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ARTICLE

Incorporation of Knowledge through acquisition in the Pharmaceutical Industry: an analysis focused on patent inventors

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ABSTRACT

This article focuses on the incorporation of knowledge conducted by large pharmaceutical corporations through the acquisition of small enterprises. The objective was to evidence to which degree the incorporation of knowledge is performed by a sample of 8 large pharmaceutical companies. In order to do this, we rely on qualitative methods, based on a sample of eight companies and 54 small enterprises they acquired in the period from 2005 to 2012. From the sample we compiled the patents granted to the small firms within the USPTO. The analysis conducted develops two central actions. The first is the inventor's usage, defined as the small enterprises inventors, which when incorporated by large pharmaceutical corporations started to develop patents through the acquiring larger company. The second is the incorporation of research trajectories, which means how inventors cite their past work as they are incorporated into the larger companies. This article concludes that the incorporation of inventors is a relevant strategy among the large companies studied so that these companies can incorporate external knowledge bases from the acquired smaller enterprises; however, just a few inventors are incorporated, which shows that just a small group of people conducts innovative research for large companies. This article contribution was to categorically evidence the incorporation of knowledge through new metrics, being them: inventor's usage and research trajectory incorporation.

KEYWORDS | Acquisitions; Pharmaceutical industry; Small enterprises; Patents

1. Introduction

The technological dynamics in the pharmaceutical R&D obliges companies to cope up with different competences and technologies outside their knowledge base and, of course, their boundaries (GAMBARDELLA, 1995; GASSMANN; REEPMEYER; VON ZEDTWITZ, 2005; HOPKINS *et al*. 2007; HOPKINS*et al.*, 2008; NIGHTINGALE, 2000). This study focuses on that process by analyzing the incorporation of inventors by large pharmaceutical companies through the acquisition of small enterprises.

The interest in analyzing this particular interaction between large and small enterprises came to our attention due to new promising technologies developed by small firms, which span out from the academic environment (ALMEIDA; HOHBERGER; PARADA, 2011; COLOMBO; PIVA, 2012; DE MATOS, 2016; HOHBERGER; ALMEIDA; PARADA, 2015; POWELL *et al.,* 2005). As such, small enterprises are seen as complementary to the large companies' R&D (CASSIMAN; VEUGELERS, 2007), compelling both to interact (BAUMOL, 2002).

Literature identifies acquisitions as one of the main forms of interaction in the pharmaceutical industry (COMANOR; SCHERER, 2013; GLEADLE *et al.*, 2014; HOPKINS *et al.,* 2013; LIGHT; LEXCHIN, 2012; HOPKINS *et al.* 2012; HIGGINS; RODRIGUEZ, 2006; MUNOS, 2009; PAUL *et al.,* 2010). Several studies have tried to address the reasons and outcomes of this process. They shed light on the correlation between acquisitions and enterprises innovative outputs (AHUJA; KATILA, 2001; ANDERSSON; XIAO, 2016; GERPOTT, 1995; GRANSTRAND, 2000; GRANSTRAND *et al.*, 1992; DESYLLAS; HUGHES, 2007, 2010; HAGEDOORN; DUYSTERS, 2002a; NORBÄCK; PERSSON, 2013; XIAO, 2015). These sectorial studies present some problems. Although the correlation between acquisition and innovative output is proved, this process - broadly known as knowledge base incorporation has many sides. As any other multifaceted process, the incorporation of knowledge in the pharmaceutical industry still lacks a detailed analysis encompassing specific elements; in our case, the knowledge held by agents. Even among the literature about knowledge incorporation (for an extensive discussion on knowledge and its outcomes for the enterprises see AMIN; COHENDET, 2004), few studies have evidenced the incorporation of knowledge in a detailed categorical analysis; therefore, we think it is necessary for a study to present interesting categories for the analyses of this specific point.

With that in mind, the focus of this study is the incorporation of inventors performed through acquisitions. The objective is to evidence to which degree inventors and, consequently, embedded knowledge is incorporated by a sample of eight large pharmaceutical enterprises.

Our main contribution is a thorough analysis on the incorporation of inventors through the development of interesting and comprehensive metrics. Consequently, this article considers the inventors as the enterprises' knowledge base "building blocks". We focus our discussing on the incorporation of knowledge that took place right after the acquisition, this moment being crucial for the acquiring enterprise to yield innovative output in the future.

In order to achieve this objective, we set two methodological steps. The first was to define and observe the incorporation of inventors. This was done by compiling the inventors in the small target enterprises that moved to the acquiring company. The second was to define and identify the incorporation of the inventors' research trajectory. This step encompasses compiling the inventors that cite their own patents as they move from the target to the acquiring company.

As the main finding, we show that embedded knowledge is incorporated from few acquired enterprises and even fewer have incorporated research trajectories. This indicates that in a large set of pharmaceutical-related technologies and potential research heuristics few of them are of the large enterprises' interest, in the first moment.

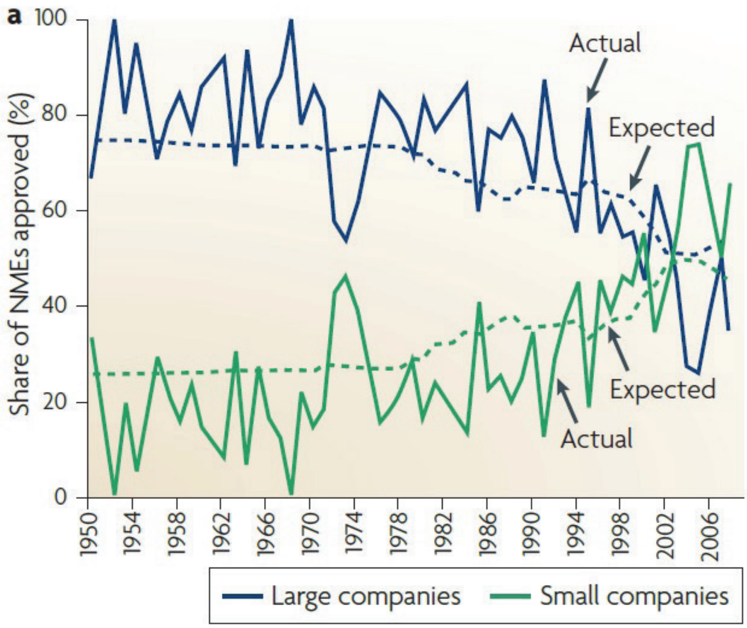
This article is composed by three more sections and a conclusion. The next section encompasses the theoretical discussion, where we focus on: (i) the importance of small enterprises in the pharmaceutical industry's innovative output; (ii) technology as the main contribution of small enterprises to large enterprises; (iii) the knowledge base features; (iv) the inventor's role among them and (v) their impact on small enterprises' innovativeness. The third section presents the methodology. The fourth section shows the results and discussion, and then the conclusion is presented.

2. Literature review

2.1 The growing importance of small enterprises and the incorporation of new competences

The share of innovative output of small enterprises has been growing (see Figure 1). Large pharmaceutical enterprises acknowledge it and create mechanisms to improve their interaction with small companies, for example the creation of scouting teams dedicated to search for promising new technologies developed by small companies. The interactions have evolved to the point that, nowadays, almost 50% of large enterprise's new technologies were originated in small companies (DE MATOS, 2016).

FIGURE 1
Share of NME approved by large and small companies

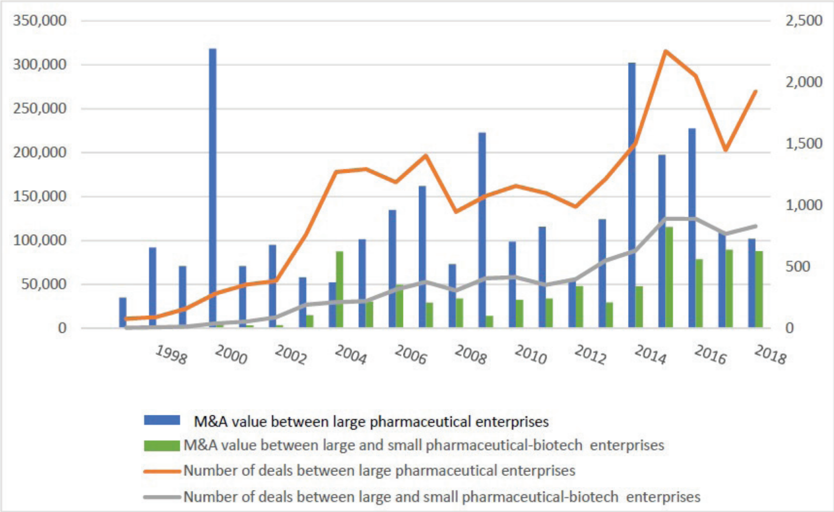


Source: Munos (2009, p. 965).

In a great myriad of interactions, acquisitions of small enterprises (Figure 2) have become a recurrent strategy and an option for developing new technologies (COMANOR; SCHERER, 2013; GLEADLE *et al.,* 2013; HOPKINS *et al.,* 2013; HOPKINS *et al.,* 2012; LANGE; WAGNER, 2019; LIGHT; LEXCHIN, 2012; HIGGINS; RODRIGUEZ, 2006; MUNOS, 2009; PAUL *et al.,* 2010).

The graphic below shows in the left axis the value, in US$ millions, of M&A in the pharmaceutical industry; the blue columns represent the acquisitions between large enterprises and the green column shows M&A between large and small enterprises. On the right side axis is the number of deals between large enterprises (orange line) and between small and large enterprises (gray line). By comparing the two colored columns, the relevance of acquisitions of small enterprises after 2002 is impressive. The two continuous lines show an increasing number of acquisitions between small and large enterprises. Both value and numbers of deals are growing; thus, the M&A between pharmaceutical and small enterprises cannot be ignored.

FIGURE 2
M&A in the pharmaceutical industry, between large and small companies from 1997 to 2018 (values in US$ millions)



Source: Own elaboration based on Orbis database

The incorporation of other enterprises' knowledge base - mainly biotechnologies - by large pharmaceutical enterprises started some time ago. According to SHARP (1999), the large pharmaceutical enterprises, at first, did not engage in creating biotechnology competencies, but they maintained some internal research to develop some absorptive capabilities to keep up with the technical advance (COHEN; LEVINTHAL, 1990). In a second moment, in the mid of the 1980s, the large pharmaceutical companies started to interact with small biotech enterprises, in particular, through collaborations and acquisitions. Those interactions were attempts to internalize some critical biotechnology competencies (AHUJA; KATILA, 2001; CASSIMAN; VEUGLERS, 2006, 2007; CULLEN; DIBNER, 1993; MALERBA; ORSENIGO, 2015; POWELL; KOPUT; SMITH-DOERR, 1996; MAKRI; HITT; LANE., 2010; GAMBARDELA, 1995; HAGEDOORN; DUYSTERS, 2002b; CLOODT; HAGEDOORN; VAN KRANENBURG, 2006; SHARP, 1999).

As part of this process of competence internalization, it is possible to observe that companies' growth are correlated to knowledge base development (GRILLITSCH; SCHUBERT; SRHOLEC, 2019). Figure 2 shows a potential incorporation of knowledge bases from small enterprises into large companies. The incorporation process follows a model, in which research teams are maintained, and the small biotech company's productive capacity is dismantled. Each purchased company acts as a new R&D team, specialized in its core capacities added to the set of innovation activities held by large corporations (SCHWEIZER, 2005). This integration model highlights the goal of pharmaceutical companies in incorporating different knowledge bases into their own R&D, establishing an acquisition-led process.

The small enterprises ability to innovate is maintained through their incorporation as an R&D unit (SCHWEIZER, 2005). In that sense, several studies have pointed a positive relation between acquisitions of small enterprises and an increase in the acquiring technological output (ANDERSSEN; XIAO, 2016; AHUJA; KATILA, 2001; DESYLLAS; HUGHES, 2007, 2010; HUSSINGER, 2010; SZÜCS, 2014).

Literature shows strong evidence that acquisitions between large and small enterprises are driven by technological aspects (e.g. CHAKRABARTI; HAUSCHILDT; SUVERKRUP, 1994; DESYLLAS; HUGHES, 2007, 2010; GRANSTRAND *et al.*, 1992; GRANSTRAND; SJÖLANDER, 1990; HUSSINGER, 2010, NORBÄCK; PERSSON, 2013; XIAO, 2015). These evidences are corroborated by the incorporation model (SCWHEIZER, 2005), the slow incorporation of biotechnologies (SHARP, 1999; NIGHTINGALE; MADHI, 2006), the industry technology evolution (DE MATOS, 2016) and the sectoral studies (ANDERSSON; XIAO, 2016; AHUJA; KATILA, 2001; DESYLLAS, HUGHES, 2007, 2010). As an outcome, these acquisitions increase the enterprise competence scope, thus developing their knowledge bases.

Therefore, by focusing on knowledge incorporation, this article is encompassing the main acquisition driver between small and large enterprises in the pharmaceutical industry. Acquisitions among large enterprises have other different drivers that are not the focus of this article.

2.2 Knowledge base and inventors' role on small enterprises innovative output

Each industry has a specific knowledge base, what leads to different innovation processes among industries and enterprises (ASHEIM; COENEN, 2005; ASHEIM;

GERTLER, 2005). As a consequence, the incorporation of knowledge bases depends on certain industry features.

The pharmaceutical and biotechnology industry are encompassed by an analytical knowledge base (ASHEIM; GERTLER, 2005; ASHEIM; COENEN, 2005; ASHEIM; HANSEN, 2009). In this industry "scientific knowledge is highly important, and […] knowledge creation is based on cognitive and rational processes (e.g. formal models)" (ASHEIM *et al*. 2007, p. 144) - this citation generally describes the drug discovery process, extensively discussed by De Matos (2016). There are many approaches for understanding knowledge in companies (AMIN; COHENDET, 2003), but the one we choose- the evolutionary economics approach- considers the company as a repository of knowledge that is constantly accessed through its routines (AMIM; COHENDET, 2003; NELSON; WINTER, 1982); in other words, the routines are the enterprises' knowledge base manifestation.

On a strategy spectrum, the acquisitions offer inputs for enterprises to build new routines through knowledge base enlargement (DE MATOS, 2016), mainly because acquisitions make the knowledge base of one enterprise accessible for the acquirer. One way of better understanding this process is to advance and expand the simple dichotomy of tacit and codified knowledge, first proposed by Pavitt (1998). These two categories will always exist simultaneously and interplay in a process where codified knowledge depends on tacit knowledge to be completely understood, "used" and becoming a new routine (NIGHTINGALE, 1998).

Nevertheless, the process of successfully incorporating the competences outside the enterprises knowledge base, through the mere access of new technologies, is not an effective element for rendering new routines (VON HIPPEL, 1994, 1998; POWELL; SNELLMAN, 2004; NELSON; WINTER, 1982). Much of the knowledge about a set of technologies and its mastery is held by its developers, making knowledge linked to its inventor (BROWN; DUGUID, 2001; POWELL; SNELLMAN, 2004; VON HIPPEL, 1994, 1998), and this can be called embedded knowledge (AMIN; COHENDET, 2003).

Embedded knowledge is a concept employed to emphasize "the work of systemic routines, shaped by stable relationships in organizational routines, technological regimes, competence and skill parameters, and interpersonal behavior" (AMIM; COHENDET, 2003, p. 3). In essence, we consider that inventors have embedded knowledge – a combination of tacit and codified knowledge – and it is used to create new routines in enterprises, but all of this is shaped by the characteristics of the enterprise and industry.

The analytical knowledge base and the embedded knowledge in the pharmaceutical industry bring new features to the analyses of enterprises and industries (ASHEIM; HANSEN, 2009; GRILLITSCH; SCHUBERT; SRHOLEC, 2019). Asheim and Gertler (2005) and Asheim and Coenen (2005) link industry features to the sources of knowledge, therefore creating a typology for knowledge bases. In more empirical studies, Asheim and Hansen (2009) and Grillitsch, Schubert and Srholec (2019) advance by linking specific occupations to different knowledge bases and, of course, their development.

In another – but complementary spectrum – to the studies cited, the literature on academic start-ups, star-scientists and founders background form a comprehensive material for understanding the role of scientists and inventors in small enterprises (ALMEIDA; HOHBERGER; PARADA, 2011; COLOMBO; GRILLI, 2005; COLOMBO; PIVA, 2012; HOHBERGER, 2016; OETTL, 2012). For these studies, academic start-ups are majorly underpinned in the research conducted by a group of scientists that enabled the company's creation (COLOMBO; PIVA, 2012; POWELL *et al.*, 2005; POWELL; KOPUT; SMITH-DOERR, 1996; ZUCKER; DARBY, 1997, 2009); their research is the main element that drives the acquisition (DE MATOS, 2016).

By combining these studies, we infer that the knowledge producers have a distinguished role on the construction of analytical knowledge bases, therefore acting as their "building blocks". For instance, the new technologies incorporated by large enterprises, like the ones dedicated to drug discovery and genetic sequencing, were born in universities as outcomes of research projects. This fact increases the importance of scientists in developing and spreading these technologies outside the academic world and inside the economic environment (COLOMBO; PIVA, 2012; ZUCKER; DARBY, 1997; ZUCKER; DARBY; LIU, 2007). In the same spectrum, studies focused on star scientists[1] as small enterprises workforce indicate a positive impact over these firms innovativeness (ZUCKER, DARBY, ARMSTRONG, 2001). In addition, scientists do not work alone, their capacity to increase the enterprises innovative activity is also correlated to how they interact with other scientist within the same enterprise (OETTL, 2012; GRIGORIU; ROATHERMEL, 2014; HESS; ROATHERMEL, 2011).

1 Zucker, Darby and Armstrong (2001) definition of star scientists is based on productivity measures for articles related to genetic sequencing discoveries. For them, only 0.7% of the authors of articles, reporting genetic sequence discoveries through 1989, are star scientists.

As scientists move from one enterprise to another, they tend to keep researching their "own stuff" (HOHBERGER, 2016); this highlights a certain path dependence held by scientists over their research achievements. In this process, the same research line can be constructed and further developed if the main inventors are maintained.

Even though the knowledge held by scientists could be, arguably, of free access, much of the process that leads to the development and mastering of a new technology is extremely embedded in the scientist, or the group of scientists that developed the technology in a similar way as it has already been presented by Nightingale (1998). Furthermore, the research of a scientist follows a path that does not depend on the place where he or she works (HOHBERGER, 2016). In conclusion, as large enterprises employ scientists, they are attempting to master a specific technology by building inside research lines that started elsewhere, then showing a successful knowledge base incorporation (DE MATOS, 2016).

In a technology evolution approach, as drug discovery activities become more complex and dependent on the embedded knowledge for its conduction (AMZEL, 1998; GASSMAN; REEPMEYER; VON ZEDTWITZ , 2005; MACARRON, *et al.*, 2011; PEREIRA; WILLIAMS, 2007), the problems related to knowledge stickiness may increase (BROWN; DUGUID, 2001; POWELL; SNELLMAN, 2004; VON HIPPEL, 1994, 1998). One way of attesting it is the outsource limit of R&D activities (MOWERY; ROSENBERG, 1989). In the pharmaceutical industry, as in other sectors, if R&D cannot be fully outsourced its core must be done inside the enterprise (MOWERY; ROSENBERG, 1989).

For instance, random screening technologies and computational models cannot build molecules on their own; they need a trained scientist able to recognize a possible molecule. Drug discovery is still highly dependent on the scientist embedded knowledge, although this industry has been facing a process of R&D industrialization (NIGHTINGALE, 2000; NIGHTINGALE; MADHI, 2006). Therefore, it is not difficult to accept that inventors have a great effect on the enterprises technological outputs (ALMEIDA; HOHBERGER; PARADA, 2011; GRIGORIU; ROATHERMEL, 2014; HESS; ROATHERMEL, 2011; HOHBERGER, 2016; ZUCKER; DARBY, 1997, 2009; ZUCKER; DARBY; LIU, 2007).

In essence, the embedded knowledge possessed by inventors – in a sector encompassed by an analytical knowledge base – is essential for building new routines leading to new competences and technologies. The enterprises' competitive dynamics and growth, undoubtedly, lies on the capacity of incorporating and developing the knowledge base (GRILLITSCH; SCHUBERT; SRHOLEC, 2019).

3. Methods

3.1 Sample

This study methodology started by setting a sample of large pharmaceutical enterprises. In order to do that, three sources of data were used. The first was the report "HBM PHARMA/BIOTECH M&A REPORT 2013", which compiles M&A between pharmaceutical companies and small pharmaceutical enterprises between 2005 and 2012, containing: (i) the acquired companies (target), (ii) the acquiring companies (acquirers) and (iii) the amount spent. Based on this report, the study could identify which companies were actively acquirers (having acquired more enterprises) and which ones spent more resources on M&A. The second was the Forbes' index of the 2000 largest companies in the world[2] used as a means of better selecting the larger enterprises. The last source were enterprises' own annual reports informing details on R&D and specific acquisitions.

These sources were combined to set a sample relevant in terms of revenues, R&D and M&A expenditures. The HBM enabled to choose relevant acquirers, the Forbes index indicated the larger revenues and the annual reports informed the R&D expenses. Not all large enterprises are intensive acquirers and some less relevant enterprises may spend a great amount on M&A, but all large companies have a similar R&D investment.

Based on these criteria we chose: (i) Pfizer; (ii) Johnson & Johnson; (iii) Roche; (iv) Sanofi; (v) Astra-Zeneca; (vi) Abbott-Laboratories; (vii) Glaxo SmithKline (GSK) and (viii) Merck. The sample is composed by these eight large enterprises that acquired fifty-four (54) small enterprises.

Finally, the patent data was collected at the PatFT (Patent Full-Text and image database), a free access database from USPTO. At the database it is possible to visualize key information - in our case, we could compile (i) the assignee's name; for this article, we looked for the company's name; (ii) the inventor's name, the name of the people responsible for developing the patent and (iii) references, as each patent has a list of all other patents or scientific work used as reference, and through it one can look for specific reference in patents.

The sample relevance can be attested in the following table.

2 This study used the 2013 edition

TABLE 1
Sample Information (US$ Billions)

Companies	R&D (2012)	Total Expenses in M&A	Annual Average Expenses in M&A (2005-2012)	R&D/ Revenue	Annual Average Expenses on M&A/ Revenues	Annual Average Expenses on M&A/ R&D
Pfizer	6,6	76,5	9,5	13%	18,6%	1,4
Johnson &Johnson	5,3	4,5	0,5	21%	2%	0,09
Merck & Co	8,1	2,9	0,3	17%	1,10%	0,05
Roche	14,16	48,3	6	35%	14,60%	0,4
Astra Zeneca	4,4	18,3	2,2	16%	7,90%	0,5
Sanofi	5	26	3,25	12%	8%	0,65
GSK	2	8,3	1	13%	6,30%	0,5
Abbott Laboratories	4,3	4,1	0,5	11%	1,30%	0,11
Total (sample)	49,68	188,9	23,45	-	-	0,57
World Total	135	585,48	73,18	-	-	0,54
Total (sample)/ World Total	37%	32%				

Source: own elaboration

The sample are extremely relevant for the pharmaceutical sector, as these enterprises encompass 37% of the PhRMA (Pharmaceutical Research and Manufacturers of America) members' expenditures in R&D. In addition, these eight enterprises account for 32% of all expenditures in M&A in the pharmaceutical industry.

This table also indicates that these enterprises may follow different strategies as their M&A/Revenue ratio differs among them, reveling enterprises that resort more on M&A than others. This could indicate a heterogeneity in terms of knowledge incorporation

3.2 Inventor's usage as measurement

As vastly discussed in the literature, the use of patents have significant problems (GRILICHES, 1979; GRILICHES; PAKES; HALL, 1986, PAKES; GRILICHES, 1980), especially when we consider useful knowledge (MOKYR, 2002). Nevertheless, patens are highly used and considered products of knowledge (AHUJA; KATILA, 2001; ANDERSSON; XIAO, 2016; CLOODT; HAGEDOORN; VAN KRANENBURG, 2006; DESYLLAS; HUGHES, 2007, 2010; HAGEDOORN; DUYSTERS, 2002a, 2002b; XIAO, 2015, among others).

Arguably, patents are inventions that partially represent the amount of knowledge available for the enterprises that engage in acquisitions. In essence, patents may be treated as techniques (MOKYR, 1992, 2002). Nevertheless, each invention has behind it a whole set of knowledge that is held by an inventor or a group of them, and this knowledge is accessed, combined and tested until a workable invention (at least in theory) is produced. Therefore, inventors are the main element responsible for producing new technologies (COLOMBO, PIVA, 2012; HOHBERGER, 2016; ALMEIDA; HOHBERGER; PARADA, 2011; OETTL, 2012; ZUCKER, DARBY, 1997; 2009.

Asheim and Hansen (2009) and Grillitsch, Schubert and Srholec (2019), propose that chemists, life sciences professionals and university teaching professionals are occupations within the analytical knowledge base, responsible for constructing it; in other words, these occupations are responsible for the innovation process among companies characterized by these structures.

In this article, we borrow their idea and consider inventors - described in the patent information – to be the main traceable occupation (element) at the innovative process among analytical knowledge bases' industries, i.e. inventors are the building blocks among analytical knowledge bases. In order to corroborate our choice, Asheim and Hansen (2009) show a significant statistical correlation between analytical knowledge base and patent index. This methodological consideration holds tighter in small companies with few employees and patents (DE MATOS, 2016). Thus, the people identified as inventors represent a major part of knowledge incorporated among enterprises.

In this line of thought, a company that needs to master a technology developed by a small enterprise must employ the inventors responsible for producing the same technology. Arguably, the evolution of technology and the successful incorporation of inventors lead to new patents. Therefore, every time an inventor develops a patent for the large company he is producing knowledge and technology that will be eventually used by this same large company.

On one hand, if this study points that large pharmaceutical companies do not incorporate the inventors in its routines, we are evidencing that technology can be understood regardless of its creator. On the other hand, by showing that inventors are incorporated in the routines of companies, we will evidence the importance of embedded knowledge beyond the abstract and theoretical realm.

This incorporation, traceable through patents, is expressed in a 'movement' of inventors from the target to the acquiring company. In order to track this movement, we analyzed (read) individually all the 2,803[3] patents issued by these fifty-four (54) small enterprises. The study compiled a total of 1.971 inventors. At the USPTO we searched each of the inventors to assess who had developed a patent assigned by the large acquiring company after it acquired a small company. In other words, we looked for inventors that started to employ their embedded knowledge for the large companies.

By tracking the inventor's movement this article could observe the ones incorporated by the large acquiring company. The mathematical relation between the inventors in the small enterprises and the ones that move to the large enterprises is the "inventors' use" that is presented as a simple percentage index indicating degrees of knowledge base incorporation.

Thus, we can advance to the second methodological step and show a research trajectory incorporation. By identifying this process, this article looks at the very interesting phenomenon of incorporating external research, and so empirically showing the creation of new techniques and synergies between tacit and codified knowledge.

3.3 Research trajectory incorporation

The research trajectory incorporation is an adaptation based on Hohberger (2016). In essence, Hohberger (2016) tries to identify if star scientists are able to developed innovations based on their past research and if other scientist can create inventions based on other star scientists' past research. Our idea, in this article, is focused on the inventor moving from the small to the large company and having his past work referenced, enabling the continuation of his research trajectory on the large enterprise. In short, we will see if the selected inventors use their past work on new patents.

The research trajectory incorporation is a method, developed in this article, which follows some steps. The first step is given by the inventor's use, which gives us the companies that had incorporated inventors. Among the 54 acquired enterprises, 33 had at least one of its inventors incorporated by the large company. The second

3 The number of patents is that informed in a search for assignee name in the USPTO.

step consists on compiling all patents issued by these 33 companies' inventors, before their incorporation. The third step encompasses looking for these inventors' patents that reference their own past work. Summing up, we are looking for patents assigned by large enterprises referencing patents assigned by small enterprises, but both must be developed by the same inventor or group of inventors.

For example: inventor A developed 3 patents for the small enterprise Y that was later acquired by large enterprise X. In the acquisition process, inventor A was incorporated by X. At the large company, A has issued 3 patents which have as reference 2 previous patents developed, by the same inventor, while he was working for the small enterprise Y. In the end, what is seen is that the large company is not only incorporating the inventor's knowledge, but now his research is been conducted by the acquiring enterprise; therefore, we are seeing a process of research incorporation.

Clearly we use the acquisition phenomenon as the main event. Therefore, we can think on processes after the acquisition and before the acquisition. For that and to make the next tables more intelligible, we adopted the following nomination:

- Prior patents: refers to patents developed by the incorporated inventor and assigned by the small enterprise
- Following patents: the patents developed by incorporated inventors and assigned by the large enterprise
- Referenced Patents: patents used as reference in the following patents. In our case, all referenced patents are prior patents but not all prior patents are referenced patents
- Generated Patents: patents that have as reference at least one prior patent. In our case all generated patents are following patents, but not all following patents are generated patents

The research trajectory incorporation evidences a full incorporation of knowledge. As inventors continue their work, they are also internalizing and spreading their knowledge across the acquirer enterprise. Not only that, but we are also able to evidence the interplay idea of codified and tacit knowledge in companies.

4. Results and Discussion

Acquisitions may have several drivers, but, in a broad sense, they all indicate an enterprise's interest in another or a mutual interest. Here we seek for acquisitions followed by the incorporation of inventors, as this behavior evidences the interest of large pharmaceutical companies in the small enterprises' embedded knowledge and, therefore, their knowledge bases.

The series of works of Asheim and Coenen, 2005; Asheim, 2007; Asheim and Hansen 2009 indicate which occupations are essential for developing different knowledge bases. Considering that the inventor's usage shows the incorporation of key people, within the analytical knowledge base in the pharmaceutical industry, whose work is fundamental for the enterprise growth (GRILLITSCH; SCHUBERT; SRHOLEC, 2019). As a consequence, the incorporation of inventors is a way of maintaining key people thus enabling to internalize critical elements and enhance the acquirer innovative capabilities (DE MATOS, 2016). Furthermore, by bringing the relevant inventors, the large enterprises are trying to emulate inside their borders the interaction among inventors, as in a small enterprise dynamics. These two elements are essential for increasing the innovative output (GRIGORIOU; ROTHAERMEL, 2014; OETTL, 2012; SCHWEIZER, 2005). We capture this dynamics by employing the idea of "inventor's usage", which results are displayed in Table 2.

TABLE 2
Inventor's usage from 2002 to 2018

Small acquired enterprises	Total of inventors in the acquired companies (A)	Inventors that started to patent for the large enterprise (B)	Inventor's Usage (B/A)
Roche	95	48	51%
Abbott-Laboratories	44	19	43%
Sanofi	137	42	31%
Pfizer	329	49	15%
Merck	255	32	13%
GSK	680	58	9%
Astra Zeneca	275	20	7%
J&J	156	9	6%
Total	**1971**	**277**	**14%(1)**

Source: own elaboration based on sample patent information retrieved at USPTO's PatFT database.
(1) Average value.

In a general perspective, the average "inventor's usage" is 14%, but the eight large pharmaceutical companies have incorporated the inventors from the acquired companies in different degrees. Some companies, such as Abbott-Laboratories and Roche, have used a large share of inventors; while J&J, Astra-Zeneca, and GSK just a few. Although the incorporation of inventors is disseminated among the sample, the degrees of incorporation are heterogeneous. This fact is even clearer when we look at the small enterprises (targets) individually, as shown in the annexes.

Each small enterprise shows how large pharmaceutical companies behave differently with each one of its targets. Piramed, Mirus-Bio, Facet-Biotech, VaxDesign, Rinat Neuroscience, Glycofi, Abmaxis, Reliant Pharmaceuticals have at least 50% of inventor's usage. This group of enterprises certainly has a distinguished group of people that meets the technological development project of the large companies. On the other spectrum, 24 small enterprises (44% of all targets) had none of its inventors incorporated.

This broad picture shown that few people are relevant while the majority is of no interest, this. fact is aligned with Blomkvist, Kappen and Zander's (2014) perception that technical advances are being put forward by a small group of people. Therefore, this perception holds for the economy as a whole and for the large pharmaceutical companies analyzed in this article.

The literature has also treated these results in a similar perspective. For instance, the relevant work focused on star scientists have strongly supported that just a few are responsible for a great amount of knowledge production (GRIGORIOU; ROTHAERMEL, 2014; HOHBERGER, 2016; OETTL, 2012; ZUCKER; DARBY, 2009. Our article shows a similar pattern for these 8 large pharmaceutical companies at which few inventors were worth to be incorporated. We may conclude that when the large pharmaceutical companies incorporate inventors, the company is attempting to benefit from star-scientists high knowledge production.

Based on the literature, the incorporation of inventors has important outcomes for the large enterprise. According to Hohberger (2016), by incorporating inventors, the large enterprises are internalizing the research paths; i. e. the large pharmaceutical company is bringing inside its borders the knowledge that was developed outside. We can look in closer detail to the incorporation of inventors in order to observe the incorporation of research trajectories. This process is in line with Nightingale (1998); Nonaka and Takeushi's (1995) discussion about the dependency on technology developers' tacit knowledge for creating new routines and mastering technologies.

The next Tables will show inventors referencing their own work, the Tables do not correspond to a specific period of time, because scientists are referencing patents issued before their incorporation. This process indicates the creation of research trajectories in companies and the internalization of embedded knowledge leading to new routines. Therefore we are empirically evidencing the relevance of embedded knowledge and also supporting several studies that discuss the interplay between codified and tacit knowledge (such as COWAN; FORAY, 1997; NIGHTINGALE, 1998; ANCOIRI; BURETH; COHENDET, 2000; JOHNSON; LORENZ; LUNDVALL, 2002; CAVUSGIL; CALANTONE; ZHAO, 2003, among others). Another element captured is the technology relevance indicated through patent citation (HALL; JAFFE; TRAJTENBERG, 2001, 2005).

TABLE 3
Comparison between target enterprises with incorporated inventors and incorporated research trajectories

Enterprises	Target enterprises (A)	Target enterprises with incorporated inventors (B)	Target enterprises with research trajectories internalized (C)	Ratio of Incorporated Inventors to Internalized Research Strategy (C/B) (%)
Pfizer	11	5	2	40
J&J	5	2	0	0
Merck	7	4	4	100
Roche	6	3	3	100
Astra-Zeneca	7	3	1	33
Sanofi	6	3	1	33
GSK	10	7	3	42
Abbott-Laboratories	2	2	0	0

Source: own elaboration based on sample patent information retrieved at USPTO's PatFT database

Table 3 can be understood as a process starting in the acquisition (column A) and ending in the inventor's research trajectory internalization (column C). Clearly, from A to C, the numbers are decreasing, which reinforces the idea of few people responsible for developing technologies (BLOMKVIST; KAPPEN; ZANDER, 2014). Interestingly, the last column (C/B) in Table 3 shows a correlation between the incorporation of inventors and research trajectories, indicating a scientist's path dependence; in other words, Table 3 shows that inventors tend to reference their own work, as was discussed by Hohberger (2016).

Mostly important, for this article, is the evidence that the incorporation of inventors often leads to a research trajectory incorporation; therefore, the inventors' knowledge continues with them, no matter if they move from one company to another. Furthermore, this knowledge has been continuously developed by the same group of inventors, and thus the company in which this research is developed is the one that captures its value.

TABLE 4
Internalized Research Trajectories and Patents Relevancy

Enterprises	Inventors Incorporated	Inventors with research trajectories Internalized	Prior Patents	Referenced Patents	Generated Patents
Pfizer	49	9	115	32	8
J&J	9	0	21	0	0
Merck	32	18	257	34	33
Roche	48	37	81	37	33
Astra-Zeneca	20	1	43	1	1
Sanofi	42	7	10	5	2
GSK	58	19	345	20	12
Abbott-Laboratories	19	0	0	0	0

Source: own elaboration based on sample patent information retrieved at USPTO's PatFT database

Table 4 points at the importance of a small group of inventors that had their research internalized. Not only their single inventions were relevant, but based on their past work, new inventions were created, then building a research trajectory in the company. This research started outside the large company borders, but as the large company acquired and maintained some relevant inventors, it was able to internalize some research done outside its borders - and apparently successful incorporated it in its R&D.

The incorporation of inventors is not only a way of mastering the developed technology, but also a strategy to appropriate the outcomes of the research conducted by the inventors. Many small enterprises have no patents, but the research conducted by their R&D team is enough to draw the attention of a large company (DE MATOS, 2016). This fact can be seen as a cycle, where technology draws the attention of the large company; after its acquisitions, this same technology can evolve as the inventor keeps researching related subjects.

Therefore we summarize our main findings in four parts. First, the incorporation of inventors is a way of observing the incorporation of knowledge base of other companies, being essential for mastering and creating new competences (DE MATOS, 2019). Even among different large pharmaceutical companies' strategies and behavior (as can be observed in Table 1), this process is widespread among the sample, but in different degrees, for example: Sanofi has an M&A/Revenue of 8% and an inventor's usage of 31%; Pfizer has an M&A/Revenue of 18,4% and an inventor's usage of 15%.

Second, some small enterprises stand out among others, like: Piramed, Facet-Biotech, Vax Design, Rinat Neuroscience, Glicofy, Reliant Pharmaceutical; all of them had more than 50% of their inventors incorporated, which is a strong evidence of these enterprises' technological relevance.

Third, the inventor's usage proves that large pharmaceutical companies are extensively incorporating the knowledge base building blocks from the target companies. As inventors are being incorporated, the large pharmaceutical companies are internalizing important knowledge, and also building new research lines internally. The incorporation of those "building blocks" has a great impact on the company's growth (GRILLITSCH; SCHUBERT; SRHOLEC, 2019).

Finally, the companies that have internalized more research strategies, such as Roche and Merck, are the ones that are building closer knowledge bases to the small acquired enterprises. Through these findings, this study contributes by detailing a categorical analysis about knowledge incorporation that corroborates past relevant studies on the theme.

5. Conclusion

This paper shed light on the incorporation of embedded knowledge through enterprise acquisition. Even though a vast literature is dedicated to knowledge, few studies have evidenced its incorporation using similar categories as the one employed in this article. The same can be said about the M&A literature that has broadly evidenced an innovativeness increase led by acquisitions, but few studies have looked at particular elements of knowledge.

Based on the studies of: Asheim and Coenen (2005), Asheim and Hansen (2009), Hohberger (2016), Grillitsch, Schubert, Srholec (2019), we introduce the idea of inventor's usage and research trajectory incorporation, both of them essential for understanding the incorporation of knowledge as key elements in the company's knowledge base development, and consequently a long-term growth. Therefore, our main contribution was to evidence through these concepts a categorical analysis on the incorporation of knowledge. We believe this to be of extreme relevance as it bridges the vast theoretical literature on knowledge to actual companies' behavior.

This study has dealt with a large amount of data and explored a new element in the acquisition studies. Our main findings were the evidence that the eight large pharmaceutical companies analyzed used the incorporation of inventors as a recurrent strategy; the inventors tend to reference their own work as they are incorporated, and just few inventors are incorporated. Those findings are new and relevant for future discussion on companies' strategies and their interaction with smaller and more innovative ventures. Meanwhile, the majority of studies are dealing with post-acquisition performance or pre-acquisition drivers, and only a few deal with the process in-between pre-acquisition and post-acquisition. In the end, this period is essential for the success or failure of an acquisition.

The incorporation of knowledge is a many-sided phenomenon; we chose to look at a specific feature. This choice brings with it some limitations and unexplored questions on the subject of knowledge incorporation. First, this study is focused on the pharmaceutical industry and on acquisitions of small enterprises conducted by eight large pharmaceutical companies. Second, for our purposes the post-acquisition performance is put aside, as we are interested in which decisions the company makes as it conducts the acquisition. Third, we do not consider the knowledge necessary for producing the patents. Fourth, small acquired enterprises with no patents were not considered. Fifth, we do not correlate the incorporated inventors to the characteristics of the technology developed by them, so some variables like novelty (priority patents), importance (citations from other enterprises) or technology field are ignored. In the future, studies could discuss why some inventors produce more patents for the large enterprise while others do not. In addition, future studies should consider novelty, importance and technology fields in the process of knowledge incorporation.

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References

AHUJA, G.; KATILA, R. Technological Acquisition and the Innovation Performance of Acquiring Firms: A Longitudinal Study. *Strategic Management Journal*, v. 22, n. 3, p. 197-220, 2001.

ALMEIDA, P.; HOHBERGER, J.; PARADA, P. Individual scientific collaborations and firm-level innovation. *Industrial and Corporate Change*, v. 20, n. 6, p. 1571-1599, 2011.

AMIN, A.; COHENDET P. *Architectures of knowledge: Firms, capabilities, and communities*. Oxford University Press, 2004.AMZEL, M. Structure-based Drug Design. *Current opinion on Biotechnology*. 9, 366-369, 1998.

ANCORI, B.; BURETH, A.; COHENDET, P. The Economics of Knowledge: The Debate between Codified and Tacit Knowledge. *Industrial and Corporate Change*, v. 9, n.1, p. 255-287, 2000

ANDERSSEN, M.; XIAO, J. Acquisitions of start-ups by incumbent businesses: A market selection process of "high-quality" entrants? *Research Policy*, v. 45, n. 1, p. 272-290, 2016.

ASHEIM, B.; COENEN, L. Knowledge bases and regional innovation systems: Comparing Nordic clusters. *Research Policy*, v. 34, n. 8, p. 1173-1190, 2005.

ASHEIM, B.; COENEN, L.; MOODYSSON, J.; VANG, J. Constructing knowledge-based regional advantage: implications for regional innovation policy. *International Journal of Entrepreneurship and Innovation Management*, v. 7, n. 2-5, p. 140-155, 2007.

ASHEIM, B.; GERTLER, M. The geography of innovation: regional innovation systems. FAGERBERG, J; MOWERY,D; NELSON, R. *The Oxford handbook of innovation,* Oxford University Press, 2005.

ASHEIM, B.; HANSEN, H. Knowledge bases, talents, and contexts: On the usefulness of the creative class approach in Sweden. *Economic geography*, v. 85, n. 4, p. 425-442, 2009.

BAUMOL, W.J. Entrepreneurship, Innovation and Growth: The David-Goliath Symbiosis. *The Journal of Entreprenurial Finance*, v. 7, n. 2, p. 1-11, 2002.

BLOMKVIST, K.; KAPPEN, P.; ZANDER, I. Superstar inventors - Towards a people-centric perspective on the geography of technological renewal in the multinational corporation. *Research Policy*, v. 43, n. 4, p. 669-682, 2014.

BROWN, J.; DUGUID, P. Knowledge and organization: A social-practice perspective. *Organization science*, v. 12, n. 2, p. 198-213, 2001.

CASSIMAN, B.; VEUGELERS, R. In Search of Complementarity in Innovation Strategy: Internal R&D and External Knowledge Acquisition. *Management Science*, vol. 52, n. 1, pp. 68-82, 2006

CASSIMAN, B.; VEUGELERS, R. Are external technology sourcing strategies substitutes or complements?: The case of embodied versus disembodied technology acquisition. *IO: Empirical Studies of Firms & Markets*, v. 3, n. 672, p. 1-22, 2007.

CAVUSGIL, S.T.; CALANTONE, R.; ZHAO, Y. Tacit knowledge transfer and firm innovation capability. *Journal of business & industrial marketing*, v. 18, n. 1, p. 6-21, 2003.

CHAKRABARTI, A., HAUSCHILDT, J., SUVERKRUP, C. Does it pay to acquire technological firms? *R&D Management*, 24, pg. 47-56, 1994

CLOODT, M.; HAGEDOORN, J.; VAN KRANENBURG, H. Mergers and acquisitions: Their effect on the innovative performance of companies in high-tech industries. *Research Policy*, v. 35, n. 5, p. 642-654, 2006.

COHEN W. M., LEVINTHAL, D., A. Absorptive capacity: a new perspective on learning and Innovation. *Administrative Quarterly*, 35, 1, 1990.

COLOMBO, M.G.; GRILLI, L. Founders' human capital and the growth of new technology-based firms: A competence-based view. *Research Policy*, v. 34, n. 6, p. 795-816, 2005.

COLOMBO, M.G.; PIVA, E. Firms' genetic characteristics and competence-enlarging strategies: A comparison between academic and non-academic high-tech start-ups. *Research Policy*, v. 41, n. 1, p. 79-92, 2012.

COMANOR, W.; SCHERER, F. Mergers and innovation in the pharmaceutical industry. *Journal of health economics*, v. 32, n. 1, p. 106-113, 2013.

COWAN, R.; FORAY, D. The economics of codification and the diffusion of knowledge. *Industrial and Corporate Change*, v. 6, n. 3, p. 595-622, 1997.

CULLEN, C.; DIBNER, M.. Strategic Alliances in biotechnology: Imperatives for the 1990's. *Biotechnology Review* 1, pg.110-119, 1993.

DE MATOS, M.M. *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.

DE MATOS, M.M.; AVELLAR, A.P. Technical and Skill Knowledge Incorporated by Big-Pharma in Acquisitions of Small Enterprises. In: ASSOCIAÇÃO NACIONAL DOS CENTROS DE PÓS-GRADUAÇÃO EM ECONOMIA, 47., 2019, São Paulo. São Paulo, ANPEC, 2019.

DESYLLAS, P.; HUGHES, A. Sourcing technological knowledge through corporate acquisition: Evidence from an international sample of high technology firms. *Journal of High Technology Management Research*, v. 18, n. 2, p. 157-172, 2007.

DESYLLAS, P.; HUGHES, A. Do high technology acquirers become more innovative? *Research Policy*, v. 39, n. 8, p. 1105-1121, 2010.

GAMBARDELLA, A. *Science and innovation:* The US pharmaceutical industry during the 1980s. Cambridge University Press, 1995.

GASSMAN, O.; REEPMEYER, G.; VON ZEDTWITZ, M. *Leading Pharmaceutical Innovation: Trends and Drivers for growth in the Pharmaceutical Industry*, Springer-Verlag, Berlin, 2005

GERPOTT, T. Successful integration of R&D functions after acquisitions: an exploratory empirical study. *R&D Management*, v.25,n.2, p. 161-178, 1995

GLEADLE, P.; PARRIS, S.; SHIPMAN, A.; SIMONETTI, P. Restructuring and innovation in pharmaceuticals and biotechs: The impact of financialisation. *Critical Perspectives on Accounting*, v. 25, n. 1, p. 67-77, 2014.

GRANSTRAND, O. *Corporate Innovation Systems* – A Comparative Study of Multi-Technology Corporations in Japan, Sweden and the USA. Sweden: Chalmers University of Technology Industrial Management and Economics, 2000. p. 1-112.

GRANSTRAND, O.; BOHLIN, E.; OSKARSSON, C.; SJÖBERG, N. External technology acquisition in large multi-technology corporations. *R&D Management*, v. 22, n. 2, p. 111-134, 1992.

GRANSTRAND, O.; SJÖLANDER, S. The Acquisitions of Technology and Small Firms by Large Firms. *Journal of Economic Behavior and Organization*, v. 13, n. 3, p. 367-386, 1990.

GRIGORIOU, K.; ROTHAERMEL, F. T. Structural Microfoundations of Innovation: The Role of Relational Stars. *Journal of Management*, v. 40, n. 2, p. 586-615, 2014.

GRILICHES, Z. Issues in assessing the contribution of research and development to productivity growth.*The bell journal of economics*, p. 92-116, 1979.

GRILICHES, Z; PAKES, A; HALL, B.The value of patents as indicators of inventive activity. *National Bureau of Economic Research*, 1986.

GRILLITSCH, M.; SCHUBERT, T.; SRHOLEC, M. Knowledge base combinations and firm growth. *Research Policy*, v. 48, n.1, p. 234-247, 2019.

HAGEDOORN, J.; DUYSTERS, G. The Effect of Mergers and Acquisitions on the Technological Performance of Companies in a High-tech Environment. *Technology Analysis & Strategic Management*, v. 14, n. 1, p. 67-85, 2002a.

HAGEDOORN, J.; DUYSTERS, G. External sources of innovative capabilities: The preference for strategic alliances or mergers and acquisitions. *Journal of Management Studies*, v. 39, n. 2, p. 167-188, 2002b.

HALL, B.H.; JAFFE, A.B.; TRAJTENBERG, M. *The NBER Patent Citations Data File*: Lessons, Insights and Methodological Tools. Cambridge, MA, National Bureau of Economic Research, 2001. (NBER Working paper, 8498).

HALL, B. H.; JAFFE, A.B.; TRAJTENBERG, M. Market Value and Patent Citations. *The RAND Journal of Economics*, v. 36, n. 1, p. 16-38, 2005.

HESS, A.; ROTHAERMEL, F. When are assets complementary? Star scientists, strategic alliances, and innovation in the pharmaceutical industry. *Strategic Management Journal*, v. 32, n. 8, p. 895-909, 2011.

HIGGINS, M.; RODRIGUEZ, D. The outsourcing of R&D through acquisitions in the pharmaceutical industry. *Journal of Financial Economics*, n. 80, pp351-383, 2006.

HOHBERGER, J. Does it pay to stand on the shoulders of giants? An analysis of the inventions of star inventors in the biotechnology sector. *Research Policy*, v. 45, n. 3, p. 682-698, 2016.

HOHBERGER, J.; ALMEIDA, P.; PARADA, P. The direction of firm innovation: The contrasting roles of strategic alliances and individual scientific collaborations. *Research Policy*, v. 44, n. 8, p. 1473-1487, 2015.

HOPKINS, M.; MARTIN, M.; NIGHTINGALE, P.; KRAFT, A.; MADHI, S. The myth of the biotech revolution: An assessment of technological, clinical and organisational change. *Research policy*, v. 36, n. 4, p. 566-589, 2007.

HOPKINS, M.; MARTIN, P.; NIGHTINGALE, P.; KRAFT, A. *Living with Dinosaurs*: Genomics, and the industrial dynamics of the pharmaceutical industry. Copenhagen, 2008. (Paper to be presented at the 25th Celebration Conference 2008 on Entrepreneurship and Innovation - Organizations, Institutions, Systems and Regions Copenhagen, CBS, Denmark, June 17 - 20, 2008).

HOPKINS, M., NIGHTINGALE, P., TINOCO, R., BADEN-FULLER, C. Servant Firms in Drug discovery: A Neglected Project Based Organizational Form. *Social Science Research Network*, march, 2012, available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2027537

HOPKINS, M.; CRANE, A.; NIGHTINGALE, P.; BADEN-FULER, C. Buying big into biotech: scale, financing and the industrial dynamics of UK biotech, 1980-2009. *Industrial and Corporate Change*, v. 22, n. 4, pp. 903-952, 2013.

HUSSINGER, K. On the importance of technological relatedness: SMEs versus Large acquisitions targets. *Technovation*, 30, pg. 57-64, 2010

JOHNSON, B.; LORENZ, E.; LUNDVALL, B. Why all this fuss about codified and tacit knowledge? *Industrial and Corporate Change*, v. 11, n. 2, p. 245-262, 2002.

LANGE, S.; WAGNER, M. The Influence of Exploratory versus Exploitative Acquisitions on Innovation Output in the Biotechnology Industry. *Small Business Economics*, p 1-22, 2019.

LIGHT, D.; LEXCHIN, J.;. Pharmaceutical research and development: what do we get for all that money?. *British Medical Journal*, v. 345, p. 1-5, 2012.

MACARRON, R.; BANKS M.; BOJANIC, D.; BURNS, D.; CIROVIC, D.; GARYANTES, T.; GREEN, D.; HERTZBERG, R.; JANZEN, W.; PASLAY, J.; SCHOPFER, U.; SITTAMPALAM, G. Impact of high-throughput screening in biomedical research.*Nature reviews Drug discovery*, v. 10, n. 3, p. 188-195, 2011.

MAKRI, M.; HITT, A.; LANE, P. Complementary Technologies, Knowledge Relatedness and Invention Outcomes in High Technology Mergers and Acquisitions. *Strategic Management Journal*, 31, pp. 602-628, 2010.

MALERBA, F., ORSENIGO, L. The evolution of the pharmaceutical industry. *Business History*, 57:5, 664-687, 2015

MARTIN, P.; NIGHTINGALE, P.; KRAFT, A. Living with "Dinosaurs": Genomics, and the industrial dynamics of the pharmaceutical industry. *Science*, n. 3, p. 0-24, 2008.

MOWERY, D.; ROSENBERG, N. *Technology and the Pursuit oF Economic Growth*. Cambridge University Press, New York, 1989.

MOKYR, J. *The lever of riches: Technological creativity and economic progress*. Oxford University Press, 1992.

MOKYR, J. *The Gifts of Athena: Historical Origins of the Knowledge Economy.* Princeton University Press, Princeton, New Jersey, 2002

MUNOS, B. Lessons form 60 years of pharmaceutical innovation. *Nature Reviews Drug Discovery*, 8, pp. 959-968, 2009.

NELSON, R.; WINTER, S. *An Evolutionary Theory of Economic Change.* Harvard University Press, 1982

NIGHTINGALE, Paul. A cognitive model of innovation.*Research policy*, v. 27, n. 7, p. 689-709, 1998.

NIGHTINGALE, P. Economies of scale in experimentation: knowledge and technology in pharmaceutical R&D. *Industrial & Corporate Change*, v. 9, n. 2, p. 315-359, 2000.

NIGHTINGALE, P.; MADHI, S. The evolution of pharmaceutical innovation. MAZZUCATO, M.; DOSI, G. (eds) *Knowledge Accumulation and Industry Evolution*, Cambridge University Press, Cambridge, 2006

NONAKA, I.; TAKEUSHI, H. *The Knowledge-Creating Company: How Japanese Companies Create the Dynamic of Innovation.* New York: Oxford University Press, 1995

NORBÄCK, P.; PERSSON, L. *Born to be global and the globalization process*. Research Institute of Industrial Economics and CEPR, 2013.

OETTL, A. Reconceptualizing stars: Scientist helpfulness and peer performance. *Management Science*, v. 58, n. 6, p. 1122-1140, 2012.

PAKES, A.; GRILICHES, Z. Patents and R&D at the firm level: A first report. *Economics letters*, v. 5, n. 4, p. 377-381, 1980.

PAUL, S.; MYTELKA, D.; DUNWIDDIE, C.; PERSINGER, C.; MUNOS, B.; LINBORG, S.; SCHACHT, A. How to improve R&D productivity: the pharmaceutical industry's grand challenge. *Nature Reviews Drug Discover*, vol. 9, 2010.

PAVITT, K. Technologies, products and organization in the innovating firm: what Adam Smith tells us and Joseph Schumpeter doesn't. *Industrial and Corporate Change*, v. 7, n. 3, p. 433-452, 1998.

PEREIRA, D. ; WILLIAMS, J. Origin and evolution of high throughput screening. *British journal of pharmacology*, v. 152, n. 1, p. 53-61, 2007.

POWELL, W.W.; KOPUT, K.W.; SMITH-DOERR, L. Interorganizational collaboration and the locus of innovation: networks of learning in biotechnology. *Administrative Science Quarterly*, v. 41, n. 1, p. 116-145, 1996.

POWELL, W.; KOPUT,K.; WHITE, D.; OWEN-SMITH, J.; Network Dynamics and Field Evolution : The Growth of Interorganizational Collaboration in the Life Sciences 1. *American Journal of Sociology*, v. 110, n. 4, p. 1132-1205, 2005.

POWELL, W.; SNELLMAN, K.;. The knowledge economy. *Annual Review of Sociology*, v. 30, p. 199-220, 2004.

SCHWEIZER, L. Organizational integration of acquired biotechnology companies into pharmaceutical companies: The need for a hybrid approach. *Academy of Management Journal*, v. 48, n. 6, p. 1051-1074, 2005.

SHARP, M. The science of nations: European multinationals and American biotechnology. *International Journal of Biotechnology*, v. 1, n. 1, p. 132-162, 1999.

SZÜCS, F. M&A and R&D: asymmetric effects on acquirers and targets? *Research Policy*, 43, pg. 1264-1273, 2014.

VON HIPPEL, E. "Sticky information" and the locus of problem solving: implications for innovation.*Management science*, v. 40, n. 4, p. 429-439, 1994.

VON HIPPEL, E. Economics of product development by users: The impact of "sticky" local information. *Management science*, v. 44, n. 5, p. 629-644, 1998.

XIAO, J. The effects of acquisition on the growth of new technology-based firms: Do different types of acquirers matter? *Small Business Economics*, v. 45, p. 487-504, 2015.

ZUCKER, L.G.; DARBY, M.R. Present at the biotechnological revolution: transformation of technological identity for a large incumbent pharmaceutical firm. *Research Policy*, v. 26, n. 4-5, p. 429-446, 1997.

ZUCKER, L.G.; DARBY, M.R. Star Scientists, Innovation and Regional and National Immigration. In: AUDRETSCH, D.B.; E. LITAN, R.E.; STROM, R. (ed.). *Entrepreneurship and Openness*. Cheltenham: Edward Elgar Publishing, 2009. p. 181-212.

ZUCKER, L.G.; DARBY, M.R.; ARMSTRONG, J.S. Commercializing Knowledge: University Science, Knowledge Capture, and Firm Performance in Biotechnology. Cambridge, MA, 2001. (NBER Working Paper Series, 8499).

ZUCKER, L; DARBY, M.; LIU, R. Minerva Unbound: Knowledge Stocks, Knowledge Flows and New Knowledge Production. *Research Policy*, v.36, n.6, p. 850-863, 2007

Annexes

TABLE A
Roche inventor's usage from 2002 to 2018

Small acquired enterprises	Total of inventors in the acquired companies (A)	Inventors that started to patent by Roche (B)	Inventor's Usage (B/A) (%)
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

Source: own elaboration based on sample patent information retrieved at USPTO's PatFT database

TABLE B
Abbott-Laboratories inventor's usage from 2002 to 2018

Small acquired enterprises	Total of inventors in the acquired companies (A)	Inventors that started to patent by Abbott-Laboratories (B)	Inventor's Usage (B/A) (%)
Facet-Biotech	30	18	60
KOS-Pharmaceuticals	14	1	7

Source: own elaboration based on sample patent information retrieved at USPTO's PatFT database

TABLE C
Sanofi inventor's usage from 2002 to 2018

Small acquired enterprises	Total of inventors in the acquired companies (A)	Inventors that started to patent by Sanofi (B)	Inventor's Usage (B/A) (%)
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

Source: own elaboration based on sample patent information retrieved at USPTO's PatFT database

TABLE D
Pfizer inventor's usage from 2002 to 2018

Small acquired enterprises	Total of inventors in the acquired companies (A)	Inventors that started to patent by Pfizer (B)	Inventor's Usage (B/A) (%)
Rinat Neuroscience	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

Source: own elaboration based on sample patent information retrieved at USPTO's PatFT database

TABLE E
Merck inventor's usage from 2002 to 2018

Small acquired enterprises	Total of inventors in the acquired companies (A)	Inventors that started to patent by Merck (B)	Inventor's Usage (B/A) (%)
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

Source: own elaboration based on sample patent information retrieved at USPTO's PatFT database

TABLE F
GSK inventor's usage from 2002 to 2018

Small acquired enterprises	Total of inventors in the acquired companies (A)	Inventors that started to patent by GSK (B)	Inventor's Usage (B/A)(%)
Reliant Pharmaceuticals	3	2	67
Praecis	75	18	24
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

Source: own elaboration based on sample patent information retrieved at USPTO's PatFT database

TABLE G
Astra-Zeneca inventor's usage from 2002 to 2018

Small acquired enterprises	Total of inventors in the acquired companies (A)	Inventors that started to patent by Astra-Zeneca (B)	Inventor's Usage (B/A) (%)
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%

Source: own elaboration based on sample patent information retrieved at USPTO's PatFT database

TABLE H
J&J inventor's usage from 2002 to 2018

Small acquired enterprises	Total of inventors in the acquired companies (A)	Inventors that started to patent by Pfizer (B)	Inventor's Usage (B/A) (%)
TransForm Pharmaceuticals	33	8	24
Crucell	81	1	1
Omrix	22	0	0
Respivert	15	0	0
Corimmun	5	0	0

Source: own elaboration based on sample patent information retrieved at USPTO's PatFT database

Contribution of each author:

A. Theoretical and conceptual foundations and problematisation: Murilo Montanari de Matos;

B. Data research and statistical analysis: Murilo Montanari de Matos;

C. Elaboration of figures and tables: Murilo Montanari de Matos;

D. Drafting and writing of the text: Murilo Montanari de Matos;

E. Selection of bibliographical references): Murilo Montanari de Matos.

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