Pharmaceutical emerging markets: technological mapping and innovation networks

Mercados farmacêuticos emergentes: mapeamento tecnológico e redes de inovação

Mercados farmacéuticos emergentes: mapa tecnológica y redes de innovación

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Abstract
Traditionally, United States (US) and Europe stand out as pioneers in global pharmaceutical field, dictating the sector dynamics due to their high innovation rates. However, there is a growth of the pharmaceutical emerging markets, especially BRICS, due to increased income, expansion of health systems, and availability of human resources. This paper aimed to carried out a technological mapping and discuss pharmaceutical innovation strategies based on collaborative networks, considering a comparative approach. To this end, a study centered on the collection and statistical treatment of patent data extracted from international banks

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(WIPO and Derwent) between 1996–2018/2019 was developed. China was the most relevant pharmaceutical emerging market with highest number of patents (90,659) followed by Russia (22,013). The higher number of patents granted to foreigners than to residents, in BRICS, pointed to the great attractiveness of pharmerging regions. The innovation networks showed that emerging markets apply different innovation strategies than the pioneering countries in the pharmaceutical field, giving priority to more partnerships and weaker ties. This paper contributes to direct science, technology, and innovation policies to optimize innovation indexes especially for pharmaceutical emerging market.

**Keywords:** Innovation. Patent. Pharmaceutical Market. BRICS. Innovation Networks. Pharmederging Countries.

**Resumo**

Tradicionalmente, os Estados Unidos (EUA) e a Europa destacam-se como pioneiros no campo farmacêutico mundial, ditando a dinâmica do sector devido às suas elevadas taxas de inovação. No entanto, há um crescimento dos mercados emergentes farmacêuticos, especialmente os BRICS, devido ao aumento da renda, expansão dos sistemas de saúde e disponibilidade de recursos humanos. Este artigo teve como objetivo realizar um mapeamento tecnológico e discutir estratégias de inovação farmacêutica baseadas em redes colaborativas, considerando uma abordagem comparativa. Para tanto, foi desenvolvido um estudo centrado na coleta e tratamento estatístico de dados de patentes extraídos de bancos internacionais (WIPO e Derwent) entre 1996–2018/2019. A China foi o mercado emergente farmacêutico mais relevante com maior número de patentes (90.659) seguido da Rússia (22.013). O maior número de patentes concedidas a estrangeiros do que a residentes, nos BRICS, apontou para a grande atratividade das regiões farmacêuticas emergentes. As redes de inovação mostraram que os mercados emergentes aplicam estratégias de inovação diferentes dos países pioneiros no campo farmacêutico, priorizando mais parcerias e laços mais fracos. Este trabalho contribui para direcionar as políticas de ciência, tecnologia e inovação para otimizar os índices de inovação, especialmente para os mercados emergentes farmacêuticos.


**Resumen**

Tradicionalmente, Estados Unidos y Europa han destacado como pioneros en el ámbito
farmacéutico mundial, dictando la dinámica del sector debido a sus elevados índices de innovación. Sin embargo, existe un crecimiento en los mercados farmacéuticos emergentes, especialmente en los BRICS, debido al aumento de los ingresos, la expansión de los sistemas sanitarios y la disponibilidad de recursos humanos. El objetivo de este artículo fue realizar un mapeo tecnológico y discutir estrategias de innovación farmacéutica basadas en redes de colaboración, considerando un enfoque comparativo. Para ello, se realizó un estudio centrado en la recopilación y tratamiento estadístico de datos de patentes extraídos de bases de datos internacionales (OMPI y Derwent) entre 1996–2018/2019. China fue el mercado farmacéutico emergente más relevante con el mayor número de patentes (90.659) seguido de Rusia (22.013). El mayor número de patentes concedidas a extranjeros que a residentes en los BRICS señaló el gran atractivo de las regiones farmacéuticas emergentes. Las redes de innovación mostraron que los mercados emergentes aplican estrategias de innovación diferentes a las de los países pioneros en el ámbito farmacéutico, dando prioridad a más asociaciones y vínculos más débiles. Este trabajo contribuye a orientar las políticas de ciencia, tecnología e innovación para optimizar los índices de innovación, especialmente en el caso de los mercados farmacéuticos emergentes.


Introduction

The pharmaceutical industry is one of the most profitable in the world, characterized by dynamism and innovation-driven approach (Tannoury and Attieh, 2017). Developing and launching a medicine requires years and extremely high investments in Research and Development (R&D) (Lee & Kim, 2021). The development cost of a new drug increased from US$ 800 million, at the end of 1990, to about US$1 billion, in early 2000, and currently it exceeds the value of US$1.3 billion. This expressive value includes the long time required before the drug reaches the market, the low clinical success rate, and the opportunity cost involved (Wouters et al., 2020).

From this perspective, patents are valuable tools in the pharmaceutical field, as this strategy restricts competitiveness and brings financial rewards to innovative companies by exploiting the period of exclusivity granted to the holder of the protection. The effort to
innovate is directly conditioned to a well-founded intellectual property system, which ensures the return of the billionaire investments in pharmaceutical R&D (Aronson, 2008).

Historically, the global pharmaceutical market has been led by the United States (US) and Europe and its large industries are commonly characterized by high investments in R&D and a high rate of innovation (Akkari et al., 2019; Gautam & Pan, 2016). However, in recent years, the fast growth of the pharmaceutical market in emerging regions, especially in the BRICS members, has stood out and stimulated the transfer of economic and research activities to these countries, known as pharmerging countries or pharma emerging countries. While North American and European markets grew, on average, 7.8% and 5.0%, respectively, the Brazilian, Chinese and Indian markets reached an increase of 11.4%, 7.3% and 11.2%, respectively, in 2014-2018 period (EPFIA, 2019).

Current data from the Institute for Human Data Science (IQVIA) estimates that pharmaceutical sales will exceed 1.5 trillion dollars by 2023 and that the main drivers of this growth will be emerging countries, with an annual growth rate (CAGR) of between 5 and 8%. These regions are therefore considered the most promising for sustainable growth in pharmaceutical sales in the coming years (IQVIA, 2019).

The new panorama of this segment shows a great external interest in the pharmerging regions, as well as a unique opportunity for the domestic market to be explored by the national industries of these countries. In this last perspective, in order to support economic growth and the appropriate policies creation to foster innovation, Cirera and Muzzi (2020) explain about the need for interventions based on adequate and comparable data, especially in developing countries that have little debate about the extent and impact of innovation due to lack of evidence.

Therefore, this paper aimed to design a panorama about pharmaceutical innovation based on patent data, resulting in the development of technological mapping and construction of innovation networks centered on a comparative approach between US, Europe, and BRICS. It is noteworthy that there are many papers in the literature evaluating pharmaceutical innovation from the perspective of R&D and industrial production. However, there is still a gap regarding discussion of patent data and collaboration networks under a technological and industrial spectrum, especially that encompass pharma emerging markets, allowing the methodological approach developed in this study to be applied to other areas of the economy. Furthermore, since patent data are commonly complex, distributed in different databases and difficult to be interpreted from pure numerical values, the compilation and contextualized
assessment of these indexes is a facilitator for directing public policies on science, technology, and innovation to optimize a country's indicators.

Theoretical Background

2.1 Characterization of Regions with a Pharmaceutical Emerging Market

From the point of view of economists, an emerging market can be conceptualized as one that presents itself in promising development and it is estimated that investments made in this country will incur a high return despite high risks (Tannoury & Attieh, 2017). In 2013, the IMS Health (2013), an audit company in the global pharmaceutical market, carried out a study in which a classification of developed and emerging countries was made, using the GDP per capita of USD 25,000. After that, a rigorous assessment of emerging countries was developed according to the main parameters that impact the pharma and health market. From this assessment, 21 regions with a pharmaceutical emerging market were identified, and the potential contribution of each emerging region to the pharmaceuticals sales was categorized at three levels (Grand View Research, 2017).

In Tier 1, as the most promising emerging market in the world, there is China. In Tier 2, there are Brazil, India and Russia, demonstrating that BRICS members have the greatest potential to contribute for pharmaceutical market sustainability. Brazil became the sixth largest pharmaceutical market in the world, in 2017, rising its position in the global ranking, behind the US, China, Japan, Germany and France. It is estimated that, in the next years, Brazil may surpass France, becoming the fifth largest market in the world (IQVIA, 2019). The remaining regions are in Tier 3, encompassing a diversity of income levels, growth rates and maturity of the health system (IMS Health, 2013). South Africa, which joined the BRICS in 2011, also has great potential for the medicines sales, standing out worldwide as the fifth country with the highest pharmaceutical expenditure per capita (Riley et al., 2019).

The potential of emerging markets is associated with the increasing income, expansion of health systems, availability of human resources, low-cost wages, and the demographic change linked to the global phenomenon population aging (Tannoury and Attieh, 2017). Furthermore, BRICS represents 40% of the world population and these regions differ from developed nations mainly in relation to the growth in health expenditure (Evaluate Pharma, 2019). Also, the cost of developing, producing and clinical trials of new medicines in these
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regions are significantly lower than in developed countries, allowing higher profits for investing companies (Rodwin et al., 2018).

2.2 Innovation Network and the Importance of Pharmaceutical Patent

The development of a new medicine is a complex process because encompasses from the development of the drug to the guarantee of safety, efficacy and quality of the final product (Lyu et al., 2019; Vidmar et al., 2020). Considering the technical and bureaucratic challenges, as well as the increasing R&D costs, innovation networks centered on strategic alliances between companies, universities, research centers and other agents are increasingly common. Innovation networks are used to indicate patent co-ownership, meaning the monopoly right over a new product or process resulting from cooperation between different players who organize around a common goal (Dong & Maccarthy, 2019).

Innovation is one of the most important strategic issues for the country's economic and social development (Nascimento & de Oliveira, 2024). Patents information are a relevant indicator for evaluating aspects of a business, sector or even a country, and is directly associated with the innovation process (Sampat and Shadlen, 2017; Ploska et al., 2019). Accordingly, mapping innovation networks allows to assess the competitive strategy and identify a company's alliance portfolio, analyzing the impact of these partnerships on the innovation process (Dong and Maccarthy, 2019).

Geum et al. (2013), Guan and Liu (2016), and Vidmar et al. (2020) showed the importance of a collaborative approach to the innovation development, establishing partnerships that promote diversification of technological competences, combining skills and increasing the flow of knowledge. Collaboration networks are strategic to foster sustainable competitive advantage to the pharmaceutical field to ensure the maintenance of investments and the launch of medicines in a timely manner.

Most new drugs are, in fact, protected by patents, which last for 20 years counted from the deposit that, in general, occurs even before clinical tests. Then, until it reaches the market, the medicine receives 12 to 14 years of exclusive sales. After this period, the patent expires and can replicate the drug, through the development of generic medicine (Razmaria, 2016; Sampat & Shadlen, 2017).

In the last years, pharmaceutical emerging countries have increased their market share due to the production of generics. This strategy makes organizations stop being R&D intensive
industry, compromising their innovation and competitiveness indexes. In contrast, in developed countries, patent protection for pharmaceuticals has a long tradition, enabling these regions to lead and dictate the dynamics of the sector (Hering et al., 2018; Tannoury & Attieh, 2017). In fact, intellectual property (IP) laws related to pharmaceuticals took place in a pioneering manner in developed countries since the beginning of the consolidation of their pharmaceutical industries, including United Kingdom (1949), France (1960), Germany (1968), Japan (1976), Switzerland (1977), Italy (1978) and Sweden (1978).

A survey conducted by WIPO, in 1988, indicated 49 regions that still did not allow the protection of pharmaceutical products, mainly referring to developing countries (Nogues, 1990), pointing out that the gap in industrial development was also reflected in the scope of the legislation. Regarding to the emerging markets, Brazil stands out as one of the countries that later enabled the protection of pharmaceutical products, through Patent Law No. 9279, in 1996 (Brazil, 1996), while China, in 1992, has already started to allow the patenting of products and processes in all sectors of its economy (Zheng, 1996).

In 1987, the Economic Commission for Latin America and the Caribbean, created by the United Nations, classified a country's pharmaceutical industry according to its capacity to perform stages of the production chain, considering four evolutionary stages: (i) R&D; (ii) production of pharmaceutical chemicals; (iii) production of pharmaceutical specialties; (iv) marketing and commercialization (CEPAL, 1987). The ability to carry out one or more stages determines the level of technological qualification and maturity of an industry and, as it progresses along the steps of the production chain, the need for intensive activities in science and technology decreases. In general, multinational companies have competence to act in the four stages of the chain, while national companies in developing countries commonly cooperate only in the final links, outsourcing the initial stages, strengthening a relationship of technological dependence and import of inputs (EPFIA, 2019).

The lack of incentives for innovation in domestic industries in emerging markets, including pharmerging regions, also has socio-political and geographical impacts. In the pharmaceutical field, the deficiency in the internal development of scientific and technological efforts compromises the consideration of regional epidemiological profiles that lead to different demands in innovation systems. In addition, there is a lack of specific medicines to treat the most common pathologies according to the country, aggravating the social context of the less favored regions (Vidotti et al., 2008).
Methodological Approach

An exploratory and descriptive research was carried out, with a quantitative approach based on secondary data collection and statistical analysis. For the literature review, Web of Science, Scopus, Science Direct, and IEEE Xplore databases were used. The main research fields included Intellectual Property, Patent, Pharmaceutical Industry, Innovation, Collaborative Networks, and BRICS. Criteria for inclusion and exclusion of articles, analysis, discussion and presentation of results were considered in the literature review.

In the first phase of this study, a technological mapping was developed according to patent data collected from Intellectual Property Statistics Data Center, promoted by World Intellectual Property Organization (WIPO), for BRICS countries, US and Europe. Europe data was obtained through the sum of protections from all European countries and patent data from India was not available on WIPO, so it was not possible to develop the analysis for that country. The search was limited between 1996 – year of the Intellectual Property Law in Brazil which was the last country among those studied to regulate the patent rights for pharmaceuticals – and 2018.

In order to allow a holistic view of pharmaceutical innovation in each region, the technological mapping considered the granting of pharmaceutical patents (patents per office) as well as the holding of pharmaceutical patents (patents by origin). Also, residents and foreigners (office) or non-residents (origin) evaluation was done.

Regarding to patents granted per office, the following search criteria were used indicator: 5 – Patent grants by technology, type: Total count by filing office; technology: 16 – Pharmaceuticals. To obtain the number of concessions per office for residents and foreigners, the criteria was changed to type: resident and non-resident count by filing office. In the search of patents by origin, the following criteria were used indicator: 5 – Patent grants by technology; type: Total count by applicant’s origin; technology: 16 – Pharmaceuticals. Finally, to obtain concessions by origin to residents and non-residents, the criterion was changed to resident and abroad count by applicant's origin (equivalent count).

In the second phase of this study, an industrial mapping was developed, considering patent data collected from Derwent World Patent Index, an industrial property research tool produced by Clarivate Analytics. For the search, the term Pharmaceutical was used and only protections in the Pharmacology Pharmacy knowledge area were selected, restricting the search between the 1996–2019 interval. The data analysis period was until 2019 in order not
to bring any deviation associated with the COVID-19 pandemic, requiring a specific approach that departs from the object of this paper. The data obtained were exported to Microsoft Office Excel software, version 2016, and tabulated in ascending order of number of patents, according to the companies.

According to the industrial mapping, collaborative innovation networks were developed for three companies considering co-ownership of patents: (i) the leading global in the number of pharmaceutical patents; (ii) the Chinese institution with the highest number of pharmaceutical patents, given that China was the emerging country that stood out in the technological mapping; (iii) and the Brazilian institution with the largest number of protection, since it refers to the region where this study was developed, being of national interest, as well as the second pharmaceutical emerging market with the greatest potential.

The data about co-ownership was also collected from Derwent, inserting the institution name as depositor, and only the protections whose co-owner referred to a legal entity were considered, since this work focused on an industrial mapping to assess the impact of interinstitutional partnerships.

For network graphic representations, UCINET 6.695 and Netdraw 2.158 were used. The agents of the innovation ecosystem were differentiated by colors and symbols according to the nature of the institution. The frequency of interaction between the actors, represented by the number of patents co-ownership, indicated the strength of the relationship and it was designated by the thickness of the edge and the number of indication of the partnerships allocated over the edges. The descriptive analysis of the structure of the networks considered the centrality of the degree (Equation 1), classification of the actors in the network, and the number of patents co-ownership.

\[
C_i = \sum_{j=1}^{n} A_{ij}
\]  

Where, \(C_i\) refers to the degree centrality of a node \(i\), \(A_{ij}\) are elements of a network’s adjacency matrix and \(n\) is the number of network vertices (Newman, 2004). The adjacency matrix consists of one of the forms of representation of a graph, in which the lines and columns are associated with the nodes. In this matrix (Figure 1), \(1\) is used when there is a relationship between nodes, and \(0\) for when there is not.
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**Figure 1**

Adjacency matrix of a non-oriented graph

![Adjacency matrix of a non-oriented graph](image)

Also, the agents of each network were classified into four categories: (i) universities or educational institutions, in which both public and private institutions will be considered; (ii) research centers, whether public or private; (iii) companies, whether from any segment and legal nature; (iv) others, including development agencies, public agencies, etc. From the point of view of economists

**Results and Discussion**

**4.1 Technological Mapping: Pharmaceutical Patents by Office**

Based on patent data granted by office, collected from WIPO, a study was carried out in order to analyze the attractiveness rate of the different pharmaceutical markets. Figure 2 expresses the number of protections granted by IP offices in Brazil, China, Russia, South Africa, US, and Europe, between 1996–2018.

**Figure 2**

Number of pharmaceutical patents granted by offices in Brazil, Russia, China, South Africa, US, and Europe (1996–2018)
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It is observed that the country that granted more patents was China, with a total of 111,381 protections, followed by US and Europe, with 109,850 and 105,861 patents granted, respectively. The prominent positions of the US and Europe were already expected, as these are leading regions in investment in R&D, with attractive economic and technological indicators. However, China's leadership confirms the growing trend of the pharmerging market, increasing foreign interest in the region.

In fact, China's growing economic and commercial expansion, as well as policies to attract foreign laboratories and to promote the pharmaceutical sector, have contributed to raising its attractiveness rate, so that foreign companies are increasingly interested in protect products or processes in the country (Qiu, 2014; Akkari et al., 2019). On the other hand, a significantly lower number of protections granted was identified in the other BRICS countries, with Russia (29,608), South Africa (14,415), and Brazil (1,399) standing out in decreasing order. This discrepancy in relation to China's attractiveness is due to factors of a technological, political and economic nature, as well as infrastructure of the productive sector and availability of qualified labor (Sanyal, 2004; Tannoury & Attieh, 2017).

In Brazil, the Intellectual Property Law was only instituted in 1996. However, the delay of National Institute of Industrial Property and other public institutions meant that patent concessions started only in 2000. In addition, it is noteworthy that only in 2004 the pharmaceutical sector was considered by the Brazilian government as strategic for the country's development. However, the lack of effectiveness of public policies, the late development of research institutions, and the fragile articulation of the triple helix university-industry-government resulted in an immature and inefficient National Innovation System (NIS), which is a barrier to the development of the leading pharmaceutical industry in the country (Palmeira Filho et al., 2012).

In South Africa, patent grants have declined significantly in recent years. These data reflect the internal political and economic crisis that this region has been experiencing since 2014, which peaked in 2016, with a succession of episodes of corruption and mismanagement that led to economic disasters, with rising unemployment and a significant drop in GDP, impacting foreign interest in the country (BMI RESEARCH, 2017).

It was observed that 77.3% of the protections granted by China were to residents (Figure 3), demonstrating the great innovation potential of national companies and an interest in ensuring protection in this country in order to explore their domestic market. For the US, a
similar profile was observed, demonstrating a high internal use, with 58.06% of protections (63,783) for residents, while 41.94% (46,067) were granted to foreigners.

**Figure 3**

*Percentage of patents granted to residents and foreigners, in offices in Brazil, Russia, China, South Africa, US, and Europe (1996–2018)*

In contrast, in Brazil, almost 90% of protections were granted to non-residents. In fact, historically, Brazil has granted far more patents to foreigners than to residents, mainly due to the low degree of innovation of national pharmaceutical companies, pointing to an internal deficiency. This issue can also be seen in other emerging countries, such as South Africa, where only 1.46% (211) of patents were granted to residents. The number of patents granted to foreigners much higher than that of residents confirms the high power of attractiveness of pharma emerging regions. It is worth mentioning that the high utilization by foreign companies may constitute an obstacle to the entry of national companies, restricting their performance and competitiveness.

In Europe, 37.04% of pharmaceutical protections (39,215) were for residents and 62.96% (66,646) were for foreigners. These data suggest the prioritization of ensuring protection outside European limits, encompassing other regions with market potential, such as pharma emerging countries. Therefore, countries such as Germany and the United Kingdom, which have a pharmaceutical market with a modest proportion, have industries with high innovative potential and which increase their capacity to generate profits through exports (Gassman & Von Zedtwitz, 1999).
4.2 Technological Mapping: Pharmaceutical Patents by Origin

From the data obtained from WIPO, a technological mapping was developed according to the number of patents granted by origin. Figure 4 expresses the number of patents granted to Brazil, China, Russia, South Africa, US and Europe. It was observed that although Europe and the US still hold the largest number of pharmaceutical patents, with 215,404 and 182,585 protections, respectively, it was highlighted the prominent position of China as the leader of pharma emerging countries, with 90,659 protections, which may indicate a potential risk to the hegemony of the historically pioneering regions.

Chinese growth can be explained by strong public support for the pharmaceutical field in recent years. In 2011, China's health reform and the 12th Five Year Plan took place, which culminated in significant investments in technologies and the opening of several research centers. In addition, according to WIPO (2019), investment in R&D in China grew from 0.6%, in 1996, to 2.1%, in 2017, reflecting in the pharmaceutical segment.

Russia also stands out with 22,013 patents. The growth of pharmaceutical innovation in this country is mainly due to public initiatives to support the sector, such as the Pharma 2020 strategy that was created in 2009, with the aim of stimulating the modernization and advancement of local companies regarding new products development and increase the market share of national medicines to 50% until 2020 (Ashamarina et al., 2016).

Figure 4
*Number of pharmaceutical patents granted to Brazil, Russia, China, South Africa, US, and Europe (1996–2018)*
On the other hand, there is a low level of expressiveness on the part of Brazil and South Africa, with 619 and 579 protections, respectively. This scenario reflects a historical political fragility to foster innovation, leading domestic industries to develop dependent on the import of technology and pharmaceutical inputs (Hering et al., 2018). In fact, the pharmaceutical market in these countries is directed to generic medicines, and that there is no strong government action that stimulates innovation and that promotes harmonious action between private and public initiatives.

From an analysis of the protections granted to residents and non-residents (Figure 5), among the 90,659 pharmaceutical patents granted to China, almost 95% were to residents. In Russia, the same profile was observed, and these data express a high utilization of domestic pharmaceutical market, since most patents belong to residents (18,211 patents).

In Brazil and South Africa, the most part of pharmaceutical patents (> 63%) were obtained by non-residents. The scenario in these countries indicates the low degree use of pharmaceutical market by domestic companies, and most of the patents are concentrated in multinational companies which have the right to exclusive commercialization in the region, pointing out a fragility. In addition, the South African scenario reflects the internal political and economic crisis, but it also highlights the historical political factor of low incentive to innovation and little use of internal potential (BMI Research, 2017).

Figure 5
Percentage of patents granted to residents and non-residents of Brazil, Russia, China, South Africa, US and Europe (1996–2018)

Finally, in US and Europe, most patents were granted to non-residents, reaching rates of 65.07% (118,802 patents) and 81.99% (176,616 protections), respectively. This finding
indicates that patents of US and Europe origin are mostly granted abroad, confirming the interest of companies in these regions to safeguard protection in countries with greater market potential. In addition, countries like US, United Kingdom, Switzerland, France and Germany have, in fact, a lot of innovation, standing out as leaders in pharmaceutical protections, but aim to explore other markets through the introduction of these innovations.

4.3 Industrial Mapping and Collaborative Networks for Innovation

Based on the industrial mapping, the main pharmaceutical patent institution identified was the Swiss pharmaceutical industry Novartis AG with a total of 1,534 patents. The main Chinese institution was China Pharmaceutical University (CPU), with 415 patents, occupying the 44th overall position. The outstanding Brazilian leader was the Federal University of Minas Gerais (UFMG), whose overall position was 308th, with 121 patents.

The first difference identified between the world leader and pharmerging leaders refers to the nature of the agent. Novartis AG is a company, while UFMG and CPU correspond to public universities. This characteristic is a reflection of the companies from regions with a pharmaceutical emerging market to concentrate at the end of the production chain and focus on generic drugs, which require little innovative activity, such that intensive activities in science and technology have not been effectively incorporated by them.

The analysis of innovation networks showed that the network with the highest degree centrality was the CPU ($C_i = 35$), followed by Novartis AG ($C_i = 24$), and UFMG ($C_i = 17$). The greater the centrality of the organization, the more connections the company has, and, consequently, the greater the amount of knowledge to which it is exposed, increasing the possibility of developing disruptive innovations (Lyu et al., 2019).

Although the CPU has made more partnerships, as well as the UFMG, the ties established with the partners were predominantly weak, explained by the frequency of the relationships (number of patents co-ownership). In contrast, Novartis AG (Figure 6) has established fewer partnerships than the Chinese leader, but has prioritized stronger ties that represent solid relationships based on commitment and responsibilities, characterized by proximity and intensity. Weak ties are characterized by little intensity and greater social distance, being the first to be established in a relationship. However, this kind of tie is very important when the objective is diversity of knowledge and not intensity (Rolt et al., 2017).
In fact, Novartis AG, being a leading pharmaceutical company in innovation, will benefit more from the quality of information and intensity of knowledge than from diversity, and this only occurs in environments of trust between partners, resulting from strong and structured interactions (Schott & Jensen, 2016). Among the 24 partnerships established by Novartis AG, between 1996–2019, collaboration with foreign companies was observed, such as British pharmaceutical Glaxosmithkline (43 patents); Canadian biopharmaceutical Xenon Pharmaceutical (8 patents); and American companies Inhale Therapeutic Systems (7 patents), Nektar Therapeutics (21 patents), and Chiron Corporation (7 patents). In addition, it was identified the collaboration with an American educational institution, the University of Pennsylvania (10 patents), and two US’s research centers, The Scripps Research Institute (11 patents) and the Dana Farber Cancer Institute (7 patents), a reference in cancer research.

The partnerships established by Novartis AG with foreign institutions demonstrate the interest in external sources of technological knowledge, crossing national limits. However, it was observed that the majority of patents co-ownership occurred with divisions of the same company, including Novartis Pharma (466 protections), Novartis Erfindungen Verw MBH (130 patents), Ciba Ceigy AG (21 patents), and Sandoz LTD (7 patents), suggesting high internal competence of a scientific and technological nature.

According to CPU innovation network (Figure 7), the 35 partnerships established were with national institutions, especially pharmaceutical companies, including Hefei Industry Pharmaceutical Institute (1 patent), Nanjing Meizhu Medicine (2 patents), Nanjing Yinghaiyue Biological Technology (3 patents) and others. Universities are a valuable source
of scientific and technological knowledge for companies, and this cooperation, according to Rosa and Doin (2020), is important to reduce the reaction time to market and technological changes, keeping organizations competitive.

**Figure 7**

*Collaborative innovation network of Pharmaceutical University of China – CPU*

Since the CPU is a public institution, partnerships with domestic companies demonstrate the government's interest in research and innovation being reverted to the training of their industries. This fact agrees with the historical stance adopted by the Chinese government, which, since 1993, has been expressing its interest in making China a technological power, especially in the pharmaceutical segment, with publics policies aimed at raising research standards in order to the development of the national productive sector, such as “Project 211”, created 1995, of which the CPU is a member (Qiu, 2014).

Finally, among the 17 cooperation established by UFMG (Figure 8), it can be seen that 10 were with educational institutions including international universities like University of Ferrara, in Italy (1 patent), the Medical University de Graz (1 patent), in Austria, and Martin Luther University of Halle-Wittenberg (1 patent), in Germany. In addition, among the 3 established business partnerships, it was noted that one of them was with an Austrian pharmaceutical company, CYL Pharm GMBH (1 patent). Also, it was identified 2 cooperation with research centers/laboratories, including a German research center, the Max Delbrück Center for Molecular Medicine (1 patent).
The presence of international partners in the network demonstrates the interest of the Brazilian leader in seeking new technologies and external sources of knowledge, and, on the other hand, reveals the institution's attractiveness to foreign partnerships. However, it also stands out the low cooperation with national companies, especially the pharmaceutical industries. This fact corroborates the study of Bazzo and Porto (2013), which pointed out that Brazilian institutions are not prepared for cooperation, nor for the transfer and absorption of new technologies, which is an obstacle to national innovation. This issue is the result of a weakness in the NIS with a historic and precarious articulation between government, university and industry.

Figure 8

*Collaborative innovation network of Federal University of Minas Gerais – UFMG*

Despite initiatives to strengthen university-industry relationship, such as the “National Science, Technology and Innovation Strategy 2016/2022”, Brazil, compared to developed countries and China, is fragile in terms of collaboration networks, mainly due to the lack of experience in network management and the precarious interaction between university and business (IQVIA, 2019).

**Conclusion**

The technological mapping developed in this paper concluded that the US and Europe are still leaders in pharmaceutical patents due to the high capacity for innovation. The patent analysis showed the growing importance of China, standing out as the pharmaceutical emerging market with the greatest capacity for innovation. This trend would reflect the
growing interest in exploring other regions with greater potential for demand for medicine, such as pharmerging countries. On the other hand, it was emphasized the low innovation rate of Brazil presenting, as well as Russia, a greater concession than the holding of pharmaceutical patents, which demonstrates the external interest in these markets and the low internal exploration by national companies.

The industrial mapping and innovation networks pointed out that Novartis AG prioritized a network with less diversity of partners and stronger ties in order to create environments of trust and cooperation. Pharmerging leaders refer to public universities, the CPU and UFMG, presented similar network structures with weak ties depicted in the diversity of actors and few patents deposited with the same partner. CPU prioritized partnerships with Chinese companies, demonstrating its interest in transferring knowledge for the training of national companies. This characteristic was shown as a result of Chinese public initiatives that aim to position China as a technological power in the pharmaceutical sector, pointing out that internal policies influence the structure of the network.

Finally, a favorable context for the leverage of the pharmaceutical market for pharmerging regions was concluded. However, it is worth mentioning that this issue depends on the transposition of barriers related to public innovation policies, on the consistent use of the knowledge transfer and collaborative networks, on the level of R&D investment, and above all, on regulatory actions.

References


Aronson, J. K., 2008. Something new every day: defining innovation and innovativeness in drug therapy. J. Ambul Care Manage, 31(1), 65-68. https://doi.org/10.1097/01.jac.0000304100.38120.b2


CEPAL, 1987. Cepalindex, resúmenes de trabajos del sistema CEPAL. CEPAL, ONU.


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Grand View Research, 2017. Pharmerging Market Analysis By Product, By Region {Tier I (China), Tier II (India, Brazil, Russia, South Africa) Tier III (Argentina, Mexico, Poland, Turkey, Indonesia)}, And Segment Forecasts, 2018 – 2025. Grand View Research, San Francisco, CA.


IQVIA, 2019. The Global use of medicine in 2019 and Outlook to 2023: Forecasts and Areas to Watch. IQVIA, Parsippany, NJ.


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