**Technical and Skill Knowledge Incorporated by Big-Pharma in Acquisitions of Small Firms**

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**Resumo:** A literatura acerca da indústria farmacêutica é extensa, porém, poucos estudos se dedicaram a aquisição de pequenas empresas orientada pelas grandes empresas farmacêuticas. Este artigo foca detalhadamente nesta relação, a fim de responder: Que elementos a pequena empresa tem a oferecer a grande empresa, que possa melhorar suas competências? Qual a potencialidade desses elementos? Para responder estas questões este estudo conduz uma pesquisa qualitativa baseada numa amostra de 8 grandes empresas farmacêuticas relevantes, sendo elas: Pfizer, Johnson & Johnson, Merck & co, Roche, Abbott-Laboratories, Sanofi, Glaxo SmithKline (GSK), Astra-Zeneca. A partir da amostra serão compiladas informações das patentes destas empresas depositadas no USPTO acessíveis por meio da *Patent Full-Text and image database* (PatFT). As informações coletadas são fundamentais para construir dois conceitos essenciais: (i) contribuição técnica e (ii) contribuição em *skills*. As potencialidades destas contribuições serão observadas por meio das referências das patentes e dos *lags* de citação. Como conclusão observa-se a presença da contribuição em *skills* por toda a amostra, contudo, esta contribuição está associada a uma baixa potencialidade. A contribuição técnica se mostra associada ao melhoramento de competências existentes, mas não se pode concluir se este tipo de contribuição gera novas competências, em contrapartida, a contribuição técnica tem um alto potencial.

**Palavras-Chave:** Indústria Farmacêutica; Fusões e Aquisições; Patentes.

**Área ANPEC**: Área 9- Economia Industrial e da Inovação

**JEL**: O32 L22 L26.

**Abstract:** Many studies have focused on the Pharmaceutical Industry. But to few have paid attention to the acquisition of small enterprises conducted by the Big-Pharma. This article closely looks at this relation in order to answer: what elements a small enterprise has to offer in order to contribute to the large enterprises pool of capabilities? What are the potentiality of these elements in terms of new competences and technologies for the acquiring enterprise? To do this we will conduct a qualitative research based on sample of the most relevant large pharmaceutical enterprises being them: Pfizer, Johnson & Johnson, Merck & co, Roche, Abbott-Laboratories, Sanofi, Glaxo SmithKline (GSK), Astra-Zeneca. Through the sample, patent information available at USPTO in the PatFT (Patent Full-Text and image database) will be gathered. The patent information will encompass the Big-Pharma and the small enterprises. These information are fundamental for constructing the main concepts of contribution, being them: (i) technical contribution, derived from patents classes (ii) skill contribution encompassed by the patent inventors, finally its potentialities will be analyzed in the light of patent references and citation lags. Those concepts are fundamental for understanding what is held by the large enterprise when it acquire a small enterprise. This study main contribution was filling a literature gap by proposing new and simple measures of contribution that small enterprise may offer to large companies. We conclude that the skills contribution is observed in all the sample showing the relevance of inventors in the acquisition, nevertheless, based on the articles concepts and data, they have a low potentiality. The technical contribution enhance competences already developed by the large enterprises we were not able to attest their relevance on creating new competences, nevertheless, technical contribution have a great potentiality. Finally the two contributions are highly linked because part of the detected potentialities depends on the use and employment of skills.

**Keywords:** Pharmaceutical Industry; Mergers and Acquisitions, Patents.

# Introduction

Technological paradigms may suffer from diminishing returns as the technological trajectories within them are explored. This process is widely discussed within the pharmaceutical industry as the “famous” R&D productivity crises. Although addressed extensively, the so-called crises lack a unanimous cause. Some stress the rising costs of developing new drugs (COMANOR AND SCHERER, 2013), while others point to the exhaustion of technological trajectories (NIGHTINGALE, 2000; HOPKINS *et al*., 2013).

However, this crisis has one solid fact: the industry is overcoming this problem by diversifying its capabilities, as Big Pharma incorporates biotechnologies in its drug discovery activities (NIGHTINGALE, 2000; QUÉRÉ, 2004). This process began in the late 1970s and early 1980s (SHARP, 1996). Presently, all Big Pharma have some kind of scouting team that looks for promising new technologies developed by small biotech companies. This strategy led to the well-established behavior of incorporating biotechnologies through acquisition (AUTHOR, 2016)[[3]](#footnote-3). Up to 50% of the large pharmaceutical enterprises’ new technologies were projects that began within biotech enterprises (AUTHOR, 2016).

The literature does not yet address this subject in a substantial way. Some studies deal with mergers and acquisitions (M&A) driven by technological aspects, ignoring the enterprise size (e.g., GERPOTT, 1995; AHUJA AND KATILA, 2001; AHUJA ANDLAMPERT, 2001; HAGEDOORN; DUYSTERS, 2002; CLOODT; HAGEDOORN AND VAN KRANENBURG, 2006), while even fewer concentrate on the interactions between small and large firms (e.g., DESYLLAS; HUGHES, 2010; NORBÄCK; PERSSON, 2013; XIAO, 2014; ANDERSSON; XIAO, 2016). Unfortunately, all of these studies are highly focused on post-acquisition performance measured through patents.

The approach in these studies has two limitations. First, the productivity problem is not a patenting activity problem, although this specific point is beyond the scope of this particular study. Second, and the main concern of this study, the post-acquisition performance approach ignores (i) the transference of elements from the small to the large enterprise and (ii) the elements that are transferred between these firms. In the end, these studies treat enterprises as black boxes, in which acquisitions are inputs and patents are outputs, thus leading to a simple matter of correlating acquisitions with increasing or decreasing patenting activity.

In this study, we overcome this black box problem by posing some important guiding questions: what elements does a small enterprise have to offer in order to improve the large enterprises pool of capabilities? What is the potential of these elements in terms of new competences and technologies for the acquiring enterprise?

The main objective of this study is to answer these guiding questions. We meet this objective qualitatively, by setting the analyzed phenomenon as Big Pharma’s incorporation of biotechnologies by acquiring small enterprises. Second, we identify and extensively discuss the elements that a small firm can transfer in an acquisition and that affect the acquiring enterprises’ capabilities, whether technical and/or skills. We use a sample of the most relevant large pharmaceutical enterprises and analyze the patent information of the large and small acquired enterprises according in terms of their technical contribution and skill contribution, and their potential. These concepts are fundamental for understanding what large enterprises hold when they acquire a small enterprise.

This study does not analyze the outcomes of acquisitions, which is discussed in other studies, many of which we cite here. The main outcome of the proposed objective is to understand through what elements can Big Pharma incorporate external sources into its innovation activities.

In this work, we mainly contribute to the literature by proposing measures of how small enterprises can enhance and increase Big Pharma’s pool of competences. We call these measures technical and skills contribution, and also analyze the potential of these contributions.

The main findings from this study are that technical and skill contributions have distinct effects on the large enterprises pool of competences. Skill contribution intensifies technical contribution, because as inventors move from small to large enterprises, they bring their research with them. There is no clear evidence that the main outcome of the technical contribution is to create new competences; however, technical contribution is an important element in enhancing existing competences.

This article proceeds as follows. The next subsections will establish the acquisitions driven by technological aspects as the main phenomenon to analyze, among which this section will discuss the elements in the enterprises that may affect their innovative activates. This discussion forms the theoretical basis for defining the main concepts. The following section will discuss the methodology, define the sample, describe the data collection and analysis processes, and present the proxies of technical and skill contribution. Section 3 will present and discuss the results, and the final section concludes.

## 1 Impact of M&As on enterprises’ innovation activities

In the M&As driven by technological aspects, several studies show that the new resources incorporated into the firm will increase its innovativeness. (AHUJA; KATILA, 2001; ANDERSSON; XIAO, 2016; CLOODT; HAGEDOORN; VAN KRANENBURG, 2006; DESYLLAS; HUGHES, 2010, 2010; HAGEDOORN; DUYSTERS, 2002b; MAKRI *et al.*, 2010; XIAO, 2015). Technological aspects could also drive acquisitions between large and small enterprises. The few studies on this subject point to these acquisitions as a high-tech sector phenomenon, whose outcome is the increase in the innovative output of the large enterprise (CASSIMAN; VEUGELERS, 2007; DESYLLAS; HUGHES, 2008; HUSSINGER, 2010; EJERMO; XIAO, 2014; LAURSEN; SALTER, 2014; XIAO, 2014;SZÜCS, 2014; ANDERSSON; XIAO, 2016).

Arguably, the acquisition is a way of uniting different pieces of knowledge within one enterprise. By gathering these pieces of knowledge, firms can increase the number of knowledge combinations, and these novel combinations can potentially lead to more innovations (AHUJA; KATILA, 2001). Surprisingly, some degree of difference between enterprises’ knowledge is even beneficial for novel knowledge creation (MAKRI *et al.*, 2010). Therefore, all knowledge incorporated through acquisitions enable the company to create new products, and in some cases, create new technological trajectories (HAGEDOORN *et al.*, 2002).

In order to analyze technology-driven acquisitions between large and small enterprises, we must consider the incorporation of capabilities of the one company into those of the other as a time-consuming process without short-term effects on technology, which, in many cases, can disguise the real effect of the acquisition (GERPOTT, 1995; DESYLLAS; HUGHES, 2007). Indeed, M&As driven by technological factors can only be analyzed through technological variables. Therefore, it is necessary to use or develop measures based on knowledge features (AUTHOR, 2016).

## Knowledgebase relatedness in M&As

In order to use external knowledge to create and enhance a firm’s capabilities, the acquirer must understand the general principles of the other enterprise’s knowledge base (COHEN; LEVINTHAL, 1989, 1990; AHUJA AND KATILA, 2001; HAGEDOORN; DUYSTERS, 2002; MAKRI *et al.*, 2010). Therefore, enterprises engaging in horizontal and vertical acquisitions should have some technological relatedness with their target (HAGEDOORN; DUYSTERS, 2002).

Several studies attempt to create concepts and measures of knowledgebase relatedness. These concepts help clarify how relatedness affects the enterprises’ technological outputs. Nevertheless, all these ideas are based on the concept of absorptive capacity. In essence, the difference and relatedness between each knowledgebase will lead to different degrees in assimilation (AHUJA; KATILA, 2001; CLOODT; HAGEDOORN, 2006; MAKRI *et al.*, 2010).

Enterprises with larger and less specialized knowledge bases have a greater probability of enhancing its R&D productivity (DESYLLAS AND HUGHES, 2008). Furthermore, the difference in the technological and scientific knowledge between companies is an important factor in the process of technical change and constructing R&D capability (HAGEDOORN AND DUYSTER, 2002; MAKRI *et al.*, 2010). For instance, the merger of extremely similar companies would only lead to duplication. Therefore, the firms must have some differences in their knowledgebases to provide opportunities for learning and building and developing absorptive capacities (MAKRI *et al*., 2010). On the other hand, when companies are extremely different from each other in terms of technical knowledge, the M&A process becomes highly complex and incorporating one company into another cannot generate any effect on the innovation rate. In other words, the acquisition targets must have a difference between their knowledgebases that provide learning opportunities that the acquirer can translate into new products and may even generate new technological trajectories (ClOODT; HAGEDOORN, 2006; MAKRI *et al.*, 2010). In conclusion, in an M&A, the relatedness of the enterprises’ knowledgebases and the innovative output have an inverted U-shaped relationship (AHUJA; KATILA, 2001).

All of those studies show that a certain amount of technological relatedness can generate opportunities for learning in areas in which science plays a significant role in sustaining the innovation process. Acquiring firms will expand their knowledge base (CLOODT AND HAGEDORN, 2006), and by doing so, companies create new routes to conduct research (MAKRI *et al*., 2010). In addition, multinational corporations increase their technological outputs by acquiring small enterprises with complementary capabilities (ANDERSEN AND XIAO, 2016).

Arguably, the contribution of small enterprises to large enterprises’ innovative output depends on the degree of their knowledgebase relatedness. Therefore, methods that try to measure the similarities between the enterprises’ knowledgebase is of extreme importance (AHUJA AND KATILA, 2001; HAGEDOORN AND DUYSTERS, 2002; DESYLLAS AND HUGHES, 2008). An important step now is to identify the sources of knowledge within the small enterprise and if it is transferred to the acquiring firm after an acquisition.

### Patents and patents classes as knowledge and measures of competences

One way to capture part of the enterprises’ knowledge is through patents. Almost all studies cited here have a patent base methodology to measure knowledge. Each patent is a piece of knowledge, a single invention that contains “only” descriptions of (instructions for) processes. In theory, patents can be replicated as long as the reader understands and follows the instructions (NELSON; WINTER, 1982). For example, U.S. Patent 8,426,363, issued to Rinat Neuroscience, describes a method based on molecular biology to reduce cholesterol. The full text of this patent describes the cell receptors, the DNA sequences of antibodies, and how these two elements bind. Based on this patent, companies that are technologically similar to Rinat Neuroscience could replicate this process.

As described in the literature, patents are specific, but classified, by the Unite States Patent Office(USPTO), European Patent Office (EPO), and others patent offices, according to a much broader view that considers the whole set of knowledge and competences employed in their creation. These are known as patent classes, which address the patent’s technological field and patent breadth (HALL *et al*., 2001; LERNER, 1994; NOVELLI, 2015). As an outcome, the more classes that a patent addresses, the larger is its breadth, thus indicating a wider knowledge scope (LERNER, 1994; NOVELLI, 2015).

Mostly important, these classes can summarize the technological capabilities necessary for a patent in a specific class (STRUMSKY, LOBO, 2015; VERHOEVEN; BAKKER; VEUGELERS, 2016). Theoretically, from the point of view of NELSON; WINTER (1982), a patent class and its subclass encompass a knowledge neighborhood, which is much closer to the results of search activities than the patent alone.

In essence, Big Pharma acquires a small firm and can access the technical knowledge the firm possesses in the form of its patents (AUTHOR, 2016). Nevertheless, incorporating this kind of knowledge and turning it into competences and routines demands learning efforts from the acquirer. Arguably, a small company can offer a Big Pharma enterprise only a potential technical contribution that also depends on knowledgebase relatedness. Thus, patents indicate a potential contribution.

Besides as potential inputs for building new technologies, patents represent a small part of these inputs. R&D-related employees are another relevant element that acquirers use to improve and create new technologies and competences. We discuss this subject in the next section.

## The role of scientists in an enterprise’s innovation activities

Within enterprises, activities may more or less depend on an employee’s skills. R&D is a typical activity that demands much from knowledge. For instance, in the pharmaceutical industry, random screening technologies cannot build molecules by themselves; they need a trained scientist able to recognize any possible molecule (SCHWARTZMAN, 1976). Even the creation of new and more “automatized” drug discovery[[4]](#footnote-4) techniques, like HTS (high throughput screening) and combinatorial chemistry, do not mitigate the scientist’s skills in the complete success of R&D (NIGHTINGALE, 2000; NIGHTINGALE AND MADHI, 2006). Thus, the effect of scientists on the technological outputs of the firms is a result of their social interaction (OETTL, 2012), such as collaborations inside the enterprise (GRIGORIOU; ROTHAERMEL, 2014), collaborations outside the enterprise (ALMEIDA; HOHBERGER; PARADA, 2011), as an outcome of their research (HOHBERGER, 2016), and due to their productivity as researchers (ZUCKER; DARBY, 2009).

In a small enterprise, scientists have a greater role. Usually, the scientist’s research outcome enabled the firm’s creation (COLOMBO; PIVA, 2012) and the firm’s survival depends on continuous research outcomes, especially in biotechnologies (COLOMBO; GRILLI, 2005; COLOMBO; PIVA, 2012).

This element may falsely indicate an attachment between the scientist and his or her workplace; as a scientist moves between firms, his or her research may suffer somehow. Nevertheless, the scientist is attached to his or her research (HOHBERG, 2016). Researchers, especially the star scientist, have a certain path dependence that means that they research the same subject as they move from one place to another (HOHBERGER, 2016). Ultimately, if scientists move due to their promising new technologies, they will continue the same line of research in the new enterprise. Therefore, researchers bring with them the same “success” trajectory that drove the acquisition (HOHBERG, 2016). Of course, the scientist’s success is linked to their network within and without the enterprise (OETTL, 2012).

### Scientists as a skill element

The trajectory of the firm is built on its scientists’ research (COLOMBO; PIVA, 2012) and the path dependence characteristic of research implies that an acquisition does not end a research heuristic (HOHBERGER, 2016). As scientists move from one enterprise to another, they bring with them their skills. This type of knowledge, within economic agents, cannot be transferred through instructions, but are acquired through learning and experience. Therefore, a workforce dedicated to research can be called the skill knowledge set of an enterprise (AUTHOR, 2016).

The pharmaceutical industry, despite its relationship with the patent system, depends highly on skills to innovate (SCHWARTZMAN; 1976) and technological development does not mitigate this dependence (GAMBARDELLA; 1995; SCHWARTZMAN; COGNAT, 1996). Indeed, technology created some techniques and their experts more relevant (SCHWARDT; KOLB; ERNST, 2003; PEREIRA; WILLIAMS, 2007). Therefore, when skills are transferred from the small to the large company, it has impacts on the large enterprise’s R&D and patent activities.

The ability of Big Pharma to retain the core people responsible for developing technologies is imperative and desirable (AUTHOR, 2016). The people responsible for creating the patents can be a great contribution to a large pharmaceutical enterprises’ R&D activity. Thus, incorporating a skill knowledge set is a contribution from a small enterprise to large one. In sum, scientists are the skill part of the knowledge, being extremely important for the firms’ technological outputs, and we can trace these scientists through patent information.

# Methodology

This study is based on acquisitions from 2005 to 2012 conducted by eight large pharmaceutical enterprises: (i) Pfizer, (ii) Johnson & Johnson, (iii) Roche, (iv) Sanofi, (v) Astra-Zeneca, (vi) Abbott-Laboratories, (vii) Glaxo SmithKline (GSK), and (viii) Merck (included only in the inventor analysis). This study examines 8 large enterprises and 51 small enterprises. While the sample period is not extremely recent, it stills captures the dynamics of incorporating new competences through acquisitions.

The data compiled through the sample is necessary to observe the small enterprises’ contribution. Therefore, we need to (i) explain the construction of *proxies*,which represent the elements of contribution of small enterprises; (ii) determine how to use the data collected; and (iii) show, if necessary, how data on the large and small firms can be combined to obtain correlations between agents.

The first source of data is the report, "HBM PHARMA/BIOTECH M&A REPORT 2013," which compiles M&As between large and small pharmaceutical companies between 2005 and 2012. This report contains: (i) the acquired companies, (ii) the acquiring companies, and (iii) the amount spent. Based on this report, we can extract the more active acquirers and the companies that spent more resources on M&As. Another important data source is the Forbes' list of the 2,000 largest companies in the world[[5]](#footnote-5), which we use to determine the larger enterprises. We collected the patent data from the Patent Full-Text and image database (PatFT) published by the USPTO.

## 2.1 Sample

In order to present the sample and show its relevancy in the pharmaceutical industry, we compare classic variables and measures of effort such as revenues, R&D, and the relationship between revenues and R&D. We also compare the M&A expenditures with these variables. We report these variables in Table 1.

The sample accounts for 37% of all R&D expenses of the Pharmaceutical Research and Manufacturers of America (PhaRMA) members. Regarding acquisitions, the 8 enterprises have 32% of all M&A expenditures in the pharmaceutical industry. The share of R&D and acquisitions expenditures of the sample strongly supports their relevance in terms of technology development and M&As.

The sample consists of European and Northern American companies, which have different behaviors. In terms of patents, all American companies have a similar number of patents; the European ones have fewer, mainly due to the enterprises’ origins. European companies tend to file more patents with the European patent office.

As high tech enterprises, the relationship between R&D and Revenue should be high. All enterprises in the sample spent at least 10% of its revenues on R&D.

The total expenditure on M&A indicates the different behavior among the enterprises in the sample. While some have high expenditures on M&A, others have comparatively low expenditures. The average M&A relation to revenue is higher than is the R&D/Revenue ratio for Pfizer and Novartis only. Abbott-Laboratories, J&J, and Merck spent less than 5% of their revenues on M&A.

Abbott-Laboratories acquired only two enterprises in the period, indicating more scrutiny on choosing acquisition targets. We can say the same for Merck (according to the study’s analyses). J&J behaves extremely different, which shows an interesting fact in the sample.

In the last column, we show the relationship between the average spend on M&A and their R&D. A relevant share of the sample expended the equivalent of half of their R&D on M&A. Some enterprises, like Novartis and Pfizer, spent more than their R&D budget on M&A. In the sample period, some enterprises conducted much more M&A than R&D, and *vice-versa*; therefore, the sample encompasses different behaviors and strategies and is relevant for the pharmaceutical industry.

**Table 1: Sample Information (data in US$ Billions )**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Enterprise  (sample) | Capital Origin | Number of Employees | Patents granted at USPTO\* | Total Revenue | R&D | Total expenditure on M&A from 2005 to 2012) | Average expenditure in M&A (from 2005 to 2013) | R&D/Revenue | M&A average/Revenue | M&A average /P&D |
| Pfizer | USA | 91,500 | 4,279 | 51 | 6,6 | 76,5 | 9,5 | 13% | 18,6% | 1,4 |
| Novartis | CH | 112,461 | 4,000 | 32,1 | 6,7 | 70,9 | 8,8 | 21% | 27,4% | 1,3 |
| 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% | 0,4 |
| Astra-Zeneca | UK | 51,700 | 1024 | 27,9 | 4,4 | 18,3 | 2,2 | 16% | 7,9% | 0,5 |
| 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% | 0,5 |
| Abbott-Laboratories | USA | 92,939 | 4,044 | 39,8 | 4,3 | 4,1 | 0,5 | 11% | 1,3% | 0,11 |

\*Patents range from 1976 to 2019

\*\*Patents information of J&J include the patents granted for Janssen

\*\*\*Revenues for only the pharmaceutical branch

Source: Own elaboration

In essence, table 1 summarizes the M&A behavior of the enterprises, showing their relevancy among the main technological activities conducted by the sample.

## 2.2 Method to analyze the overall contribution process

The study is based on the idea that the small enterprises can offer (contribute with) important elements and large enterprises use them to develop new technologies and competences. The sum of these elements can be called overall contribution. So far, the first section showed what these elements are in theory. This study addresses a knowledge base consisting of a technology-related element, namely, the patents and its classes, and a second element in terms of the skills embedded in the enterprise’s scientists. By considering these two elements, we propose that for a large enterprise acquiring a small enterprise, these two elements are the main external sources that can improve Big-Phama’s competences.

### 2.2.1 Technical contribution analysis

To understand how this study traces and considers the technical contribution, it is necessary to raise four important points. First, we chose the acquisition of small enterprises by large enterprises as a specific phenomenon for analysis. Within this phenomenon, we deal with the incorporation of biotechnologies by Big Pharma to overcome the productivity crises. We focus on biotechnologies in this study by following the technological categories classification in by HALL; JAFFE; TRAJTENBERG (2001), which includes the classes 435 and 800 of the USPTO.

Second, patents have two important properties: (i) they can be used to generate new patents (HALL; JAFFE; TRAJTENBERG, 2001; TRAJTENBERG; HENDERSON; JAFFE, 1997) and (ii) the patent classes convey the capabilities necessary to produce patents with certain characteristics (STRUMSY; LOBO, 2015;VERHOEVEN; BAKKER; VEUGELERS, 2016). Thus, the patent classes dominated by an enterprise can show their technical knowledge set.

Third, when a large firm acquires a small firm, it has access to the small firm’s knowledge set and products, in this case, the patents. However, incorporating and using the small enterprise’s knowledge set successfully is uncertain. This process depends on the ability of the large enterprise to cope with the small enterprise’s contribution. As discussed in the previous section, incorporating much of the technical knowledge successfully depends on knowledgebase relatedness.

Finally, the proposed line of though here is that the enterprises’ knowledge bases start with some degree of relatedness that may grow over time. This process means that large pharmaceutical enterprises are building competences close to the ones held by small enterprises. Then, the idea is to trace the process through which the knowledge bases become similar.

So far, there are two types of technical contribution. Large enterprises can use the small enterprise’s patents to generate new patents (direct) or the large enterprises can use the small enterprise’s technical knowledge to develop new patents in new classes or increase its patent activities in existing classes (indirect).

We can see the direct use of the small enterprise’s technical knowledge when large enterprises reference the patents developed by the acquired small enterprises in their own patents. Here, we combine the direct use of patents with citation lags, following HALL; JAFFE; TRAJTENBERG, (2001) calculation of these lags. These lags are estimations of patent citations over time and show the potential of each patent.

The indirect form of contribution requires that we compile the small enterprises’ knowledge set. We do this by gathering the patent classes and subclasses within the small enterprises’ patent universe. This will generate a set of data consisting of all the patents classes dominated by the small enterprise. To build a correlation, we need observe when the Big Pharma firms started to issue patents in the same classes held by the small enterprise. This process will allow us to draw an evolutionary picture that compares knowledgebase relatedness.

The indirect technical contribution analysis is focused on the US patent classes 435 and 800, these classes, according to HALL;JAFFE; TRAJTENBERG (2001) convey the biotechnologies. This focus is in accordance with the enterprises strategies to overcome the R&D productivity crises

The technical contribution analysis is way to observe the use of the large firm’s technical knowledge. In summary, it shows the process of evolution of competence development and creation. By doing this, we can observe when the acquiring company began to incorporate new classes and subclasses into its technical knowledge set.

### 2.2.2 Skill contribution

Patents reflect only a part of the knowledge available for the enterprises that engage in acquisitions. Patents as techniques are “inherited” in the acquisition process. Nevertheless, the scientists that work in an enterprise are another important source of knowledge.

On the one hand, the technological knowledge described in a patent is very specific and has a particular purpose, as the example of patent No. 8,426,363 (see pg. 6) shows. On the other hand, skills have the characteristic of being more elastic and amorphous. They can be considered less rigid because they can be applied to similar technological elements. Skills with greater flexibility allows scientists to employ them in similar research subjects that will lead to different kind of drugs. Nevertheless, the drug purposes should not be so distinct. The same scientist can work on a series of research that encompass the same mechanism, such as inhibition of a cell receptor. Arguably, inhibiting a cellular receptor has the same principle, whether this receptor is responsible for kidney or liver enzymes. Yet, technical knowledge, as patent 8,426,363 shows, cannot be applied to anything other than what it describes. In contrast, the skills embodied in agents can be allocated to similar R&D processes (AUTHOR, 2016).

The types of knowledge embedded in employees are broad. Arguably, all employees in an enterprise have a certain level of skills. In an attempt to reduce this broadness, and therefore have a better *proxy* for skills, we consider only R&D related activities.

Another important point is the weight of skills in small enterprises. As stressed before, in firms with just a few employees and patents, the people identified as inventors may represent the core skillset. Therefore, we define the skillset as all of the inventors compiled through the company’s patents. In order to track the skill contribution of a small company to a large company, we aim to identify inventor’s movement from the small acquired small company to the large acquiring company.

This study does not focus on the outcomes of skills, but rather concentrates on observing if skills are indeed incorporated. Due to their importance, the large firm should incorporate them.

# Data Analysis

## 3.1 Technical contribution analysis

The technical contribution traces the technical-related elements expressed though patents that could contribute to the large enterprises’ technological development. The analysis observes the direct technical contribution using the large firms’ patents citation. In essence, this study traces the role of patents as a direct generator of technologies (AHUJA; LAMPERT, 2001; HALL; JAFFE; TRAJTENBERG, 2001; 2005). In order to give a greater depth to the analysis, we use the citation lag calculated following HALL; JAFFE; TRAJTENBERG (2001) to indicate the potential of the referenced patents.

The other part of technical contribution is indirect. This analysis takes a broader, evolutionary approach. In this analysis, we try to trace when Big Pharma started to develop patent classes that are dominated by the acquired small firms. This broader approach is underpinned by two important elements. First, the patents classes can be taken as competences (STRUMSKY; LOBO, 2015; AUTHOR, 2016; VERHOEVEN; BAKKER; VEUGELERS, 2016). Second, the evolution of Big Pharma’s competencies development is linked to the technical knowledge set of the small enterprises competencies (AUTHOR, 2016).

Table 2 summarizes the direct technical contribution. The table shows only the acquired enterprises that had at least one of its patents referenced by the Big Pharma acquirer. The table 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 with the referenced patents.

**Table 2: Direct Technical Contribution**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Large Enterprises** | **Enterprises Acquired** | **Number of Small Enterprises Patents**  **(A)** | **Patents Used as Reference (small enterprise's 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 |
| 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 | 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: Own elaboration

The 8 Big Pharma firms acquired, from 2005 to 2012, 51 small enterprises; 24 of which had at least one patent reference by the acquiring large enterprise. Almost 44% of the sample had a direct contribution to the large enterprise. Following HALL, JAFFE, TRAJTENBERG (2005), who link enterprise market value to patent citations, one can say that these 24 enterprises have a great value for the acquiring Big Pharma firm. We can see this process even within a short time period. In addition, these small enterprises’ patents can now yield value for the large enterprises that own them (HALL; JAFFE; TRAJTENBERG, 2005).

In essence, the most cited patents are more important or relevant for the enterprise, indicating promising inventions (HALL; JAFFE; TRAJTENBERG, 2005; HENDERSON; JAFFE; TRAJTENBERG, 1998; TRAJTENBERG; HENDERSON; JAFFE, 1997). Table 3 also indicates the most important small enterprises in terms of single technologies. For instance, cases like Arius, Piramed, and Transform-Pharma show enterprises whose patents were more intensively cited. Thus, the large enterprise determined their technology to be relevant. We report these cases in the last column of Table 2, in which we show the patents generated through the small enterprises’ patents. There are several cases in which more patents were generated than cited, even in a short amount of time.

Another relevant element among patents is their citation potential. Patents reach their maximum citation rate after some years, and then this rate slows down. This potential is captured by citation lags, creating a general pattern in which new patents have a greater potential for being cited (HALL; JAFFE; TRAJTENBERG, 2001).

One can understand this citation pattern as the depreciation rate of patents. Therefore, large enterprises can acquire highly depreciated patents or not. Figure 1 shows this depreciation based on the citation lag proposed by HALL; JAFFE; TRAJTENBERG (2001). The figure compiles all patents filled by the small acquired enterprises that were cited by the large enterprises. 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 have 78% of all citations possible; 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 the large enterprise; for example, in 1997, the large enterprises cited 4 patents of their acquired enterprises.

All of the Big Pharma firms in the sample cited 196 patents from the small acquired enterprises. To provide a better comprehension of the patents’ potential, we divide the 196 patents into tiers according to their total citations. The first tier includes patents with 0% - 25% of its total citations, the second tier includes patents with 25% - 50% of its total citations, the third tier includes patents with 50% - 75% of its total citations, and the last tier includes patents with 75% - 100% of its total citations. In other words, the patents in the first and second tiers are the ones with greater potential, and the patents in the last tier have a lower potential. Most patents (187) had from 25% to 75% of the possible citations.

We can better examine the potential of the patents dividing the patents into more tiers, from 25%-40%, 40%-55%, and 55-75% as a share of their total citations. In summary, 57 patents had between 25% to 40% of total citations; 76 patents had from 40% to 55% of all possible citations, and 59 patents had between 55% and 75% of all possible citations. The citation lag data shows that the patents held by the large enterprises still have a good potential to generate new patents. This fact explains why Table 1 shows low patent productivity; that is, a small number of patents created by the small enterprises’ patents. However, the patents still have citation potential, and can thus yield value for the large enterprise (HALL; JAFFE; TRAJTENBERG, 2005)

The direct contribution shown above can indicate the potential and specificities of patents. To broaden the analysis and consider technological capabilities, we also propose a method to observe the indirect contribution. This analysis adds an evolutionary character as the process of constructing new competences is observed over time. As a reminder, this study deals with patents in classes 435 and 800.

The indirect technical contribution has some potential, because fulfilling it depends on the ability of the large enterprises to develop the same competences held by the small enterprise. For instance, the acquired small enterprise may have patents in several classes that the patents of the large enterprise do not cover. However, this means that the Big Pharma firms will only develop in these classes by creating related patents if it chooses to do so.

**Figure 1: Direct Contribution and Citation Lags**



**Source: Own Elaboration**

Another important aspect is to consider that Big Pharma firms use the small acquired enterprises to further develop patent classes that the firm began to develop some time prior. This aspect is highly related to the process of biotechnologies diffusion (HOPKINS et al., 2007, 2013)

The process of further developing patent classes is a process of creating absorptive capabilities, and by so doing, the Big Pharma firms become aware of new technological developments. In addition, the increasing understanding about the general principles of some technology allows firms to choose more suitable techniques for the enterprise (COHEN; LEVINTHAL, 1990).

Figure 2 illustrates the indirect technical contribution analysis. The Y axis shows the number of new classes developed. A new class is the first time the large enterprise filed a patent in a patent subclass that it had not done so previously. The X axis indicates the years. For example, in 1994, GSK started to patent in five new classes.

**Figure 2: Big-pharma’s technical Knowledge set development**

Source: Own elaboration

The classes and subclasses considered are those that comprise the small enterprises’ technical knowledge set. Therefore, this figure presents the correlation between the knowledge developed by the small enterprises, and how, over time, this knowledge was developed by the Big Pharma acquirers.

This graphic can be divided in three main areas: (i) from 1974 to 1988, (ii) from 1988 to 2004, and (iii) from 2004 onwards. From 1974 to 1988, a few enterprises developed a few new classes. This period resembles an early period in the development of biotechnologies, as SHARP (1996) proposes. From 1988 to 2004, this process became more intensive, as more classes and more enterprises started to developed new classes. The 1990s are distinguished by new biotechnologies, like High Throughput Screening, and their results appear at the end of the 1990s and the beginning of the 2000s (HOUNSTON, BANKS, 1997; PEREIRA; WILLIAMS, 2007). Graphic 1 captures this process by showing the increasing number of new classes. The development slows down from 2004 onwards.

Graphic 1 summarizes the arguments of SHARP (1996) and MALERBA; ORSENIGO (2015), who point to the scattered and slow development of biotechnologies among the large enterprises. Over time, and as collaborations between large and small enterprises increased (SHARP, 1996; OECD, 2013), the development of biotechnologies increased. Another important element is the Bayh-Dole act of 1980, which allows researchers and universities to own and commercialize their research outputs.

The figure overall shows an evolutionary perspective indicating that biotechnology "follows a well-established, historical pattern of slow and incremental of technological diffusion" (NIGHTINGALE AND MARTIN, 2004, pg. 564), in which large pharmaceutical companies are gradually incorporating new technology (ZUCKER; DARBY, 1997).

Based on Figure 2, the technical contribution of small enterprises allows the Big Pharma firms to further develop elements that it started in the past. The great majority of classes were developed before the acquisition of the small enterprises in the sample. Additionally, these enterprises were acquired at the moment when the development of new classes was losing its pace, from 2004 to 2012.

Figure 2 can be further explored in terms of potential. As citation lags can measure a patent’s potential, patent classes can offer a similar measurement of potential. The idea is rather simple. By considering that the small enterprises’ knowledge set are their pool of competences (AUTHOR, 2016) with patent classes as *proxies* (STRUMSKY; LOBO, 2015; VERHOEVEN; BAKKER; VEUGELERS, 2016), Big Pharma can develop the same pool of competences and enhance them via acquisitions (AHUJA; KATILA, 2001; DESYLLAS; HUGHES,2010).

Arguably, as the small enterprise is incorporated, the Big Pharma firm may develop the same knowledge set. As the two enterprises knowledge sets became similar, the possibility of creating new patent classes decreases. The other way is also true, the less similar is both enterprises’ knowledge sets, the more opportunities the Big Pharma firm has to developed new patent classes Therefore, in the process of acquisition, the small enterprises’ indirect contribution is linked to the patent classes not developed by the Big Pharma firm (AUTHOR, 2016)

In order to observe this potential, Table 3 traces the undeveloped classes.

**Table 3: The portion of not developed technical knowledge set**

|  |  |
| --- | --- |
| **Enterprise** | **Percentage** |
|
| J&J | 66% |
| Astra-Zeneca | 32% |
| Abbott-Laboratories | 27% |
| GSK | 14% |
| Pfizer | 12% |
| Roche | 10% |
| Sanofi | 6% |

Source: Own elaboration

InTable 3, for instance, if the Big Pharma firm already developed a large portion of the small enterprise’s technical knowledge set, then this same small enterprise can contribute much less, technically, to creating new competences in the large enterprise. A large portion of the contribution, in this case, will be linked to enhancing existing competences.

Table 3 shows the different potential. J&J has a very high potential; even Astra-Zeneca and Abbott-Laboratories have an intermediate potential, but all other enterprises do not. However, low potential has an important aspect; it may indicate that these small enterprises contribute toward improvements to already developed classes. In other words, in terms of technologies, the small enterprises are much more prominent in improving existing competences.

## 3.2 Skill Knowledge Analysis

The other important element is the skills contribution, which we consider to be the knowledge embedded in the agents that deal with R&D. Therefore, when large enterprises acquire small firms, they can keep the key people dedicated to R&D, and thus keep the skills (SCHWEIZER, 2005).

The skills contribution is based on patent information. We compile all inventors that filled at least on patent for the acquired small enterprise. We refer to this group of inventors as the skill knowledge set. After establishing the skill knowledge set, we search for the same inventors in the Big Pharma acquirer’s patents. Thereby, we can establish a relationship called inventor use as the percentage of the acquired small enterprise’s skill knowledge set that the large enterprise used. Table 4 summarizes the findings.

**Table 4: Skill Contribution Summary Table**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Large Enterprises** | **Small acquired enterprises** | **Total of inventors in the acquired companies (B)** | **Inventors that started to patent for the acquiring enterprise**  **( C)** | **Use of Inventors (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% |

**Table 4: Continuation**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Large Enterprises** | **Small acquired enterprises** | **Total of inventors in the acquired companies (B)** | | **Inventors that started to patent for the acquiring enterprise**  **(C)** | **Use of Inventors (C/B)** |
| J&J | 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% |
| 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% |
| GSK | 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% |
| Sirtirs | | 23 | 0 | 0% |

Source: Own elaboration

The skills contribution is relevant when considering that the group of acquirers (the 8 Big Pharma firms) incorporated inventors from some of its acquisitions targets. Among all of the small enterprises acquired, 40% contributed skills to some degree. Figure 3 provides a broader view of skills contribution by comparing the sample’s average use of inventors with each Big Pharma average use of inventors.

**Figure 3: - Inventors Use**

Source: own elaboration

One declared objective of Big Pharma firms is to retain key employees (AUTHOR, 2016). In addition, inventors do not move alone from one enterprise to another, it is rare to see just one inventor of a patent start patenting for the large enterprise; typically the inventor group of a patent move together. This point further confirms the importance of the relationships among inventors within their own groups, as stated by OETTL (2012) and (GRIGORIOU; ROTHAERMEL, 2014).

Another extremely relevant point is the advantage that skills may have due to the path dependence of the scientists (HOHBERGER, 2016). Therefore, scientists that move from the small to the large enterprise allow the Big Pharma firm to internalize prior research and its future results, because, HOHBERGER (2016) stresses, scientists tend to research the same agenda. We can extrapolate this line of thought: if the scientist’s research agenda drew attention from a Big Pharma firm, then incorporating this scientist is also to incorporate the scientist’s research agenda.

**Table 5: Comparison between Patents Reference and Inventors Use**

|  |  |  |  |
| --- | --- | --- | --- |
| **Large Enterprises** | **Small Enterprises Acquired** | **Patents Used as Reference (small enteprise's patents used)** | **Use 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% |

**Table 5: Continuation**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Large Enterprises** | | **Small Enterprises Acquired** | | **Patents Used as Reference (small enteprise's patents used)** | | **Use of Inventors** | |
| GSK | Human Genome Science | | 14 | | 1% | |
| ID Biomedical | | 3 | | 11% | |
| Corixa | | 33 | | 14% | |
| Praecis | | 3 | | 24% | |
| Sirtirs | | 9 | | 0% | |
| fizer | Idun Pharmaceuticals | | 1 | | 0% | |
| Rinat Neuroscience | | 2 | | 51% | |
| Coley | | 34 | | 15% | |
| Covx | | 1 | | 0% | |
| Incagen | | 2 | | 12% | |
| J&J | Transform-Pharma | | 1 | | 24% | |
| Omrix | | 6 | | 0% | |
| Merck | Sirna (Ribozyme) | | 35 | | 11% | |
| Glycofi | | 26 | | 77% | |
| Abmaxis | | 5 | | 60% | |
| Inspire | | 1 | | 4% | |

Source: own elaboration

Based on HOHBERGER (2016) and on the analytical variables in this study, we might may say that as inventors move to a Big-Pharma firm, they will reference their past work and generate more patents, creating a research trajectory. Therefore, there must be a correlation between inventors’ use and direct technical contribution. Table 5 shows a clear correlation between direct technical contribution and inventors use, proving HOHBERGER’s (2016) argument.

One last important relation stands out when analyzing the classes not developed and skills contribution together. The enterprises with a higher rate of non-developed classes used fewer inventors. For instance, J&J has 66% developed classes and a low use of inventors. This fact may lead to an important relation. The inventors are responsible for developing new technologies; therefore, the higher the rate of inventor use, the higher is the development of competence by a large enterprise. Thus, the effective use of technical contribution depends on the level of skills contribution.

# Conclusion

This study aims to open the black box and reveal the elements that large enterprises keep in their acquisitions of small firms. This is only possible by looking in detail at single large enterprises. Therefore, this study is based on the M&A data of 8 Big Pharma firms from 2005 to 2012.

This study offers several contributions. First, the analyses overcome problems in past studies. Second, we create several variables: (i) direct technical contribution, (ii) indirect technical contribution, and (iii) inventor use. These variables have an interesting explanatory power for the individual cases of acquisitions. By combining these variables, the analysis becomes stronger and leads to new conclusions. A final important contribution relates to the relevance of small enterprises in the development of technology and competence within Big Pharma firms. Through the chosen variables, this study shows that small enterprises are relevant for technological development among the Big Pharma firms.

This study first established that small enterprises can contribute to large enterprises, increasing their innovative outputs. We divided the contribution into two main elements: the technical and skills contribution. Both have different sources. Technical contribution comes from the techniques developed by the small enterprises and skills contribution comes from the employees working on R&D. By uniting these two elements, we can then define this as the overall contribution.

Therefore, we can trace the elements that Big Pharma firms incorporate from small firms by analyzing technical knowledge and skills. The technical contribution analysis examines the patents used as reference by the large enterprises and how the large enterprise’ knowledge set became more similar to that of the small enterprise. We do this by compiling when the large enterprise started to file patents in the same patent classes dominated by the small enterprises. As a conclusion, we observed that the large firms did not use the technical contribution to create new competences, but rather to improve existing competences.

We analyzed the skills contribution by observing whether the small enterprises’ inventors started to file patents for the large acquiring enterprise. We find that skills are used much more extensively than techniques, as it is the more prominent element incorporated.

When we compared the variables created to measures of potential in terms of whether we could identify a high potential contribution for these enterprises in the future.

Surprisingly, in this study based on patent data and, of course, a technical kind of information, the variables related to skills, a not technical element, are the ones that stands outs. This is another element that points to relevancy of skills in enterprises promising contribution.

This study has some limitations. The first is the overdependence on patent information, along with its related issues, including the debates on patent methodology problems. An interesting limitation is that we do not consider any effort that does lead to patents. In addition, we excluded enterprises that have no patents at the USPTO. Further, collaborations play an important role, which we also do not consider. The inventor’s information is also too restrictive when one looks at skills.

We can identify two paths to overcome this study’s methodology. The first is to focus on one enterprise and a longer time period. The second path is to consider other empirical methods; unfortunately, this could lead to some black box problems. To overcome the skills restrictiveness we could consider the scientific publications of the inventors. A future model should include collaborations. Finally, future studies should increase the sample size and test the results for other sectors, such as through a comparison with low-tech sectors.

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1. \* Pós-doutorando no Programa de Pós-Graduação em Economia do Instituto de Economia e Relações Internacionais (IERI) - Universidade Federal de Uberlândia (UFU). [↑](#footnote-ref-1)
2. a Professora Associada do Instituto de Economia e Relações Internacionais (IERI) - Universidade Federa de Uberlândia (UFU). [↑](#footnote-ref-2)
3. To avoid identification, all self-citations in this version of the article appear as AUHTOR, YEAR. [↑](#footnote-ref-3)
4. In the pharmaceutical industry, the process that leads to an innovation can be divided into 4 main stages: (i) target identification, characterization, and validation, followed by assay development; (ii) lead finding and optimization; (iii) and (iv) clinical trials (Schwardt *et al*., 2003, pg. 2). Roughly, in pharmaceutical R&D, the activities conducted before the clinical trials encompass the drug discovery process or activities; a set of activities that are highly focused in science in which large enterprises employ their external sources of innovation. [↑](#footnote-ref-4)
5. This study used the 2013 edition. [↑](#footnote-ref-5)