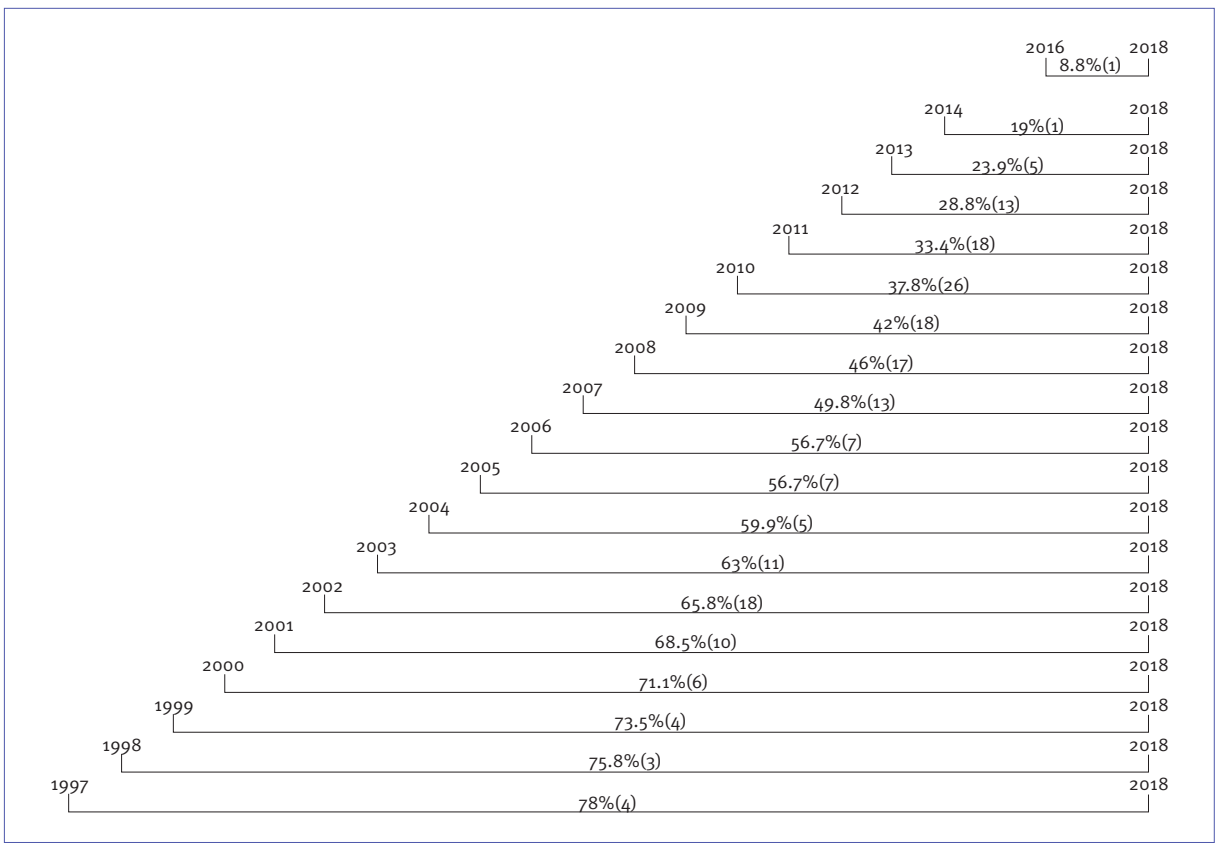
By further developing our analyses and focusing on patent citations based on (Hall *et al.*, 2001; Henderson, Jaffe, & Trajtenberg, 1998; Trajtenberg *et al.*, 1997) we can state that the most cited patents are the most important for the firm. A high citation level indicates a promising invention. By extrapolating, the small firms that had the most patents cited by the acquiring firm are also the most important targets. Therefore, Table 3 also indicates the most important small firms in terms of single technologies. For instance, cases like Arius, Piramed, and Transform-Pharma show the firms whose patents were most frequently cited. Thus, their knowledge base is valuable for the acquiring firm. We report these cases in the last column of Table 3, in which we show the patents generated through small firms' patents.

Because of the short analysis period, a way of attesting the potential of small firms' knowledge bases is by their citation potential. Patents reach their maximum citation rate after a few years (depending especially on the

economic sector - for more details see: Hall *et al.*, 2001), and then this rate slows down. This potential is captured by citation lag, creating a general pattern (Hall *et al.*, 2001).

This citation pattern can be understood as the depreciation rate of patents. Therefore, large firms can choose to acquire highly depreciated patents, or not. Figure 2 shows this depreciation based on the citation lag proposed by Hall *et al.* (2001). This figure compiles all patents filed by the small acquired firms that were cited by the large firms. The left side shows the year in which the patent was granted and the right side indicates the end of the period. The center shows the number of citations for the period according to the citation lag. For example, patents granted in 1997 accounted for 78% of all citations; therefore, 22% of all possible citations are yet to occur. In parentheses, we indicate the numbers of patents granted in the year that were cited by large enterprises; for example, in 1997, large firms cited four patents belonging to firms they had acquired.

Figure 2. **Knowledge potential according to citation lags**



Source: Prepared by the authors.

The LPHFs in the sample cited 196 patents of their targets. For a better understanding of the patents' potential, we divided the 196 patents into tiers according to their potential number of citations for the period. The first tier included patents that had between 0% - 25% of all the potential citations; the second tier included 25% - 50% of the potential citations; the third tier included 50% - 75% of the potential citations; and the last tier had from 75% - 100%. In other words, the patents in the first and second tiers are those with greatest potential, and the patents in the last tier have the lowest potential. Most patents (187) had between 25% and 75% of the possible citations.

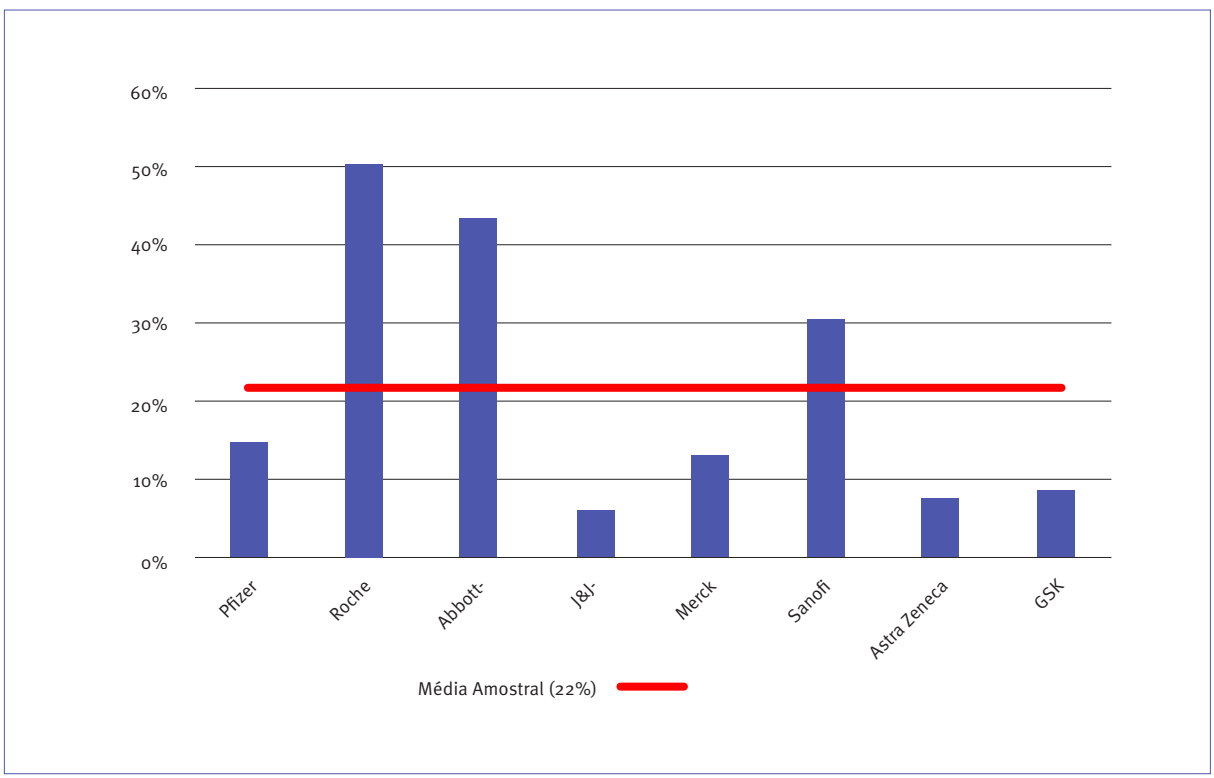
We can examine the potential of the patents better by dividing the patents into more tiers, from 25%-40%, 40%-55%, and 55-75% as a share of the total number of citations. In summary, 57 patents accounted for between 25% and 40% of all citations; 76 patents accounted for between 40% and 55% of all possible citations; and 59 patents accounted for between 55% and 75% of all possible citations. The citation lag data show that the patents held by the large firms still have a good potential to generate new patents. This fact explains why Table 3 shows low patent productivity; that is, a small number of patents created from the small firms' patents. The patents still have citation potential, however, and can thus yield value for the large enterprise (Hall *et al.*, 2005).

In short, the direct impact of SPHFs' knowledge bases is directed to further developing already existing knowledge. This same conclusion was reached by Wagner (2011) and Szücs (2014); in their study both authors showed the acquiring firms' preference for exploiting rather than exploring their targets' knowledge bases. Arguably, this behavior generates more results in the short run.

Knowledge bases: the impact of inventor utilization

Table 4 presents the total number of inventors in the target firms, and the inventors who started to produce patents for the LPHF after it acquired its target. Finally, we calculate a relationship that shows the percentage of "incorporated" inventors. In Figure 3 and Table 4 we can see the proportion of knowledge base incorporated by the sample company.

Figure 3. **Utilization of inventors**



Source: Prepared by the authors.

Table 4. **Inventor utilization summary table**

Large Pharmaceutical Company	Target Firm	Number of inventors in the Target Enterprise (B)	Inventors that started to patent for the LPHC (C)	Knowledge base incorporation (C/B)
Pfizer	Rinat Neurosicence	35	18	51%
	Encysive	25	8	32%
	Coley	61	9	15%
	Vicuron	47	6	13%
	Icagen	68	8	12%
	Idun Pharmaceuticals	25	0	0%
	Biorexis	5	0	0%
	CovX	27	0	0%
	Serenex	25	0	0%
	FoldRx	3	0	0%
	Excaliard	8	0	0%
Roche	Piramed	24	24	100%
	Mirus-Bio	25	19	76%
	Arius	14	5	36%
	Therapeutic Human Polyclonals	4	0	0%
	Memory Pharmaceuticals	26	0	0%
	Macardia	2	0	0%
Abbott-Laboratories	Facet-Biotech	30	18	60%
	KOS-Pharmaceuthicals	14	1	7%
J&J + Jansen	TransForm Pharmaceuticals	33	8	24%
	Crucell	81	1	1%
	Omrix	22	0	0%
	Respivert	15	0	0%
	Corimmun	5	0	0%
Merck	Glycofi	13	10	77%
	Abmaxis	10	6	60%
	Sirna (Ribozyme)	112	12	11%
	Inspire	80	3	4%
	Insmed	27	1	3%
	Novacardia	5	0	0%
	Smartcells	8	0	0%

Continue

Table 4. Inventor utilization summary table

Concludes

Large Pharmaceutical Company	Target Firm	Number of inventors in the Target Enterprise (B)	Inventors that started to patent for the LPHC (C)	Knowledge base incorporation (C/B)
Sanofi	VaxDesign	28	28	100%
	Acambis (ex Peptide Therapeutics)	30	12	40%
	Fovea	6	2	33%
	Zentiva	42	0	0%
	BiPar Sciences	12	0	0%
	TargeGen Inc.	19	0	0%
Astra-Zeneca	Novexel	21	7	33%
	Kudos	52	10	19%
	Medimmune	105	3	3%
	Cambridge Antibody Technology	45	0	0%
	Arrow Therapeutics	10	0	0%
	Ardea Biosciences	34	0	0%
	Pearl Therapeutics	8	0	0%
	Reliant Pharmaceuticals	3	2	67%
GSK	Praecis	75	18	24%
GSK	Domantis	41	6	15%
	Corixa	124	17	14%
	ID Biomedical	46	5	11%
	Cellzome	41	4	10%
	Genelabs Techn.	101	3	3%
	Human Genome Science	214	3	1%
	Stiefel Laboratories	35	0	0%
	Sirtirs	23	0	0%

Source: Prepared by the authors.

Both Table 4 and Figure 3 corroborate Matos (2016) finding that LPHFs deliberately make an effort to retain key personnel of the target companies as a strategy. Inventors do not move alone from one firm to another; it is rare to see an individual inventor of a patent start working on patents for the large enterprise; typically, inventors move as a group. This point further confirms the importance of the relationships that exist between inventors within their own groups, as stated by Oettl (2012) and Grigoriou and Rothaermel (2014).

According to Hohberger (2016), scientists who move from the small company to the large enterprise internalize their research and yield value for the firm through their research results, due to their path dependence. This fact can be easily seen by comparing the "incorporation" of inventors with the use of patents as a reference, as shown in the next table.

Table 5. **Comparison between reference patents and inventor utilization**

Large Firms	Target Firms	Patents used as a reference (small firm's patents used)	Utilisation of inventors
Astra-Zeneca	Kudos	5	19%
	Medimmune	1	3%
	Novexel	3	33%
Sanofi	Fovea	1	33%
	VaxDesign	3	100%
Roche	Piramed	4	100%
	Arius	5	36%
	Mirus-bio	12	76%
GSK	Human Genome Science	14	1%
	ID Biomedical	3	11%
	Corixa	33	14%
	Praecis	3	24%
	Sirtirs	9	0%
Pfizer	Idun Pharmaceuticals	1	0%
	Rinat Neuroscience	2	51%
	Coley	34	15%
	Covx	1	0%
	Incagen	2	12%
J&J + Jansen	Transform-Pharma	1	24%
	Omrix	6	0%
Merck	Sirna (Ribozyme)	35	11%
	Glycofi	26	77%
	Abmaxis	5	60%
	Inspire	1	4%

Source: Prepared by the authors.

The previous table shows evidence that links the "incorporation" of inventors to patent use. The reference patents and inventors of the vast majority of the target firms were incorporated; there were only two cases in which patents were used without "incorporating" the inventors. Arguably, the "incorporated" inventors produce new patents in the LPHF using their past patents as a reference, thus showing the possibility of their line of research being incorporated by the acquiring LPHF.

In summary, the data analyses showed that target firms' inventors are heavily "incorporated" by the acquiring companies, and their "incorporation" can be linked to the use of patents. We see, therefore, that inventors tend to continue researching in the same line when they move from one enterprise to another (Hohberger, 2016).

CONCLUSION

This study was based on a qualitative methodology that analyzed the acquisitions of 51 SPHFs by 8 LPHFs, and in which we examined the impact of the targets' knowledge bases on the acquirers' knowledge bases. This type of study demands close observation of each single acquisition.

This study's contribution is that it provides firm-level analyses that enable us to understand some of the possible uses LPHFs make of their targets' knowledge. This contribution helps clarify some of the gaps in the literature on M&A studies. More importantly, our contribution stresses the relevance of small firms to the development of technology and competence in LPHFs.

In preparing this contribution, we identified patents and inventors as proxies for the building blocks of company knowledge bases. We then developed an approach that allows us to observe the impact of the target on the acquirer's technological development. As a result, our approach provides evidence of three main ways in which knowledge bases can be impacted.

First, the dissemination of biotechnology is boosted by acquisitions. Second, as a result of the acquisitions some LPHFs' knowledge bases become similar to their targets' knowledge bases. Third, the targets' patents still offer a great potential for developing other patents in related fields of knowledge (same patent classes). Finally, inventors are "incorporated" as a way of internalizing research lines.

This study has its limitations. It is overdependent on patent information and related issues, including the debate about problems associated with patent methodology. Another interesting limitation is that we do not consider the effort that leads to a patent being granted. We also excluded firms that have no patents in the USPTO. Collaboration also plays an important part, and we did not consider this. Information about inventors is also too restrictive when looking at the cognitive process.

There are two ways to overcome any issues associated with this study's methodology. The first is to focus on one enterprise only and for a longer period of time, and the second is to consider the scientific publications that is broader way of considering scientific knowledge.

REFERENCES

Ahuja, G., & Katila, R. (2001). Technological acquisition and the innovation performance of acquiring firms: A longitudinal study. *Strategic Management Journal, 22*(3), 197-220. doi: 10.1002/smj.157

Ahuja, G., & Lampert, C. M. (2001). Entrepreneurship in the large corporation: A longitudinal study of how established firms create breakthrough inventions. *Strategic Management Journal, 22*(6-7), 521-543. doi: 10.1002/smj.176

Andersson, M., & Xiao, J. (2016). Acquisitions of start-ups by incumbent businesses: A market selection process of "high-quality" entrants? *Research Policy, 45*(1), 272-290. doi: 10.1016/j.respol.2015.10.002

Asheim, B. & Gertler, M. S. (2005), '*The Geography of Innovation; Regional innnovation systems*', in Fagerberg, J., Mowery, D. and Nelson, R.R. (eds.), The Oxford Handbook of Innovation, Norfolk, Oxford University Press.

Asheim, B., Coenen, L., & Vang, J. (2007). Constructing knowledge-based regional advantage: Implications for regional innovation policy. *International Journal of Entrepreneurship and Innovtion Management, 7*(5), 140-155. doi: 10.1504/IJEIM.2007.012879

Asheim, B., & Hansen, H. (2009). On the usefulness of the creative class. *Economic Geography, 85*(9) p424-442. doi: 10.1111/j.1944-8287.2009.01051.x

Boschma, R. (2005). Proximity and innovation: A critical assessment. *Regional Studies, 39*(1), 61-74. doi: 10.1080/0034340052000320887

Bryan, K., Ozcan, Y., & Sampat, B. (2020). In-text patent citations: A user's guide. *Research Policy, 49*(4), 103946. doi: /10.1016/j.respol.2020.103946

Chakrabarti, A., Hauschildt, J., & Sürverkrüp, C. (1994). Does it pay to acquire technological firms? *R&D Management, 1*(24), 47-56. doi:10.1111/j.1467-9310.1994.tb00846.x

Chen, I. J., Hsu, P. H., Officer, M. S., & Wang, Y. (2020). The Oscar goes to...: High-tech firms' acquisitions in response to rivals' technology breakthroughs. *Research Policy, 49*(7), 104078. doi: 10.1016/j.respol.2020.104078

Cloodt, M., Hagedoorn, J., & Kranenburg, H. Van. (2006). Mergers and acquisitions: Their effect on the innovative performance of companies in high-tech industries. *Research Policy, 35*(5), 642-654. doi: 10.1016/j.respol.2006.02.007

Cohen, W. M., & Levinthal, D. A. (1989). Innovation and learning: The two faces of R&D, *The Economic Journal 99*(397), 569-596. doi: 10.2307/2233763

Cohen, W. M., & Levinthal, D. A. (1990). Absorptive capacity: A new perspective on and innovation learning. *Administrative Science Quarterly – Special Issue: Technology, 35*(1), 128-152. doi: 10.2307/2393553

Colombo, M. G., & Grilli, L. (2005). Founders' human capital and the growth of new technology-based firms: A competence-based view. *Research Policy, 34*(6), 795-816. doi: 10.1016/j.respol.2005.03.010

Colombo, M. G., & Piva, E. (2012). Firms' genetic characteristics and competence-enlarging strategies: A comparison between academic and non-academic high-tech start-ups. *Research Policy, 41*(1), 79-92. doi: 10.1016/j.respol.2011.08.010

Desyllas, P., & Hughes, A. (2007). Sourcing technological knowledge through corporate acquisition: Evidence from an international sample of high technology firms. *Journal of High Technology Management Research, 18*(2), 157-172. doi: 10.1016/j.hitech.2007.12.003

Desyllas, P., & Hughes, A. (2010). Do high technology acquirers become more innovative? *Research Policy, 39*(8), 1105-1121. doi: 10.1016/j.respol.2010.05.005

Giovanni Dosi. (1988). Sources, Procedures, and Microeconomic Effects of Innovation. Journal of Economic Literature, 26(3), 1120–1171. Retrieved from http://www.jstor.org/stable/2726526

Ejdemo, T., & Örtqvist, D. (2020). Related variety as a driver of regional innovation and entrepreneurship: A moderated and mediated model with non-linear effects. *Research Policy, 49*(7), 104073. doi: 10.1016/j.respol.2020.104073

Eliasson, K., Hansson, P., & Lindvert, M. (2017). Effects of foreign acquisitions on R&D and high-skill activities. *Small Business Economics, 49*(1), 163-187. doi: 10.1007/s11187-016-9815-9

Fernandes, C., Farinha, L., Ferreira, J., Asheim, B., & Rutten, R. (2020). Regional innovation systems: What can we learn from 25 years of scientific achievements? *Regional Studies, 55*(1), 1-13. doi:10.1080/00343404.2020.1782878

Gerpott, T. J. (1995). Successful integration of R&D functions after acquisitions: An exploratory empirical study. *R&D Management, 25*(2), 161-178. doi: 10.1111/j.1467-9310.1995.tb00909.x

Grigoriou, K., & Rothaermel, F. T. (2014). Structural microfoundations of innovation: The role of relational stars. *Journal of Management, 40*(2), 586-615. doi: 10.1177/0149206313513612

Grillitsch, M., Schubert, T., & Srholec, M. (2019). Knowledge base combinations and firm growth. *Research Policy, 48*(1), 234-247. doi: 10.1016/j.respol.2018.08.009

Hagedoorn, J., & Duysters, G. (2002). External sources of innovative capabilities: The preference for strategic alliances or mergers and acquisitions. *Journal of Management Studies, 39*(2), 167-188. doi: 10.1111/1467-6486.00287

Hall, B. H. (2004). Exploring the patent explosion. *The Journal of Technology Transfer, 30*(1-2), 35-48. doi:10.1007/s10961-004-4356-9

Hall, B. H., Jaffe, A. B., & Trajtenberg, M. (2001). The NBER patent citations data file: Lessons, insights and methodological tools. National Bureau of Economic Research, NBER, No Title Working Paper n. 8498.

Hall, B. H., Jaffe, A., & Trajtenberg, M. (2005). Market value and patent citations. *RAND Journal of economics,* 16-38. Retrieved from http://www.jstor.org/stable/1593752

Henderson, R., Jaffe, A. B., & Trajtenberg, M. (1998). Universities as a source of commercial technology: A detailed analysis of university patenting, 1965–1988. *Review of Economics and Statistics, 80*(1), 119-127. doi: 10.1162/003465398557221

Hohberger, J. (2016). Does it pay to stand on the shoulders of giants? An analysis of the inventions of star inventors in the biotechnology sector. *Research Policy, 45*(3), 682-698. doi: 10.1016/j.respol.2015.12.003

Houston, J., G.; Banks, M. (1997). *The Chemical-biological interface: developments in automated and miniaturized screening technology*. In: Current Opinion in Biotechnology, 8, pp 734-740.

Hussinger, K. (2010). On the importance of technological relatedness: SMEs versus large acquisition targets. *Technovation, 30*(1), 57-64. doi: 10.1016/j.technovation.2009.07.006

Lange, S., & Wagner, M. (2019). The influence of exploratory versus exploitative acquisitions on innovation output in the biotechnology industry. *Small Business Economics, 52*(2), 1-229. doi: 10.1007/s11187-019-00194-1

Lerner, J. (1994) The importance of patent scope: an empirical analysis RAND. *Journal of Economics, 25*(2), 319. doi: 10.2307/2555833

Makri, M., Hitt, M. A., & Lane, P. (2010). Friends, acquaintances, or strangers? Partner selection in R&D alliances. *Strategic Management Journal*, (31), 602-628. doi: 10.5465/amj.2008.31767271

Malerba, F., & McKelvey, M. (2016). *Conceptulizing knowledge intensive entrepreneurship: Definition and model.* In F. Malerba, Y. Caloghirou, M. Mckelvey, & S. Radosevic (Eds.), Dynamics of knowledge-intensive entrepreneurship: Business strategy and public policy. ´p. 19-48. New York: Routledge.

Malerba, F., & McKelvey, M. (2020). Knowledge-intensive innovative entrepreneurship integrating Schumpeter, evolutionary economics, and innovation systems. *Small Business Economics, 54*(2), 503-522. doi: 10.1007/s11187-018-0060-2

Malerba, F., & Orsenigo, L. (2015). The evolution of the pharmaceutical industry. *Business History, 57*(5), 664-687. doi:10.1007/s11187-018-0060-2

Matos, M. M. de (2016). *Changes in Innovation Dynamics of the Pharmaceutical Industry: A Study of the Interaction between Large pharmaceutical Companies and the Acquired Small Biotechnology Enterprises*. Tese (Doutorado) – Unicamp, Campinas, 2016.

Matos, M. M. de (2020). Incorporação de conhecimento por meio de aquisições na indústria farmacêutica: uma análise focada nos inventores das patentes. *Revista Brasileira de Inovação, 19,* p. e0200016. doi: 10.20396/rbi.v19i0.8658178

Mokyr, J. (2002). *The gifts of Athena: Historical origins of the knowledge economy.* Princeton, New Jersey: Princeton University Press.

Nelson, R., & Winter, S. (1982). *An Evolutionary Theory of Economic Change*. Belknap Press of Havard University Press: Cambridge MA.

Nightingale, P. (1998). A cognitive model of innovation. *Research Policy, 27*(7), 689-709.

Nightingale, P. (2000). Economies of scale in experimentation: Knowledge and technology in pharmaceutical R&D. *Industrial & Corporate Change, 9*(2), 315. doi: 10.1093/icc/9.2.315

Nightingle, P., & MARTIN, P. (2004). The myth of the biotec revolution. In: Trends in Biotechnology, vol. 22, n. 11. doi: 10.1016/j.tibtech.2004.09.010

Norbäck, P. J., Persson, L., & Tåg, J. (2014). Acquisitions, entry, and innovation in oligopolistic network industries. *International Journal of Industrial Organization*, 37, 1-12. doi: 10.1016/j.ijindorg.2014.07.003

Novelli, E. (2015). An examination of the antecedents and implications of patent scope. *Research Policy, 44*(2), 493-507. doi: 10.1016/j.respol.2014.09.005

Oettl, A. (2012). Reconceptualizing stars: Scientist helpfulness and peer performance. *Management Science, 58*(6), 1122-1140. doi: 10.1287/mnsc.1110.1470

Organization for Economic Cooperation and Development. (2013). *OECD Science, Technology and Industry Scoreboard* 2013. OECD.

Pereira, D. A., & Williams, J. A. (2007). Origin and evolution of high throughput screening. *British Journal of Pharmacology, 152*(1), 53-61. doi: 10.1038/sj.bjp.0707373

Quéré, M. *The post-genome era: rupture in the organization of the life science industry?* In: Mckelvey, M., Rickne, A., Laage-Hellman, J. The Economic Dynamics of Modern Biotechnology, Edward Elgar, Northhampton, USA, 2004

Shapin, S. (2018). *The scientific revolution*. University of Chicago Press.

Sharp, M. (1996). *Knowledge transfer and biotechnology. Knowledge, technology transfer and foresight,* NATO Asi Series, pp. 3-24. Dordrecht: Springer.

Shkolnykova, M., & Kudic, M. (2021). Who benefits from SMEs' radical innovations? Empirical evidence from German biotechnology. *Small Business Economics*, 1-29. doi: 10.1007/s11187-021-00464-x

Strumsky, D., & Lobo, J. (2015). Identifying the sources of technological novelty in the process of invention. *Research Policy, 44*(8), 1445-1461. doi: 10.1016/j.respol.2015.05.008

Szücs, F. (2014). M&A and R&D: Asymmetric effects on acquirers and targets? *Research Policy, 43*(7), 1264-1273. doi: 10.1016/j.respol.2014.03.007

Trajtenberg, M., Henderson, R., & Jaffe, A. (1997). University versus corporate patents: A window on the basicness of invention. *Economics of Innovation and New Technology, 5*(1), 19-50. doi: 10.1080/10438599700000006

Verhoeven, D., Bakker, J., & Veugelers, R. (2016). Measuring technological novelty with patent-based indicators. *Research Policy, 45*(3), 707-723. doi: 10.1016/j.respol.2015.11.010

Wagner, M. (2011). To explore or to exploit? An empirical investigation of acquisition by large incumbents. *Research Policy, 40*(9), 1217–1225. doi: 10.1016/j.respol.2011.07.006

Xiao, J. (2015). The effects of acquisition on the growth of new technology-based firms: Do different types of acquirers matter? *Small Business Economics,* (45), 487-504. doi: 10.1007/s11187-015-9656-y

Zucker, L. G., & Darby, M. R. (1997). Present at the biotechnological revolution: Transformation of technological identity for a large incumbent pharmaceutical firm. *Research Policy, 26*(4-5), 429-446. doi: 10.1016/S0048-7333(97)00017-6

AUTHOR'S CONTRIBUTION

Murilo Montanari de Matos worked on the conceptualization and theoretical-methodological approach. The theoretical review was conducted by Ana Paula Macedo de Avellar. Data collection was coordinated by Murilo Montanari de Matos. Data analysis included Murilo Montanari de Matos and Ana Paula Macedo de Avellar. Murilo Montanari de Matos and Ana Paula Macedo de Avellar worked together in the writing and final revision of the manuscript.