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Digital Transformation: Patents as a Determinant Proxy for Industry 4.0

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Abstract
This study seeks to identify the relationships between patent indicators in the process of digital transformation of industries in Brazil and Portugal to try to figure out the changes in course, as well as the reflections that have arisen in the context of the Fourth Industrial Revolution. Specifically, an analysis of patents is carried out to characterise the level of industry 4.0 in Brazil and Portugal in the period 2008 to 2018. The article aims to answer the following question: How do these countries react to the emergence of new technological domains with strong innovation potential, such as the 4.0 industry? The methodology is descriptive as to the objectives. As such, the study has an applied nature, being designed from bibliometric research and accessing databases of legal intellectual protection institutes in both countries and the Orbit® Intelligence database. As results, the comparative analysis of patents that composed the essentials of this work demonstrates that Brazil and Portugal participated, although in an unequal way, both in terms of periods and sectors and intensity, in the general process of development of enabling technologies in the context of digital transformation. Despite the technological "gaps" that still affect both countries, this has not prevented them from taking an active and growing part in patent filing, in the search for recognition of their ability to innovate through their companies and scientific centres of excellence, in technological areas that are still little developed internally, but that require sophistication and advanced scientific knowledge and its application.

Keywords: Digital Transformation. Patents. Industry 4.0. Technological Catching-up.

1.Introduction

According to market logic, the convergence between manufacturing and the basic technologies of Industry 4.0 (I4.0) makes it increasingly essential for companies to formulate innovation strategies to strengthen their technological capabilities. Also, digital transformation changes industrial processes and procedures, as well as changes the relative positions of key actors in the value chain and intellectual property regimes. In this shifting changing landscape, Dechezleprêtre et al. (2017) agree on the distinction of three sectors in which industry 4.0 stands: (1) core technologies (hardware, software, connectivity); (2) basic technologies (analytical, security, artificial intelligence, electrical, 3D systems); and (3) application technologies (home, personnel, company, manufacturing industry, infrastructure, vehicles, etc.). In view of this distinction, it should be noted that industry 4.0 is a peculiar concept to the Fourth Industrial Revolution (4IR), which accompanies digital transformation, automation and data exchange in technologies including the internet of things (IoT); big data; 3D printing (additive manufacturing); cloud computing; autonomous robots; augmented virtual reality; internet of industrial things (IIoT); cyber-physical systems; block-chain; artificial intelligence; intelligent sensors; smart logistics; drones; simulation and digital twin; smart factory; nanotechnology; biotechnology, among others (Kagermann et al., 2013; Sven-Vegard Buer et al., 2018; Radziwill, 2018; Zhong et al., 2019; Ardito et al., 2019; Schroeder et al., 2019; Ghobakhloo, 2019).

Since the technological evolution leads to the convergence between the components and the knowledge of new technologies (Fleming & Sorenson, 2001; Antonelli, 2011; OECD, 2017), the industry 4.0 allows the management of industries that manufacture products with greater complexity, but also with flexibility. Thus, 4IR, through the digitalisation and interconnection of all objects (projects, parts, machines, devices, etc.) implies a significant improvement in the manufacturing systems. In contrast with previous industrial revolutions, industry 4.0 is based on the creation of networks and interconnectivity between existing assets and technologies, therefore not limiting itself to the replacement of existing assets and technologies, and mainly using Information and Communication Technologies (ICT). After Germany has implemented the industry 4.0 concept and other countries have also progressed in the use of their inherent technologies, patent rights are crucial for companies because they are exclusive, corresponding to rights of their owner.

Although patents are undoubtedly one of the indicators less highlighted by the market, they are indispensable to distinguish the advance of technologies in the countries and, above all, they provide financial benefits through the sale or licensing of the technology, in addition to the front position that its holders achieve in the production of knowledge. Further, in the traditional axiom of the patents, inventions in the industry have historically been protected by the system of intellectual property law (Hattenbach & Glucoft, 2015; Kim & Bae, 2017; Kim & Lee, 2105; White & Piroozi. 2019). This fact results, especially, because patent law has its roots deeply anchored in the industrial revolution, reflecting the idea that new knowledge and processes have a cost contrary to what prescribes the perfect competition model so much used in the textbooks of mainstream economics. Although it has also been criticized as an obstacle to the faster dissemination of knowledge and the benefits that may result from it (if it is excessively prolonged, strengthening a sort of durable monopoly power), and has been the object of conditioning in cases of greater social emergency as in the medical care field, the legal framework of patents has been able to adapt to successive revolutions, with the context of ICT standing out, as well as presenting some peculiar challenges in the process of digital transformation. The present work will analyse this process, based on the cases of Brazil and Portugal, as explained below.

The analysis of patents refers to the examination of various features of technological progress and innovation activities that characterise a given industrial or technological domain (Kim & Lee, 2015). Among some recent empirical studies, Albino et al. (2014) adopted the analysis of patents to present organisations and countries mainly involved in the development of technologies related to low carbon energies. Zheng et al. (2014) examined patenting activities to study international collaborations in nanotechnology development. Other studies refer to the analyses related to digitalisation (Fang et al., 2016; Ardito et al., 2017) in the context solutions, thus highlighting the adequacy of patents in this specific field. It must be added that the analysis of patents has been widely used to establish public policies, such as in the area of energy policies (Mueller et al., 2014), with very important implications for companies, particularly when they seek to innovate.

From the perspective of technology management and planning, the analysis of patented inventions allows organisations to identify innovation trends, leaders, and technological followers in certain domains (Ernst & Omland, 2011). Eventually, patent analysis may allow companies to recognise an integrating technology and support its best application in the market. According to the European Patent Office (EPO) Report (2017), since the mid-1990s Europe, together with the US and Japan, has been one of the leading technology innovation centres of 4IR, with European inventors accounting for almost 30% of all EPO patent applications until 2016 within this category. Thus, there is a sense of urgency for governments of developed as well as developing nations to assimilate industrial revitalisation, by means of innovation policies leading to the deployment and diffusion of new technologies from industry 4.0 (Lee, Bagheri & Kao, 2015; Zhou, Liu & Zhou, 2015; Liao et al, 2017; Müller, Buliga & Voigt, 2018; Telukdarie et al., 2018; Almeida, 2019; Kusiak, 2019; Veile, Kiel, Müller & Voigt, 2019), which constitutes a centre of transformation of the boundaries between physical production, digital and systems technologies.

According to the European Patent Office (EPO, 2017), in 2014-2016, the growth rate of patent applications of 4IR by EPO has been 54%. This rate exceeded by far the overall growth of patent applications in the same period, which was 7.65%. Companies have been responsible for the largest number of patent applications, with the highest growth in 3D technologies and systems, artificial intelligence and human-machine interaction. According to the United States Patent and Trademark Office (USPTO) through February 2018, the patent filings document presented a 60.2% increase between 2000 and 2013 and a 168.6% increase in applications during the same period of patent applications related to 4IR. It must also be noted that the growth was greater for new technologies such as robotisation and cloud computing.

In Brazil, the number of patent applications of industry technologies 4.0 has increased 11 times over the last decade comparing with the total number of deposits, according to the study of the National Confederation of Industry (NCI, 2020). In fact, in 2008, 1.202 patents were deposited for inventions related to industry 4.0 technologies, which represented 5% of the total of 23.170 requests made that year. A decade later, in 2017, 14.634 patents related to this industry were deposited, which represented 57% of the total of 25.658 requests.

In Portugal, in 2019, companies, research institutes and universities registered 272 (two hundred and seventy-two) applications with the European Patent Office (EPO), representing a 23% increase over the previous year. In the last decade, patent applications by national entities have tripled (+236%). The expansion in the number of intellectual protection requests from Portugal is mainly due to the significant expansion in 10 of the 15 most important technological areas of the country. The area of medical technology was the one that registered the most applications (22), followed by pharmaceutical (19) and furniture and games. In addition, the number of patent applications in the areas of "information technology for management" rose from one to ten applications, "control (of machinery)", which also rose from one to ten applications, and that of "electrical machinery, devices, energy" from four to fourteen applications.

Despite its growing importance, there are still a limited number of studies focusing on the technological dimension of countries' competitiveness based on digital technologies from patents applications. In recent years, to measure digital competitiveness, some new approaches have emerged (IMD, 2017; WEF, 2018) using a definition of competitiveness that includes not only technological factors, but also the macroeconomic and institutional environment. This article intents to fill this gap by developing a conceptual and empirical framework based on patent indicators. Thus, the objective of this research is to investigate the patent indicators in the process of digital transformation of industries in Brazil and Portugal in order to understand the changes underway, as well as the reflections that have arisen before 4IR. In this context, an analysis of patents is carried out to characterise the level of industry 4.0 in Brazil and Portugal from 2008 to 2018. The choice of these countries is justified by the fact that, despite regional differences (developing countries and Latin America, for Brazil, European Union for Portugal), they are still in a state of technological catching-up. How do these countries react to the emergence of new technological domains with strong innovation potential, such as industry 4.0? Do they actively participate in the process, just replicate or stay on the sidelines? Our study aims to answer these questions through the analysis of patents, which is a privileged field for this purpose.

More specifically, the following research questions are asked: How do the total number of patents filed in Brazil and Portugal are evaluated in terms of changes in Science and Technology (S&T) policies and what are the main differences between these countries? Which are the main enabling technologies of the industry 4.0 and what is the participation of Brazil and Portugal in the global patent process? Which technological domains, countries and actors in the world stand out the most in the period 2008-2018, as well as the endogenous intensity in the search for patents, considering the largest depositors, especially China? Which are the main depositors or what is the main objective of enabling technologies in industrial environments as such those of Brazil and Portugal? At the same time, the technological mapping, the identification of the main players, the total patent deposits, the characteristics and differences between Brazil and Portugal are carried out. Also, there are comparisons with other countries, notably China, a country that clearly faced the question of the recovery of technological delays and integration in the global system.

In order to achieve the proposed objectives, and in particular to answer the research questions, the patents were analysed in the databases of the reference institutes of both countries and the Orbit® Intelligence database was accessed, an international system of search and analysis of information contained in patents, which provides access to patent publications in more than 100 countries for analysis of technological overviews and studies of patentability (Kulp, 1984; Stock & Stock, 2005; Pires et al., 2020).

The structure of the article is organised as follows. Section 1 covers a brief introduction to the core issues. Section 2 presents the conceptual framework and develops the analytical structure of our approach. Section 3 describes the methodology used in the quantitative criteria underlying the analytical processes, which includes patent research, patent holders, main technical domains, markets and players, trends of technological investment over the last years. Also, it is visualised the patent roadmap for evaluating the process, considering that the analysis developed has a strong empirical orientation, resulting from the access to the databases and because of the behaviour of Boolean descriptors in both countries. Section 4 shows the results that were obtained in the empirical research through the identification of the main trends found in the field under study, and proceeds to the comparative analysis as well as its discussion. The final section summarises the main findings, refers to the limitations of the research and opens new paths for its continuation.

2. Conceptual Framework

In this section, the conceptual bases on the multiple themes of digital technology, disruptive technologies and patents are pointed out, illustrating concepts from the perspective of industry 4.0. Hereupon, it is possible to develop a conceptual and theoretical framework that integrates two dimensions: i) the role of digital technology in the industry 4.0 and its multiple disruptive technologies; ii) patents as a proxy for digital transformation in the industry 4.0.

2.1. The role of digital technology in industry 4.0 and its multiple disruptive technologies

The literature has investigated many aspects of 4IR, both in the field of applications and in the academy (Chiarello et al., 2018, Liao et al., 2017). The industry 4.0 has been considered a new industrial stage in which several emerging technologies converge to provide digital solutions. The inventions of 4IR have been classified in three big sectors, each of which is subdivided into several technological domains: i) Main technologies (Hardware, Software and Connectivity) that allow transforming any object into an intelligent device connected through the Internet; ii) Enabling technologies (big data, artificial intelligence, 3D systems, human-machine interaction) that are used in combination with linked objects; iii) Application technologies (home, personal, company, transformation industry, infrastructure, vehicles) in which the potential of linked objects can be explored (EPO, 2017).

Under this approach, Ciffolilli & Muscio (2018) use a more restricted definition, in where industry 4.0 is connected to intelligent manufactures in which new and distinct technologies change the organisation of value chains. The scope is the "digitalisation" of production that integrates with the new ICT. This conception of industry 4.0 has reflected a strong will by national governments to promote re-industrialisation (Santos et al., 2017), being smart industry its central element (Kagermann et al., 2013). Naturally, smart industry requires wide availability and integration of the factory with the entire product life cycle and production chain activities (Wang et al., 2016, Frank et al., 2019), including changes in the way people work. In fact, the smart industry depends on the adoption of digital technologies to collect real-time data and analyse it, providing useful information to the manufacturing system (Lee et al., 2015; Wang et al., 2020).

This approach will consider the second level of industry 4.0 technologies, called "enabling technologies", since they support all the other "smart" dimensions that involve technologies composed by ICT (which include internet of things, cloud services, big data and analysis (Tao et al., 2018, Trotta & Garengo 2018). These technologies are considered as basic because they are present in all domains and in different technologies, making possible the interconnectivity and providing the intelligence of the production system. The advent of the Internet of Things (IoT), cloud services, big data, has made possible, the concept of cyber-physical systems (Wang et al., 2016; Lu, 2017). According to Schroder (2019), industry 4.0 is central to the digital transformation in the areas of the industrial process, therefore, it must make a paradigm change in production systems as it includes industrial production, organisation and management of the entire value chain, and its technologies between the spheres of physical, digital and biological production or manufacturing system. In this research, the main enabling technologies will be presented as follows.

The Internet of Things - IoT, in its definition, goes beyond an intelligent and invisible network that can be detected, controlled and programmed through which the objects of the physical world become intelligent and independently communicate online. Specifically, IoT is referred to as the Internet of everything, and "things" can be electronic sensors, digital sensors devices, or any other objects (for example, people and buildings). IoT represents the integration of sensors and computing into an internet environment through wireless communication (Tao et al., 2018, Bongomin et al., 2020). In turn, the Industrial Internet of Things (IIoT) consists of machines connected to the internet and advanced analysis platforms that process the data produced by industries. As such, the IIoT is a subcategory of the Internet of Things, which aggregates customer-driven applications such as usable devices, technology for smart homes and autonomous cars. The IIoT devices range from tiny environmental sensors to complex industrial robots. The advances in the internet enabled the communication of various objects, supported by the reduction of sensor costs (Yang et al., 2019), allowing the detection of any type of object and its connection to a wider network (Boyes et al., 2018).

Cloud computing is a model where computer services that are available at a distance letting the users to access applications, data and computing resources over a network. Cloud services permit network access to a shared set of ICT resources (Bongomin et al., 2020). This technology has the ability to store data on an internet server that can be easily retrieved via remote access (Zhuet al., 2019). So, cloud services facilitate the integration of different devices, once they do not need to be physically close and can share information and coordinate activities (Zhu et al., 2019, Thoben et al., 2017).

The combination of IoT and cloud computing enables the connection of different devices, collecting a huge amount of data, which results in big data warehousing (Lu, 2017, Hu, 2018). Big Data are very different from traditional data due to the large growth of the data set. Conceptually, big data is defined in terms of a large data set consisting of six main characteristics, namely: volume, variety, speed, veracity, value and complexity. Moreover, it consists of the stratification of data from systems and objects, such as sensor readings (He & Wang, 2018; Bongomin et al., 2020). Together with data mining and intelligent machines, it is considered one of the most important drivers of the 4IR and one of the key competitive advantage sources for the industry (Tao et al., 2018; Ahuett-Garza & Kurfess, 2018).

One of the important dimensions in the industry 4.0 discussion (Agwu et al., 2018; Mendonça et al., 2018) refers to Artificial Intelligence (AI) as the coordination of knowledge based on coded thought programs designed on machines to imitate human or animal thinking capacity. At present, AI has been applied in complex operations such as drilling fluid, underground extraction and maintenance, as well as manufacturing monitoring in sophisticated systems. Emerging applications of AI include automotive and stand-alone markets, facial recognition and autonomy of drugs and healthcare equipment, for example, applied to cardiovascular medicine.

Another technology in this context is Augmented Reality (AR) used to ensure a consistent overlap of objects in which they must estimate in real time the position and orientation of the virtual object by cameras with previously defined standards (Chatzopoulos et al., 2017) that can be applied in different areas such as medicine, education, architecture, marketing, maintenance and assembly process (Billinghurst et al., 2015, Chatzopoulos et al., 2017). In addition, 3D Printing (additive manufacturing), unlike subtractive manufacturing, is the technology that builds physical objects based on 3D CAD by consecutive addition of liquid materials, in sheets or powder. The materials used by 3D printers are plastics or metallic materials such as steel, stainless steel, titanium, gold and silver. Universally, 3D printing has been applied to produce almost everything from buildings to human organs (such as the kidney and heart) and tissues (bones, muscles and teeth) and although its application for printing body parts (3D bioprinting) is premature, a growth with industry 4.0 is predicted (Xu et al., 2018; Chen et al., 2018; Frank et al., 2019; Bongomin et al., 2020).

Additionally, the Cybernetic and Physical Systems (CPS) are increasingly interconnected. The physical and software components are deeply interconnected, each operating at different spatial and temporal scales and interacting with each other in a way that changes with the context. Smart CPS will drive innovations in industries such as manufacturing, energy, transportation, agriculture, automation and health. Other enabling technologies such as smart sensors, block-chain, robotisation, smart logistics, drones, simulation and twin digital, smart factory are integrated with CPS (Oliveira & Álvares 2016; UNIDO, 2017; Lezzi, 2018; Xu, 2018; Cruz Machado & Alcácer, 2019).

The fact that industry 4.0 ensures the integration and interoperability of technologies, where technological standardisation has become essential, must be added to the discussion (Lee et al., 2015; Babiceanu & Seker, 2016; Dalenogare et al., 2018). Previous research has proposed maturity models for the implementation of these technologies (Schuh et al., 2017; Lee et al., 2015; Lu & Weng, 2018; Mittal et al., 2018), while other studies have figured out the impact of these technologies on industrial performance (Dalenogare et al., 2018). In this regard, there is a renewed interest from industry 4.0 to drive digitalisation and therefore process integration both horizontally (i.e. between functional areas) and vertically (i.e. along the entire value chain from product development and purchasing to manufacturing, distribution and customer service). Thus, digital technologies (Ciortea, Mayer, & Michahelles, 2018; Motyl et al., 2017) must ensure interoperability between the various information technologies (IT) and systems to minimise implementation costs.

Moreover, the literature often suggests that industry 4.0 will expand the opportunities for many regions, create new regional leaders combined with the potential to shift the geography of knowledge production in various directions (Strange and Zucchella 2017; Ciffolilli and Muscio 2018). This is, in any case, one of the aspects to be analysed in the present study.

2.2 Patents as a proxy for digital transformation in the industry 4.0

A vast literature (Acs et al., 2002; Barbieri, 2015, Chang, Lin, & Hu, 2015; Chen & Guan, 2016; Chen, Fang, & Hsu, 2016; Bakker, 2017; Moehrle & Caferoglu, 2019) has highlighted the design of patent data as intangible, legally protected assets essential for companies to sustain a competitive advantage in the marketplace as they can effectively indicate innovation performance, including product, process and technology innovation. In fact, patents are recognized for holding more than 90% of the existing technical information in the world, and 80% of the existing technical information in patent documents are not published in any other form of document (Greif, 1987; Bregonje, 2005).

The condition of patentability is the first and most important issue to be considered in the process of granting patents to the extent that if an invention does not meet the requirements for patentability, it can not have for granted the benefits of its application. Taking into account the key importance of this condition, several patent offices and international patent law regimes have demanding legal requirements that must be met for an application in order to satisfy the prerequisites of patentability in advance. Moreover, because of this, the process is usually long and uncertain, which has consequences for the applicant, for example at the level of costs.

The literature is plenty of studies relating patents as results closer to the profiles of industry technologies, assuming that patents protect technological revolutions and that these reflect the specialisation of a country in this domain. According to this view, still dominant for emerging and developing countries, through the analysis of patents, it is possible to obtain an initial understanding and an overview of technology in industry following the lines of technological cooperation. On this basis, the analysis of patents is a fundamental mechanism to study the stage of development of technology (Corrocher et al., 2014; Abbas et al., 2014). Previous studies have also evaluated the performance results of the industry based on information related to patents (Okamuro & Nishimura, 2013; Ponomariov, 2013; Zhang et al., 2014; MingJi & Ping, 2014). Indeed for the economics mainstream, the condition of patentability can serve as one of the main indicators for assessing the degree of technological development of a country.

Presently, it is recognised the differential of various possible instruments as methods of investigation on the degree of digital transformation in a given country. Lee et al. (2017) investigated the effects of the convergence of science and technology and demonstrated an increase in the proportion of scientific knowledge and a positive relationship with impact on innovation by showing consistency in measuring the R&D activity of companies through various indexes based on patents. The additional analysis shows the robustness of the patent indexes in the treatment of the scientific aspect of the patent data, using both the proportions and the average values. In contrast, Wollschlaeger et al. (2017) introduced the application of IoT in industry analysing the technological trends and the impact that they may have on patenting.

It should be noted that Curran & Leker (2011) previously proposed three methods for identifying industrial convergence: the first, using scientific papers to reflect the trend towards integration of scientific or technical knowledge bases; the second, using patent analysis to reflect the degree of involvement of companies in different industries at different times; and the third, using cooperation projects to evaluate industrial integration.

Dechezlepretre et al. (2017) estimated that only twenty-five global ICT companies, located in Asia, US and Europe, are responsible for about half of all industry 4.0 patent applications, especially in basic technologies. Ciffolilli and Muscio (2018) examined the geography of participation in industry 4.0 reflected in patents, publications or productivity, showing the disparities within the EU, highly concentrated in Germany (Baden-Württemberg and Bavaria, south; and Rhine-Westphalia, North), France (Rhône-Alpes and Île-de-France), and the Italian region of Lombardy, while eastern and southern Europe participate only to a very limited and marginal extent in the process.

One of the most relevant aspects in the discussion of patents as a proxy for digital transformation in industry 4.0 refers to the fact that competitiveness is strictly linked to technological innovations, which is reflected in the comparative technological advantages of a country. As underlined before, granted patents often protect technological innovations allowing inventors to use their intellectual property rights and offset research and development costs (Menell & Scotchmer, 2005; OECD, 2009), which, if well managed create conditions to the continuation of the innovation process. Moreover, at the macro-level, these benefits have a positive effect in the balance of payments.

Considering the actual literature, it should be recognised that technological change is difficult to capture by a single indicator (Johnstone, 2010; Abrams, 2013; Abbas, Zhang, & Khan, 2014; Kowalski & Michorowska, 2014; Ferraro, Dutt, & Kerikmäe, 2017). In spite of this, patent statistics have been widely used to assess the competitive position in various technological domains both at company and country level (Archibugi & Pianta, 1996; Archambault, 2002; Kim & Lee, 2015; Dziallas & Blindt, 2019). In fact, different empirical findings evidenced in Weresa's study (2019) suggest a strong positive link between techniques and indicators in the analysis of patent based technological changes, such as propensity for patenting (Pantano, Priporas, & Stylos, 2018), model-based approach (Choi & Song, 2018), patent citation (Ernst & Omland, 2011); Van Raan, 2017; Tijssen & Winnink, 2018), patent based indices through technological advantages, patent h-index, patent asset index, impact index (Ernst & Omland, 2011; Wisla & Sierotowicz, 2016; Montresor & Quatraro, 2017; Makhoba & Pouris, 2019).

Aristodemou and Tietze (2018) consider that the clear identification of technological trends is crucial for decision makers in R&D management. In this direction, different authors (Sunghae et al., 2015; Suominen et al., 2017) proposed a methodology to make the technological impact more transparent, based on a quantitative analysis of the R&D trends and of an organization's competitors, comparing them with the technological impact and the trends of the organization's own R&D through technologies. Therefore, these studies are able to identify technological trends and predict the evolution through a holistic approach in which published articles, in particular articles and patents on developing technologies, are analysed in order to identify scientific and technological trends, discussing, as an example, the benefits and limitations of approaches to learning machines in the analysis of patents at the industrial level.

As European data show, patent analysis allows a more specific view of the development of digital technologies in different countries. There is a wide range of patent indicators that can be used to assess technological competitiveness (Mehrotra, Sabitha, Nagpal, & Mattas, 2016). Patent indicators are used to measure the technological evolution and specialisation of countries in different digital technologies but can also be considered from an economic and legal point of view (Lee, 2017).

It must be added that, in the discussion, the literature has investigated many aspects of the unitary patent (PU) and the unified patent court system, considered as elements of strategic change for the activity of patent claims in Europe (Love et al., 2017). But beyond the effects of the increase in the patenting indicator, it should be noted that a rising number of patent processes can significantly improve in light of market liquidity, boosting incentives for R&D investment, and helping small and medium-sized enterprises (SME) to monetize their value (Clarke, 2018). However, most of the available data on patent intermediaries are based on the US, while little is known about Europe. On the one hand, patent claims can promote innovation by providing innovators with effective options to monetize patents and increase their liquidity in the markets. On another hand, additional litigation can impose a cost on the innovation ecosystem and obstruct innovative initiatives. In the first meaning, the claim can be understood as a way to simplify access to patents and make it easier to obtain licenses, as mentioned, relevant aspects that legislators do not underestimate.

The fundamental assumption of the studies described above is that there is a change in the conditions under which intellectual property and patents, in particular, are gaining importance as a strategic tool in the context of industry 4.0 technologies due to the lack of a set of fixed standards for industry 4.0, patent portfolios are referred to as a factor of competitiveness. In 2016, about 30% of patent applications submitted to EPO were directly related to ICT domains. In addition, the European Parliament Office (2018) estimates that in the period 2015-2017, up to 50% of applications in major non-ICT fields, such as medical or even automotive or aerospace technologies were qualified as "digital patents".

Another important issue in the patent debate as a proxy for digital transformation in the industry 4.0 can be supported by Laursen and Salter (2014) and Stefan and Bengtsson (2017),insofar they argue for more emphatic intellectual property regimes to be associated with open innovation. This position allows conditioning the mechanisms and strategies of patenting that are correlated with participation in collaborative R&D. In fact, empirical studies, such as Bagherzadeh et al. (2019), relate the orientation of patenting not only as relevant to open innovation, but also to organizational innovation performance.

3. Methodology

This section describes the methodology used in the research. Thus, regarding the objectives, using concepts from which the analysis of patents is carried out, the research is characterised as a descriptive study with the purpose of observing, registering and analysing the phenomena or technical systems, without deepening the merit and reasons for the contents (Sampieri, Collado & Lucio, 2006). As for its nature, according to Bryman (2011), the research is quantitative in function of the metrics of numbers, classified and analysed, based on statistical techniques. As such, this an applied study, being designed from bibliometric research and the use of statistical software R and the access to the databases of the institutes of legal protection in Brazil and Portugal, and the database Orbit Intelligence, produced by Questel Commercial database with information and access to patents and applications of Q-Pat (European and US patents) and FILE PLUSPAT (from 107 patent jurisdictions). According to Pires et al. (2020), in 2018, the system already counted for 58.185 million families of patents and more than 107 million individual patent documents, resulting from the search for different patent classifications (International Patent Classification - IPC, Cooperative Patent Classification - CPC, European Classification System - ECLA, Japanese FI/F-tClassification -JP (FI), United States Patent Classification - USPC).

The selection of keywords in the patent study was derived from two methods: frequency of articles' terms by means of a bibliometric study in the Web of Science database and weight of Boolean descriptors that emerged from a first search with the term "industry 4.0" in Orbit. The frequency method consists in selecting the keywords that appear most frequently in the literature and which would be one of the most commonly used methods. Thus, this study used the combination of the two methods to select the keywords.

In order to build a list of enabling technologies of industry 4.0, a total of 229 articles were identified from 2008 to 2020 through the bibliometric search, including topics, titles, abstracts and keywords in the Web of Science database. The related keywords were filtered based on the importance of Boolean descriptors "Digital Transformation AND Industr* 4. 0" OR "cyber-physical-system*" OR "internet of things" OR "IoT" OR "cloud computing" OR "big data" OR "artificial intelligence" OR "additive manufacturing" OR "virtual reality" OR "analytics" OR "machine learning" OR "robotic" which emerged from a first search with the term "digital transformation and industry" and, sequentially through the use of statistical software R were identified 6 (six) technologies with greater representativeness of the 18 (eighteen) enabling technologies cited in different studies (internet of things; big data; 3D printing (additive manufacturing); cloud computing; autonomous robots; augmented virtual reality; IIoT and cyber-physical systems; block-chain; artificial intelligence; intelligent sensors; smart logistics; drones; simulation, digital twin; smart factory; nanotechnology; biotechnology). The related terms were organised in research chains.

For the empirical analysis, data from patent deposits in Brazil and Portugal in general were considered to answer the first research question and the data from the enabling technologies of industry 4.0 are limited to the period 2008-2018 in both countries to answer the subsequent questions. Thus, the analysis of patents was adopted to provide a global view of the dynamics of innovation that characterises the technologies of industry 4.0, as well as seeking to identify symmetries and distinctions between the two countries. In this sense, a recent work of the EPO (2017) was explored, which provides a new classification of 4IR patents (EPO, 2017). This classification defines a list of technological patents; each one related to the CPC codes, which identify the 4IR technologies. Considering the EPO (2017), a second step has been carried out aimed at minimising type I errors (i.e. false positives) through a combination of full text patent searching for different keywords.

The search strategy used to access data on patents related to the six associated technologies was organised with Boolean OR connectors in the Orbit search. For the data analysis, figures were plotted in order to map the main inventors, the countries where the patents were filed, the legal status of the technologies and the technological application. The analytical process included a search of the patent holder, the International

Patent Classification (IPC), family of patents and the analysis of citations, as well as visualisation of the patent script. Thus, a research of specific cases in both countries was conducted to identify the relationship between enabling technologies of industry 4.0. A patent map method was followed to summarise the technologies, countries and applications related to technology to develop the matrix of their applications. Finally, through a patent matrix, it was analysed the development of the patent by the selected countries. As mentioned before, the patents were found and collected from Orbit's database focused on intelligent tool applications. To be included in the analysis, the enabling technologies of industry 4.0 had to meet two criteria. Firstly, they have been identified in Section 2 as key technologies associated with 4IR. Secondly, they should directly or indirectly adhere to the International Patent Classification (IPC). For this basis, two search criteria were applied in the fields "Title" and "Summary". The IPC uses a numerical code to classify patents in specific technical domains. The number of patent families and the citations of a patent were used as a measure of the meaning of a patent.

In summary, of the total of 18 (eighteen) enabling technologies related to industry 4.0 were arranged in patent search chains, 6 (six) technologies selected by the frequency resulting from the bibliometric research and by a first search with the terms of the "disruptive technologies". In the Orbit research chain, the first group of keywords comprised the intersection of cyber-physical systems, IIoT, internet of things. The second group of keywords was additive manufacturing and artificial intelligence. The third group of keywords was robotics and artificial intelligence applied to industry. In particular, ("Cyber-Physical System*" OR "Internet of Things*"] ["Artificial Intelligence" OR " Addictive Manufacturing] ["Synthetic Biology" OR " Robotic *"]). Filters were used for World, China, EPO, Brazil and Portugal. In addition, as explained above, the period for patent search was limited to 2008-2018, considering that the year 2019 might not capture the deposits of all jurisdictions due to the secrecy time of these documents, which is 18 months. The period clearly has a certain homogeneity, a period of rapid changes on a global scale where the progressive implementation of new technologies, namely digitalisation, played a major role.

Mainly based on the selected enabling technologies of industry 4.0, the study follows with an analysis through the patent map approach, which presents the development of patents by the visualisation of various graphs and tables. Patent maps can effectively convey patent information and its potential knowledge in graphic terms can be used in order to develop strategies.

4. Results and Discussion

In this section, the patent applications of the two countries investigated in this research are presented and characterised. The results of the comparative analysis are then discussed, taking into consideration the IPC code of each section of the classification of enabling technologies in industry 4.0 in the period 2008-2018.

Q1: How do the total number of patents filed in Brazil and Portugal are evaluated in the light of changes in Science and Technology policies and what are the main differences between the two countries?

To answer this research question, at first, the patent data of the intellectual property institutes of both countries were collected. In Brazil, the patent deposit process is conducted at the National Institute of Industrial Property (INPI-Brazil) except in cases of direct requests to international institutions. In Portugal, the deposit can be made by the national system, through the deposit of a patent application at the National Institute of Industrial Property (INPI-Portugal), as well as the deposit can be made before the European Patent Office (EPO) to the extent that the European system due to the European Patent Agreement also grants patents on a European scale. Finally, the patent application can be channelled by the international system via PCT (Patent Cooperation Treaty), which allows requesting patent protection for each of the contracting countries, through a single application designated international application, in addition to the North American Patent or "USPTO patent". Table 1 presents the distribution of the number of deposits and concessions of Portugal by national route (patents, utility models, provisional patent applications, PCT entries in national phase and complementary protection certificates) and European and international routes (Origin PT and Office Receiver) and Brazil by national route and via PCT (patents, utility models and certificates of addition).

In 2019, the patent applications (965) deposited in Portugal to INPI via national route were mostly of Portuguese origin, being 78.4% of the deposits (752) carried out by local residents. In Brazil, the patent applications submitted to INPI are mostly of non-Brazilian origin, even with an increase in recent years of local residents. As an example, in 2013, there were 4,955 patent applications from residents, representing 14.55% of the 34,050 applications for the year, and in 2019, 8,313 patent applications from residents in Brazil, representing 19.12% of a total 28,667. In 2019, according to INPI-Brazil (2020), among the 10 countries that filed the most applications for invention patents were the United States (30%), Brazil (22%), Germany (7%), Japan (6%), China (5%), France and Switzerland (4%, respectively), the Netherlands (3%), the United Kingdom and Italy (2% respectively). In 2019, among the 10 countries that have filed the most applications for invention patents, all have more than 79% of their applications via PCT, with the exception of Brazil, with only 2.3% of these applications via PCT.

Considering the data in Table 1, it can be seen that there are significant differences between Portugal and Brazil. On average, the number of patents per million inhabitants in Brazil reaches 19.8 and in Portugal 48.5 which puts relatively this country in a more comfortable position in most global innovation indicators. Another difference refers to the fact that in Portugal, applicants are mostly Portuguese residents, while in Brazil there is a prevalent number of deposits in INPI-Brazil from other countries via PCT, which are multinational subsidiaries, although there has been a drop after 2014 reducing the number of Invention Requests per million habitants whilst Portugal continues with a growing trend, especially in the year 2015. In the period from 2000 to 2012, INPI-Brazil received almost 320,000 patent applications. According to INPI (2015), in relation to the origin of the applicants in the total deposits received by the INPI-Brazil, the participation of resident requests fell from 31% to 23% and the participation of non-residents grew from 68% to 77%, a period that consolidated the increase in the participation of multinational requests in the country. In 2000, of the 20,854 requests deposited, 14,181 were deposits from non-residents and 6,449 from Brazilian residents. In 2012, of the 33,569 deposits, 25,724 were from non-residents and 7,808 deposits from Brazilian residents. Moreover, taking into account the beginning of the crisis in 2014 when leading companies in patent deposits in Brazil, such as Whirlpool and Petrobras, showed a significant drop, while also Vale, after the peak of 32 patents in 2015, fell in 2016/17, being the three most representative of the nationals that pulled the number of deposits of residents in Brazil.

In Portugal, according to INPI (2020), considering that the majority of the requests to INPI are from national residents, of the National Inventions Requests of Portuguese origin, in 2019, 40.6% were presented by Corporate Persons (392), 34.9% by Independent Inventors (337), 18.4% by Higher Education Institutions (178) and 6.0% by Research Institutions (58). In this context, the data highlight that in Portugal, of the National Inventions Requests of Portuguese origin the largest number is originated from legal persons (40.6%), different from Brazil where the individuals of the residents present the highest percentage with 42%, although the difference is not significant. There is an increase in the filing of Portuguese patents by academic entities involved in patenting activities, where the University of Minho emerged as the entity with the greatest individual protagonist in the national way. In 2019, among the 10 largest applicants, 7 were higher education institutions. In turn, applications through European and international routes associated with the EPO and USPTO, in good measure, is essentially creditable to the business sector, whose holders reside in other countries, mainly subsidiaries of multinationals or technology-based companies of Portuguese origin operating on an international scale. Also, in Portugal, the number of Invention Requests per million inhabitants in the year 2019 was 74, and in 2008 this figure was 45. Finally, the data in Table 1 also reveal that most patent applications originating in Portugal have the country itself as their first place of application.

Despite their importance, Brazilian companies no longer lead the filing of patents in the country. Counting with 9 of the 15 leading organizations in 2000-2005, only 3 are on the 2013 to 2017 list, and only 1 in 2017. On the other hand, the universities, from 3 included in the 2000-2005 list, became 11 between 2013 and 2017, and 16 of the 172 leading organizations in the last year, even with the reduction of investments S&T in public spending. This fact translates an important change in Brazil's patent structure. Another difference shows us that in 2019 only 8.313 of the 28.318 deposits were from residents of Brazil, with 5,464 being of the type Patent of Invention (IP) deposits from residents, namely: individuals (2,274 deposits or 42%); educational and research institutions and government (1,525 or 28%); medium and large companies (1,053 or 19%) and MEI, microenterprise and EPP (520 or 10%), associations and societies of non-economic intent (91 or 2%) and cooperatives (1 or 0.02%).

Table 1- Analysis of Patents in Brazil and Portugal

Anos	Brazil Patents (INPI Deposits)		Patents Portugal (INPI Deposits) by the National Way		Patents Portugal by the European Pathway (EPO)		Patents Portugal by Via Internacional	
	Requests from residents and non-residents in Brazil	Grants to residents and non-residents in Brazil	Requests from residents and non-residents in Portugal	Awards to residents and non-residents in Portugal	Requests from residents and non-residents in Portugal	Awards to residents and non-residents in Portugal	Requests from residents and non-residents in Portugal	Awards to residents and non-residents in Portugal
2008	26.640	2.830	514	236	n.d	25	58	n.d
2009	25.890	3.160	723	213	n.d	24	201	n.d
2010	28.100	3.620	654	201	148	28	187	n.d
2011	31.880	3.810	772	219	136	26	144	n.d
2012	33.569	3.140	803	235	149	30	156	n.d
2013	34.050	3.325	867	228	215	26	216	n.d
2014	33.182	3.122	929	197	129	22	240	n.d
2015	33.043	3.895	1.178	186	152	46	211	n.d
2016	31.020	4.771	939	150	163	59	232	n.d
2017	28.667	6.250	846	159	155	68	180	n.d
2018	27.551	11.090	842	179	233	90	324	n.d
2019	28.318	13.750	965	202	290	110	254	n.d
Total	**361.910**	**62.763**	**10.032**	**2.405**	**1.770**	**554**	**2.403**	

Source: Authors' own elaboration based on INPI data, Portugal and Brazil (2020)

Q2: Which are the main enabling technologies of the industry 4.0 and what is the participation of Brazil and Portugal in the global patent process?

To answer the second question, the Questel-Orbit® was used as a keyword search field for patent data mining. The unstructured text data of the patents of the enabling technologies of the industry 4.0 were analysed using the search of six key technologies related to the field or scope of the industry. The main results were: "Additive Manufacturing "; "Artificial Intelligence"; "Internet of Things"; “Synthetic Biology”; "Cyber-Physical Systems (CPS) "; "Robotic".

The search for patents in Orbit resulted in the total number of patents in Table 2, respectively, thus obtaining a total of patents filed (69,452) in the world in 6 enabling technologies added plus 2 technologies applied to industry (IIoT and IA). After analysis, a total of 82 patents or 0.12% of valid patents of these technologies were confirmed for analysis in Portugal and 924 or 1.33% in Brazil of the total deposits of the technologies in the world in the period 2008 to 2018. In numerical terms, by the number of patents filed of all technologies at INPI-Brazil in 2008 to 2018, that is 333,592, these 8 technologies with 924 deposits represent only 0.28% of the total. In Portugal, by the number of patents filed with INPI-Portugal in the same period, 9,067, these 8 technologies with 82 deposits represent 0.90% of the total. If we consider the deposits by European and international routes, this percentage is a little below with 0.65%, but still above the percentage of Brazil.

From the perspective of the last decades, Brazil and Portugal, as was China, are late developing countries in comparison with the United States, Japan and Germany. The United States has a strong technological base in robotics and additive manufacturing, recognised for the integration of production and research. Thus, the number of patents correlates with the number of patents of high technological applications, innovation and sophisticated industrialisation. Brazil and Portugal are not recognised in any of the enabling technologies, but when compared with patenting in a global system and in selected countries or regions (United States, China, Japan, South Korea, European Patent Office, among others), Portugal, despite its structural limitations has increased the incidence of deposits, including through the European Patent Office.

Table 2- Search Terms and Deposits of the main Enabling Technologies (2008-2018)

TERMS OF TOTAL SEARCH	Total	China	Portugal	Brazil	EPO
Additive 1W manufactur*	7331	3533	17	196	2477
Artificial w intelligence	10160	6489	4	77	441
(Artificial w intelligence) AND Industry	149	113	0	1	3
IIoT	228	150	0	2	18
Internet of things OR IoT	37580	30409	14	177	1474
Cyber w physic*	234	89	0	5	33
Synthetic w biology*	52	0	36	4	17
Robotic*	13718	5965	47	462	2860
Total	69.452	46.748	118	924	7.323

Source: Authors' own elaboration from the Questel-Orbit (2020) search

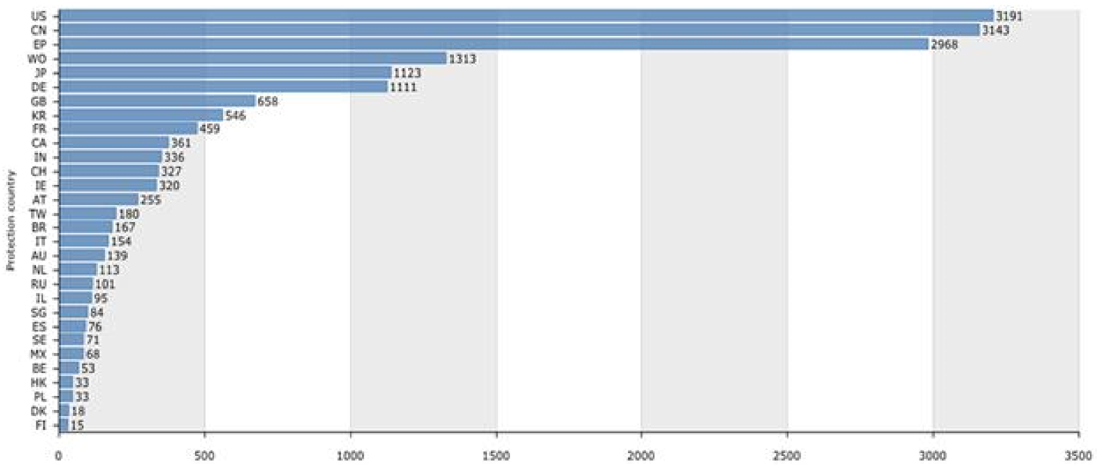
Q3: Which technological domains, countries and actors in the world stand out the most in 2008-2018, as well as the endogenous intensity in the search for patents, considering the largest depositors, especially China?

In an effort to answer this question, and considering the methodology of this work based on the analysis of patents, the enabling technologies, technological domains, countries and actors will be presented, aiming to identify the position of Brazil and Portugal in the global framework.

In a first search for the Additive Manufacturing technology, which emphasises the importance of R&D activities in the associated fields during the period under analysis, results were obtained in terms of keywords. The data obtained from Questel-Orbit® on patents in the sector were grouped into IPC codes. The legal situation of patents filed in the world in additive manufacturing technology pointed out that more than 49% of patents filed in all technological domains were considered as pending. It was found that the number of deposits in the world was 7,331 and the number of pending patent applications was 3,596, comparatively higher than the patents granted 2,928. Of this total number of applications, 3,533 were filed by China, 2,477 by the EPO, 17 by Portugal and 196 by Brazil.

The 30 priority countries that have filed additive manufacturing patents under the three thematic area codes are represented in Figure 1. China, USA and EPO were the main depositing countries. There is not much difference in the number of deposits between the first two places, with the United States appearing with some more deposits than China.

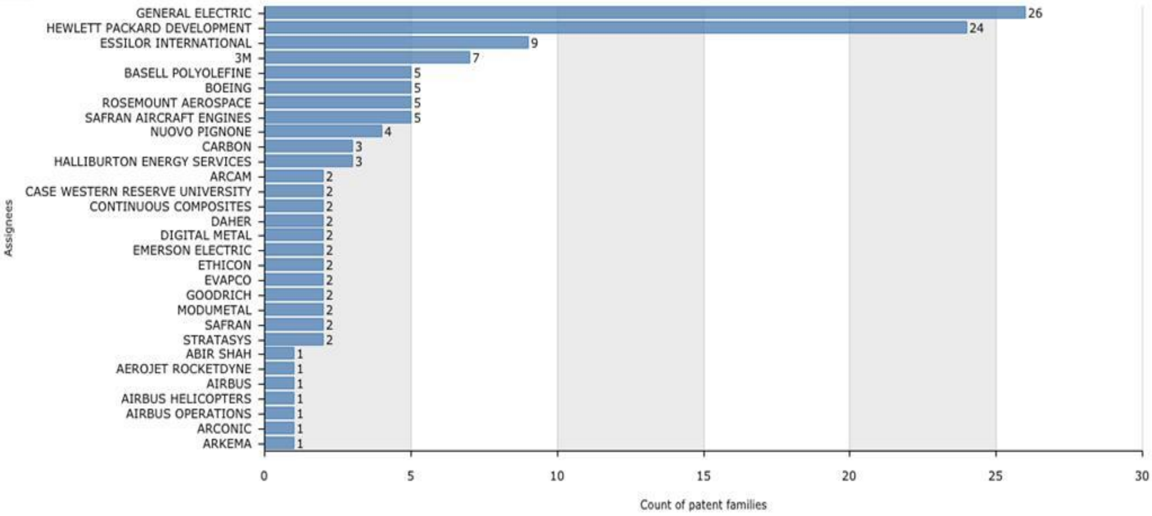
Figure 1 - Top 30 Priority Countries - Additive Manufacturing



Source: Orbit Questel (2020)

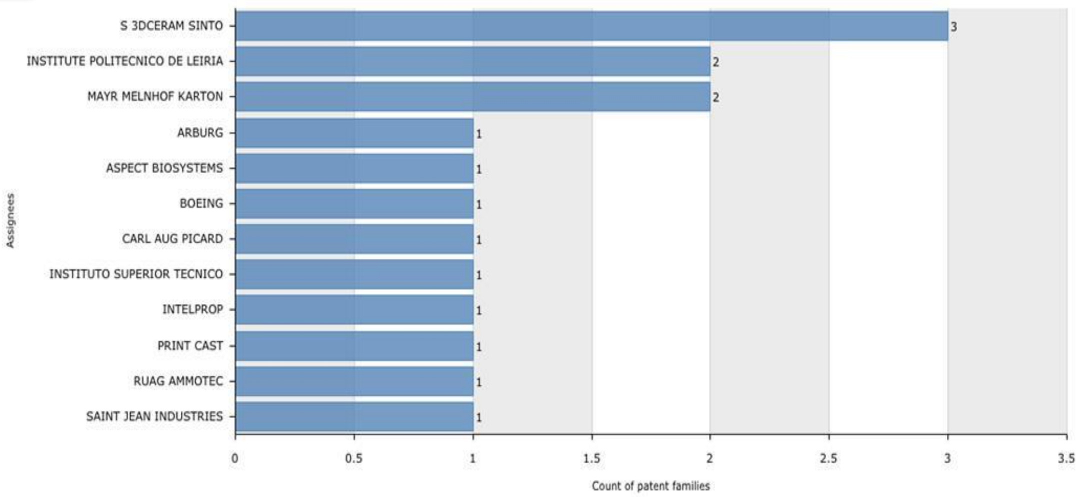
The 30 largest patent applicants in Brazil based on the IPC code are shown in Figure 2. It is confirmed that the patent applicants in the technological domains of the additive manufacturing in this country have their largest participation through subsidiaries of multinationals such as General Electric (GE) and Hewlett-Packard Company (HP). This emphasises the growth of R&D and patent activities by multinationals in Brazil, mainly because they already occupy the first position in the global ranking, since GE has 5.5% of global deposits in 3D printing and HP about 3%. It can be observed the predominance of American origin depositors, which total the sum of the first three depositors or 367 deposits. In Portugal, the two largest depositors are Portuguese residents, described in Figure 3. It is noteworthy that some depositors choose not to make their priority requests in the countries where they reside, motivated, among several factors, by the finding that other countries present more attractive markets, specifically for Portugal, considering the possibility of the deposit to be made by the EPO which has the third position in the ranking of deposits.

Figure 2 - Depositors in Brazil - Additive Manufacturing



Source: Orbit Questel (2020)

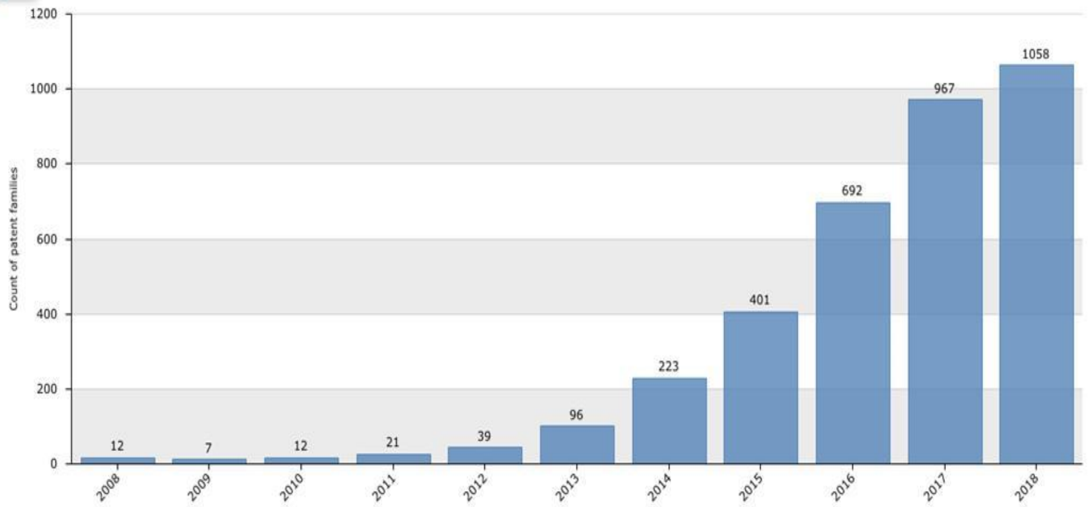
Figure 3 - Depositors in Portugal - Additive Manufacturing.



Source: Orbit Questel (2020)

The Figure 4 registers the growing interest in patent protection through the increase of deposits by China from 2014, which also occurs in Brazil, respecting the quantitative difference of deposits. It is important to emphasise the expressive growth in the period 2014 to 2018, being, therefore, the focus of patent deposits allied to the digital transformation of these countries. It is important to mention that even if China totals around 3,533 deposits or 48% of total deposits recognised in the period, it has only 20 applications in this category, representing no more than 2.5% of total deposits considered technologically relevant, internationally, within the referred category of additive manufacturing. The largest depositor, the American company GE has 222 deposits, or 6.2% of total deposits. The vast majority of Chinese deposits were made only in the country itself, either by the intellectual property policy that encourages local patenting or by the non-existence of globally dominant technologies in the area.

Figure 4 - Patent families until the 1st year of application in China - Additive Manufacturing

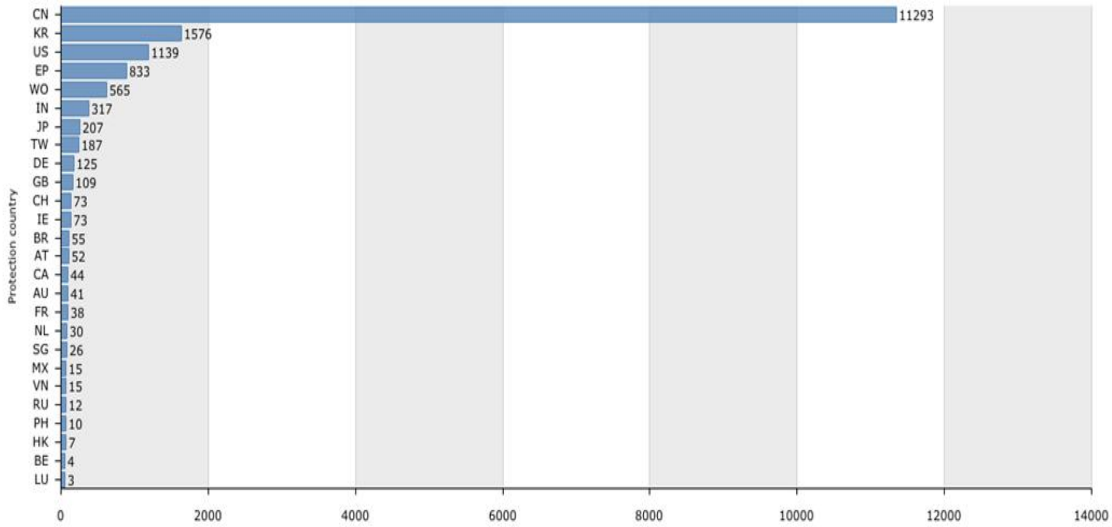


Source: Orbit Questel (2020)

The data obtained from Questel-Orbit on patents for Internet of Things (IoT) technology were grouped into IPC codes applied to the industry so that the analysis already shows the number of deposits in industry 4.0, called IIoT. Of a total of 37,580 deposits, 30,409 were required by China, 1,474 by the EPO, 14 by Portugal and 177 by Brazil. In turn, the number of patent applications filed in the world of IIoT was 228, being pending 138 a comparatively higher number than the patents granted 54. Out of a total of 228 deposits applied to IIoT, 150 were deposits required by China, no deposit by Portugal and 2 by Brazil from 2008 to 2018.

The 30 priority countries that filed patents under the three thematic area codes are described in Figure 5. China, South Korea and USA were the main depositing countries. As for the leaders of high-speed Internet-driven digitalisation, previous studies describe the US leadership role challenged by Asian countries, including China, although the US still holds the second position of leadership. Among them, through a patent analysis, Ardito et al. (2018) noted that Asian countries have begun to catch up with the United States, while Mehmood et al., (2016) noted that China is already leading IoT-driven digitalisation in a survey with an analysis of scientific papers, reinforcing China's transition from accelerated catching up to the innovation economy.

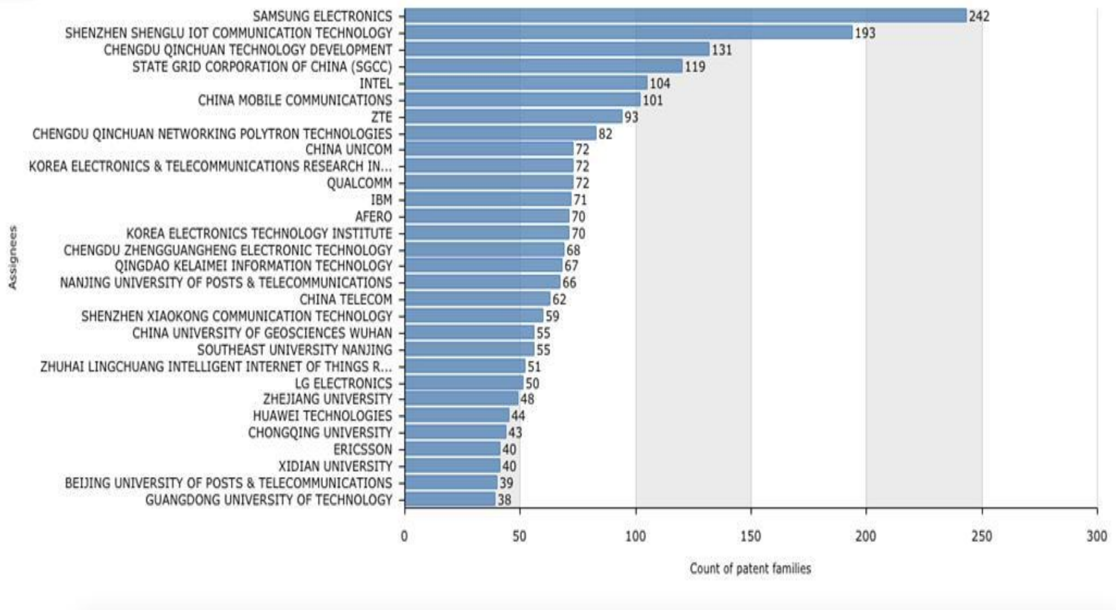
Figure 5 - Top 30 Priority Countries - Internet of Things



Source: Orbit Questel (2020)

The diversity of the areas of technological concentration concerning IoT technology allows inference to be made about new purposes, as well as the growing trend of patent protection in the sector worldwide. The total number of deposits required by China that develop IoT technology increases in a large-scale production environment that are implementations or revisions of applications, being in the analysed period (2008-2018) the country with the highest number of deposits, that is, 80.9%, and South Korea the second in the ranking of countries with the highest number of deposits. So, in IoT technology, Asian countries overtook leading countries like the United States, taking advantage of the rapid changes in the cycle of innovation by digitalisation, which has led to a predominant perception that these countries have made rapid use of the cycle of digitalisation innovation conducted by IoT. The United States holds a superior position in the international co-invention network. As expected, the number of deposits has increased in the last seven years and among the top 30 depositors are several Chinese companies, according to Figure 6.

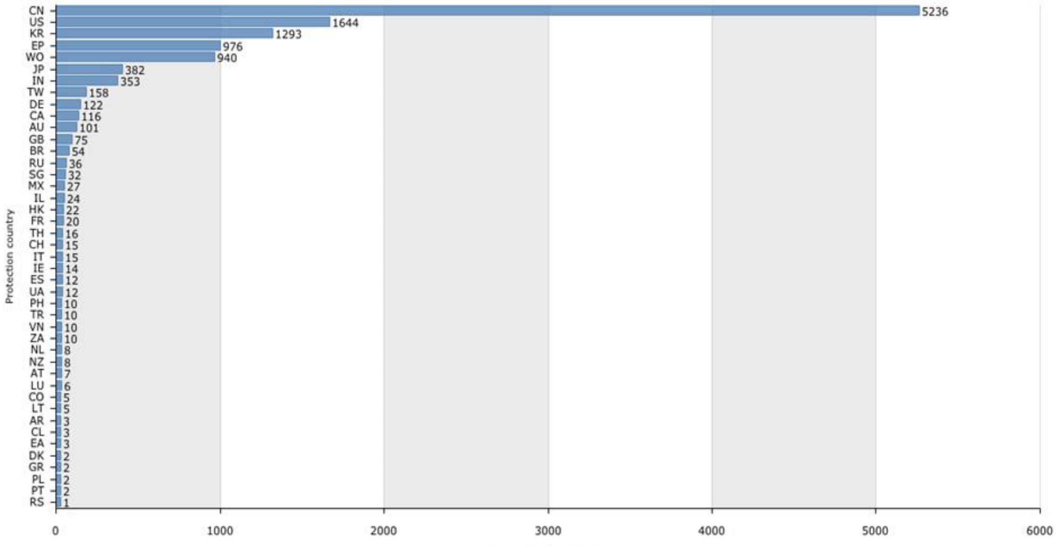
Figure 6 - Top 30 Top Depositors in the World - Internet of Things



Source: Orbit Questel (2020)

The data obtained from Questel-Orbit on patents for Artificial Intelligence technology were grouped into IPC codes. It was found that the number of deposits was 10,160 in the world, and the number of pending patent applications 5,657 was comparatively higher than the patents granted 2,736. Thus, the legal situation of patents filed in this technological field was investigated and it was found that 227 were revoked and 1.412 expired in all technological fields. Of a total of 10,160 deposits, 5.236 were requested by China, 441 by the EPO, 3 by Portugal and 54 by Brazil. The 30 priority countries that filed artificial intelligence patents under the three thematic area codes are presented in Figure 7, with China, the US, and South Korea in the top three places.

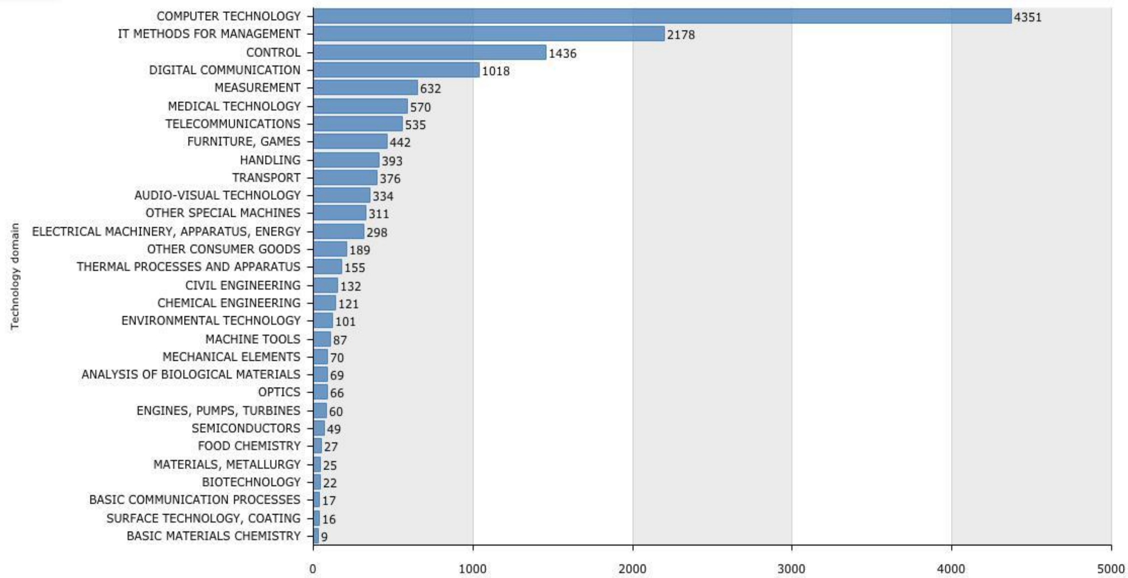
Figure 7 - Top 30 Priority Countries - Artificial Intelligence



Source: Orbit Questel (2020)

The companies also represent the largest patent applicants related to AI technology. This standard applies to most techniques, applications and fields of AI. It is also worth mentioning that the AI companies, among the 30 main companies that register patents related to AI, 60% are based in Japan, 18% in the USA and 10% in China. However, the patent deposits in this technology, despite the leading position of companies in the area, are the Chinese universities and public research entities that play a leading role in areas of automatic learning, deep learning and neuroscience. Chinese universities represent 80% of universities in terms of AI-related patenting, as well as 50% of important AI-related scientific publications.

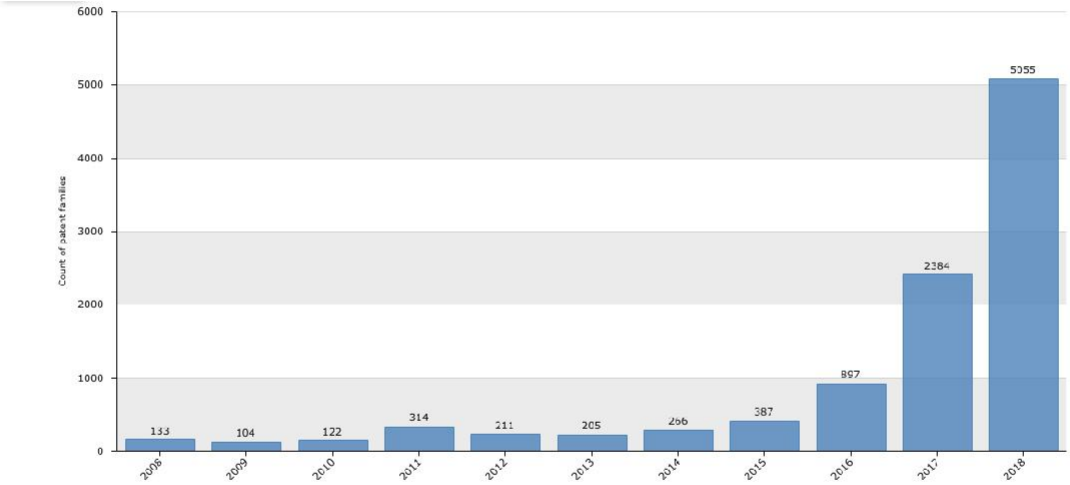
Figure 8 - Top 30 Technologies dominating the world - Artificial Intelligence



Source: Orbit Questel (2020)

The years of deposits based on the IPC codes are shown in Figure 9. A greater increase from 2016 to 2018 in terms of technological domains in the area of artificial intelligence is noticeable. This emphasises the growth of industry 4.0 from 2012 onwards, which was subsequently reflected in the increase of intellectual property in the enabling technologies of industry 4.0. All over the world patent data have been increasing for over a decade, with the exception of 2009 due to the global financial crisis, and in Brazil the data are up from 2008 to 2013, however, since 2014 deposit data have been falling. The condition of fall can be explained by the turn in the economic environment (in particular, resulting from the end of the commodities boom that came since the turn to new century), but also by the level of patent stocks awaiting analysis. In February 2020, according to INPI- Brazil (2020) there were 143,353 patent applications pending from a decision, with an examination request. Of the total, 132,221 were awaiting the technical examination and 11,132 had already received a technical examination decision but were awaiting the final decision.

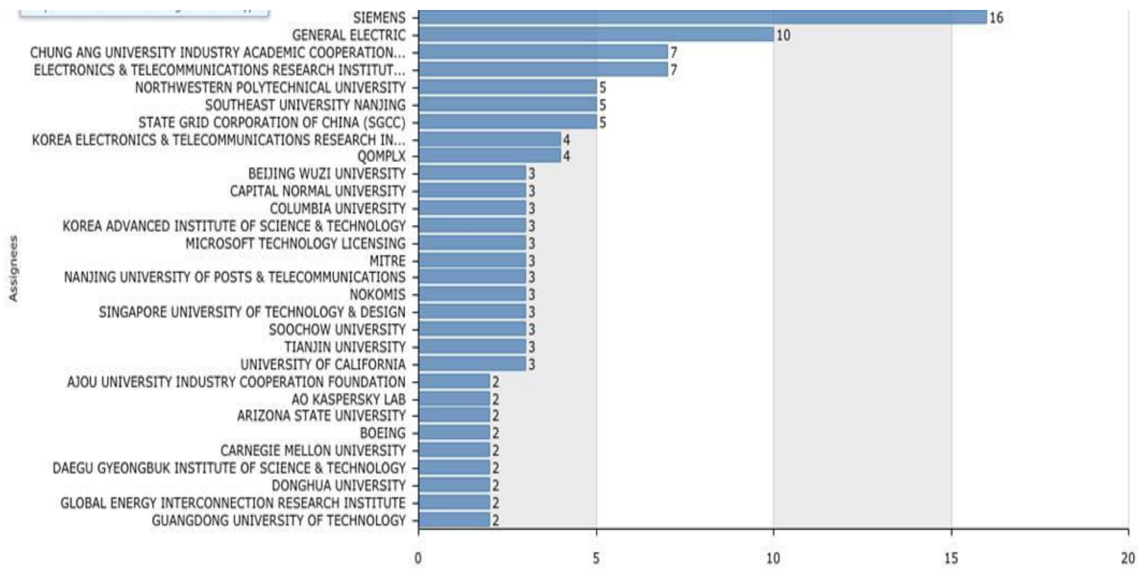
Figure 9 - Year of Deposit in the World - Artificial Intelligence



Source: Orbit Questel (2020)

The data obtained from Questel-Orbit® on patents in Cyber-Physical Systems (CPS) technology were grouped into IPC codes. Of a total of 235 deposits in the period 2008-2018, 89 were applied for by China, zero by Portugal and 5 by Brazil. In turn, of the number of patent applications filed in the world 235, being pending 90, a slightly higher number than the patents granted (89). Besides China, USA and EPO were the main applicants. The 30 largest patent applicants in the world based on the IPC codes in this category are presented in Figure 10. Siemens and General Electric head the 30 largest patent applicants in CPS technology.

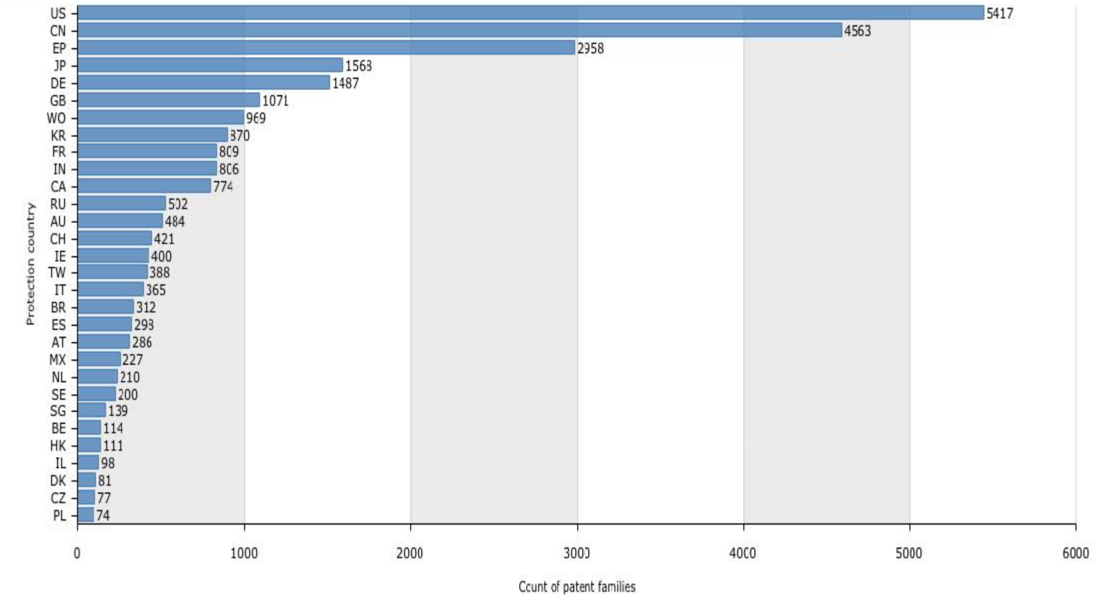
Figure 10 - Top 30 Depositors in the World - Cyber Physical Systems (CPS)



Source: Orbit Questel (2020)

The data obtained from Questel-Orbit® on patents in Industrial Robotics technology were also grouped into IPC codes. According to Figure 11, out of a total 13,718 deposits, 5,417 came from the USA, while 4,563 were from by China, 2,958 from the EPO, 1,568 from Japan.

Figure 11 - Top 30 Countries in the World – Robotics

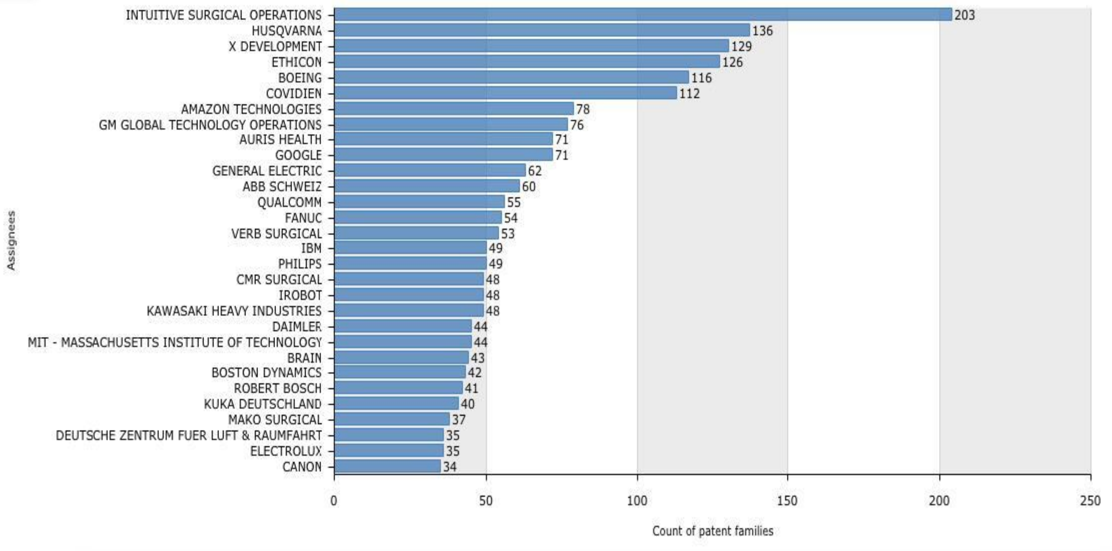


Source: Orbit Questel (2020)

The United States and Japan continue to have technological platforms for innovation in industrial robotics and are more developed compared to China (which has growing deposits but no frontier positioning) and South Korea. While in Germany there are no efforts in the development of industrial robotics. The results of the empirical analysis indicate that there is an innovation gap between China and the country's patent applications. One of the determinants of this gap can be identified in the absence of Chinese companies in the 30-strand depositors, with only the deposit by Chinese universities being highlighted. This condition is due to the existence, to a large extent, of the university-industry relationship or open innovation as a driver of innovation in the USA and Japan, while in China there is a gap between innovation and its commercialisation, explained by the weakest technological base and the lack of collaborative experiences. However, the innovation gap between China and the United States, Japan, and Germany is closing with Chinese advances in industrial robotics investment.

The Chinese patents on robotics have grown rapidly since the 2000s, but it was not until 2015 that they began to account for almost half the total number of patents on robotics worldwide. It is evident that Japan, despite the fourth place in the period under review, lost participation during the 1990s because of the Japanese economic bubble, but patents on robotics filed in Japan are still significant. It is possible that the difference between these two countries is a result of the incentives for innovation in industrial robotics, initially stronger in Japan, resulting from differences between their respective labour markets, although the Chinese situation in this field is rapidly changing. Figure 12 shows the 30 largest depositors in technology and highlights the Intuitive Surgical Operations company, founded in 1995 in the US to create robotic systems that help doctors and hospitals to make less invasive surgeries. China's breakthrough is predictable as it plans to produce about 70% of the world's robots through the semiconductor and integrated systems industry in 2020 in competition with Japan, Germany and the United States.

Figure 12- Top 30 Depositors in the World - Robotics

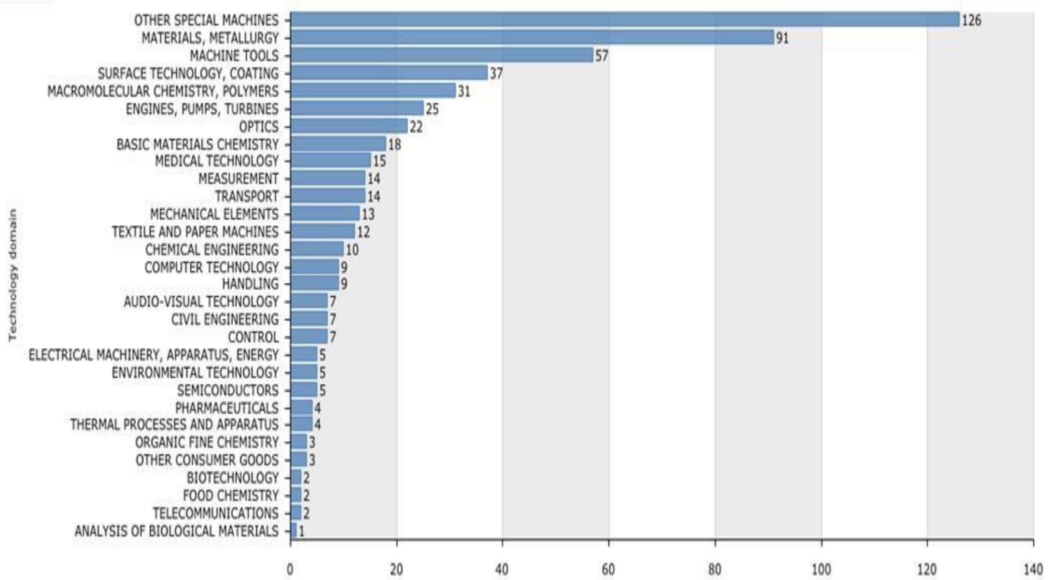


Source: Orbit Questel (2020)

Q4: Who are the main depositors or what is the main objective of enabling technologies in Brazil and Portugal industrial environments?

In an attempt to answer this question, the enabling technologies, dominant in Portugal and Brazil, will be presented. For a more detailed assessment of the 196 patents filed by Brazil and 16 for Portugal in additive manufacturing, based on their relevance and application, the categories covered by each technological domain and the trends of patent filing during 2008-2018 are shown in Figures 13 and 14. The categories under the domains "other machinery and metallurgical materials" were the main contributors to the patents of additive manufacturing. This illustrates the significant development in the respective technological field, emphasising the need for strategic R&D planning for future growth of the sector. In general, patent applications have increased more sharply in the last three years for both countries.

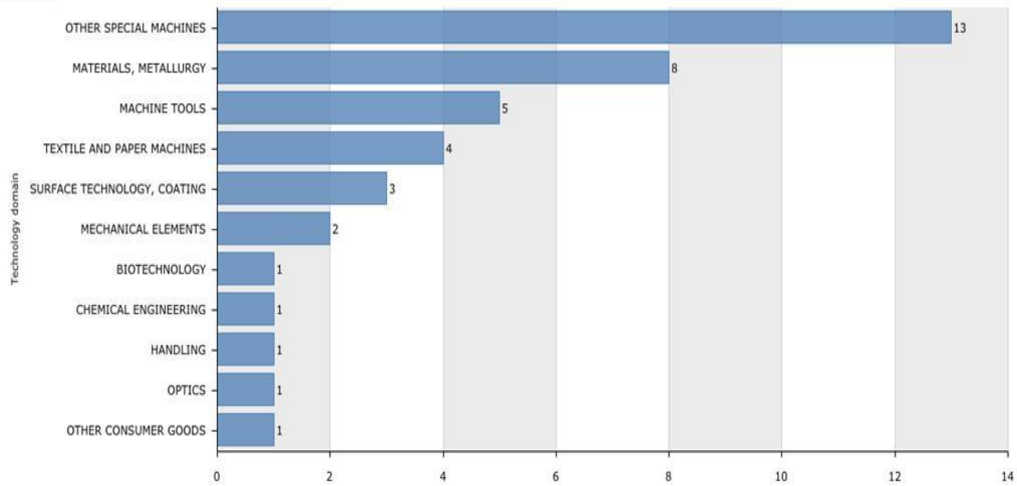
Figure 13 - Dominant Technologies in Brazil - Additive Manufacturing



Source: Orbit Questel (2020)

In industry, the application areas of additive manufacturing are extensive: automotive, aerospace, medical, dental, construction, textiles, and jewellery, among others. In Brazil, most additive manufacturing applications in industrial environments are focused on metalworking process and tooling, providing users with working instructions on how to perform an industrial activity. These instructions are also presented in maintenance and training activities, quality and measurement inspections, machining logistics processes and transportation. Among the innovations highlighted for these applications, firstly, can be mentioned 3D printing devices, methods or processes for 3D printing and control and acquisition in data processing, and secondly, auxiliary equipment and operations and chemical materials. In the whole, these applications are also responsible for 69% of AI patents, which suggests a level of innovation potential.

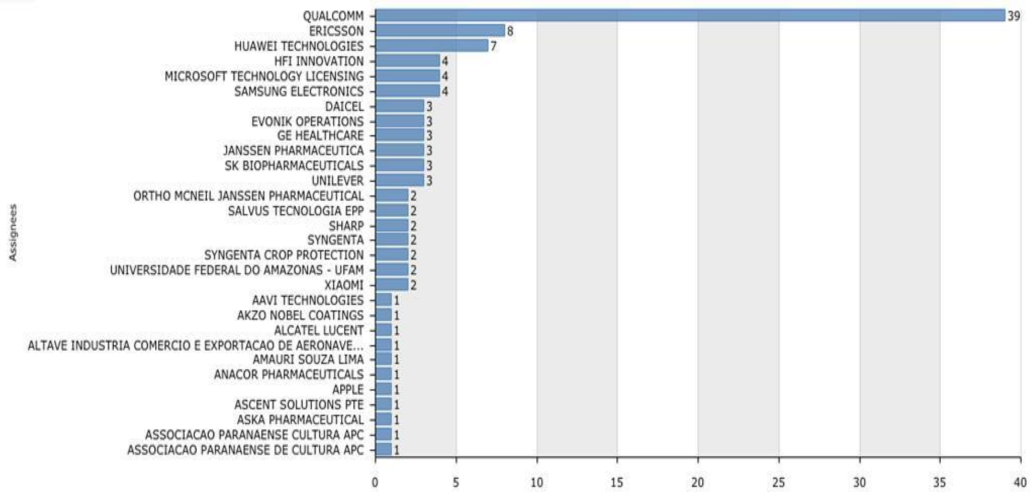
Figure 14 - Dominant Technologies in Portugal - Additive Manufacturing



Source: Orbit Questel (2020)

The 30 largest patent applicants in Brazil and Portugal based on the IPC Internet of Things code are shown in Figures 15 and 16. Among the largest patent applicants in these technological domains the participation of Qualcomm (chip manufacturer of CDMA and W-CDMA technology cell phones and Brew mobile application creation platform) and Ericsson stands out.

Figure 15 - Top 30 Depositors from Brazil - Internet of Things

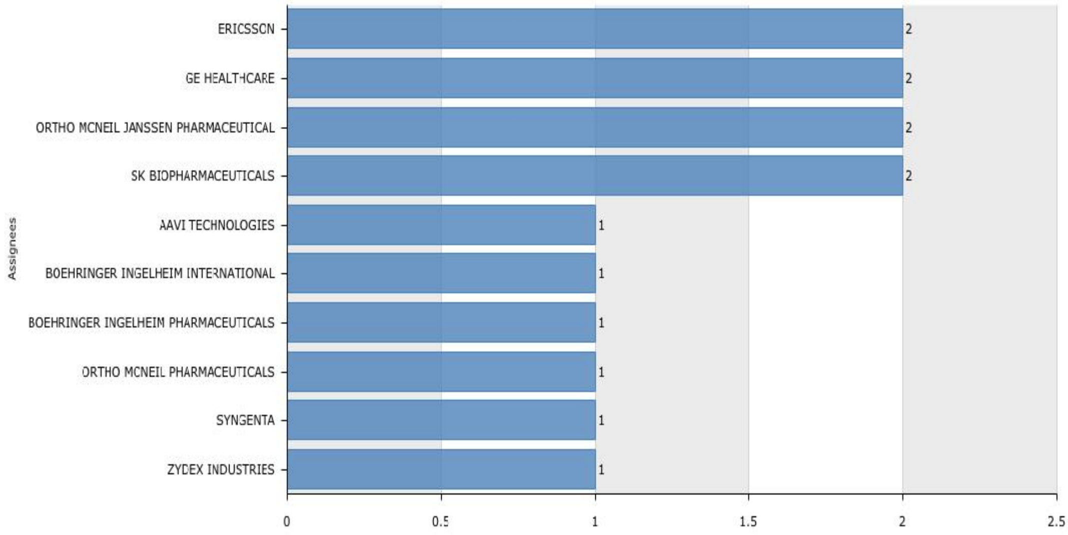


Source: Orbit Questel (2020)

The categories under digital communication and computer technology were the main contributors to the IIoT patents. However, taking into account the age of the applicant, other important features emerge as the lower average age of patent applicants in this sector in 2010-2017 that may suggest the successful entry of young companies into the market. In Brazil, 2017 was the year with the highest number of IoT technologies, while in Portugal 2015 is the year with the highest number of deposits in this technology.

These results are different from previous studies in that in the area of Internet of Things, the companies Samsung Electronics, Sony and Philips, traditional leaders in home appliances, stand out, but there is already an expansion of ICT companies like Google, Microsoft, IBM, Huawei, Cisco. Siemens and General Electric have created solutions for enterprise resources, planning in hospitals, medical devices, among others. Besides Toyota, Honda and Ford that are competing with Google and Microsoft in the field of automotive IoT. In the field of smart manufacturing, Rockwell and Siemens have specialised in smart factory solutions. The research differs from the studies of Mehmood et al. (2016) and Ardito et al. (2018) in which the United States is identified as a leading country.

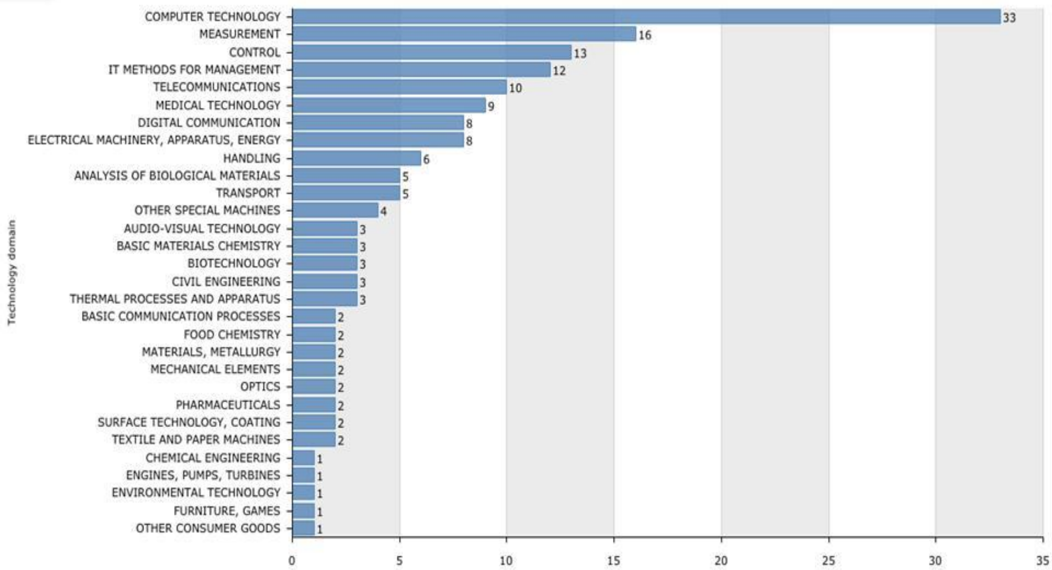
Figure 16 - Depositors from Portugal - Internet of Things



Source Orbit Questel (2020)

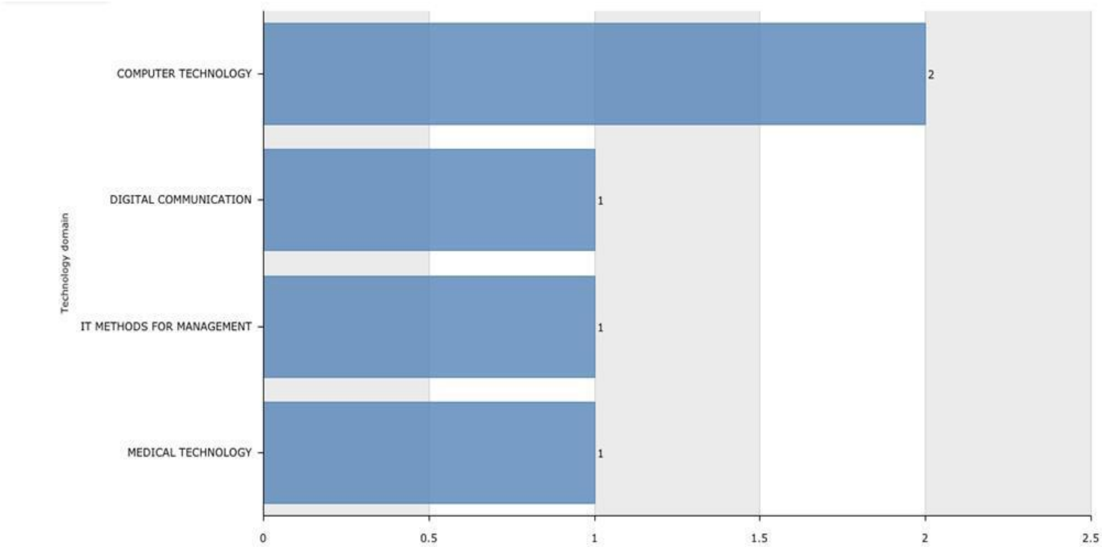
The categories covered by each technological domain and the trends of patent filing in Artificial Intelligence (AI) in 2008-2018 are presented in Figures 17 and 18. AI is widely used in different industries such as energy electronics, transportation, health and telecommunications. In the scope of this research, its application is evidenced in patent filings for email spam, travel sharing and online shopping applications, autonomous vehicle manufacturing and security. Among the functional applications of AI, the computational vision that includes image recognition is the most significant. The categories under computer technology, measurement and digital communication domains in Portugal were the main contributors to AI patents. There were changes in the application areas of AI during the period of analysis in which the transmission of digital information and image and processing data were highly considered applications of AI that attracted more attention in this period in Brazil.

Figure 17 - Top 30 Dominant Technologies Brazil- Artificial Intelligence



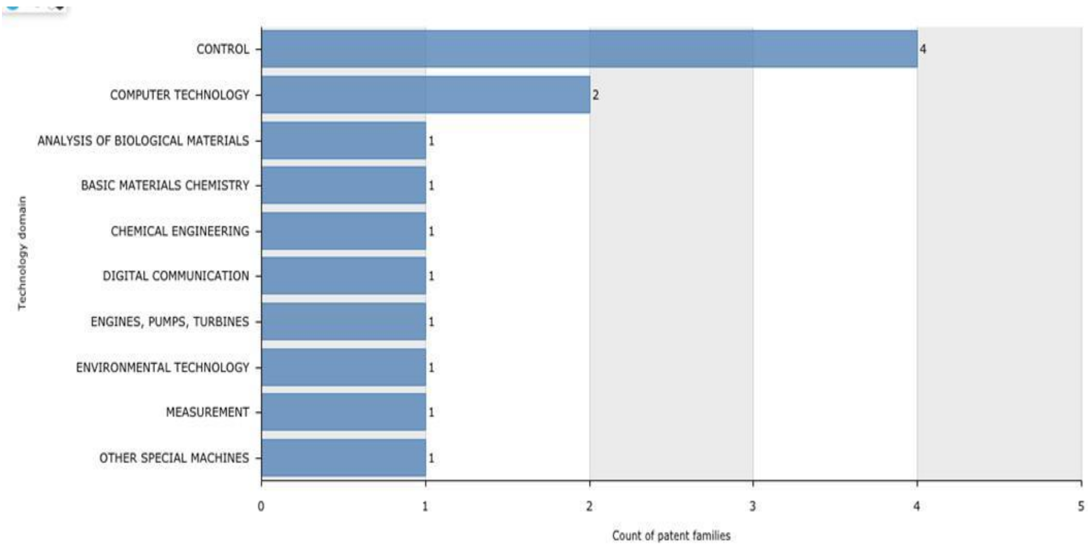
Source: Orbit da Questel (2020)

The selected countries that are in the ranking of AI use excel in data processing more than other areas except Japan, which has mostly taken advantage of AI in data recognition and presentation. China has focused more on the use of AI in transmitting digital information than other countries. For a more detailed evaluation of 77 patents filed in AI by Brazil and 4 for Portugal, the data were categorised by the technological domain of AI, based on its relevance and applicationFigure 18 - Dominant Technologies in Portugal- Artificial Intelligence



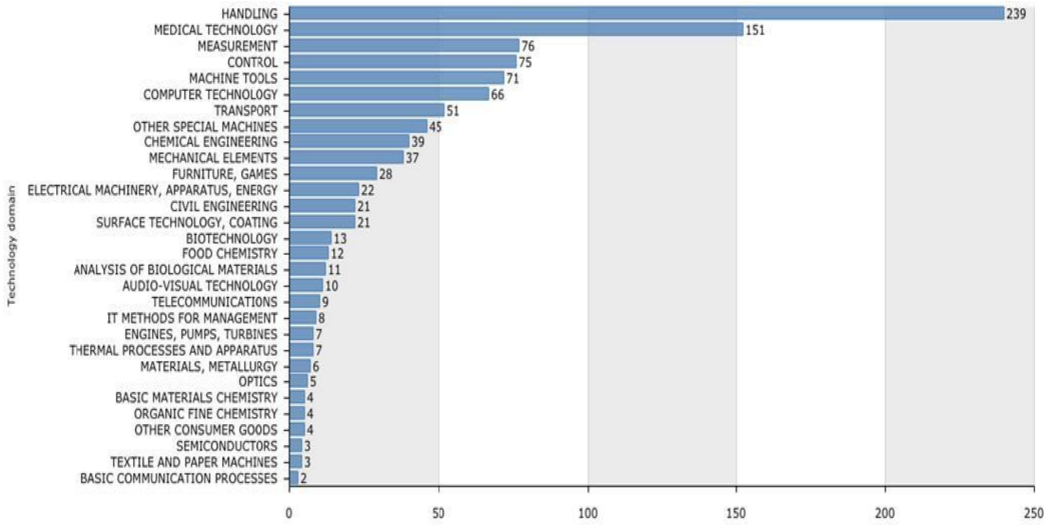
Source: Orbit da Questel (2020)

Figure 19 - Dominant Technologies in Brazil- Artificial Intelligence



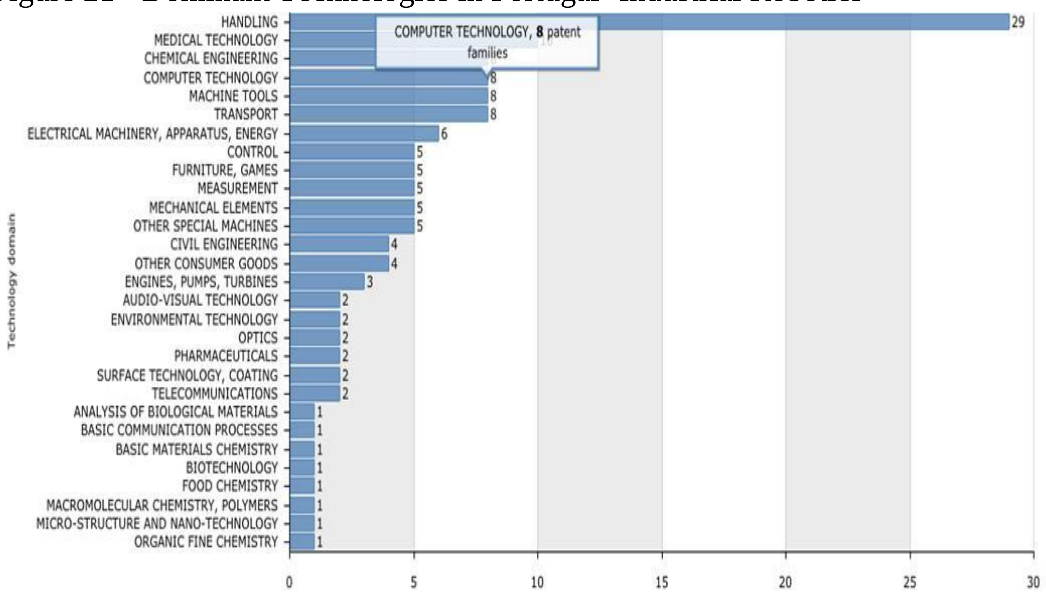
Source: Orbit Questel (2020)

The panorama of robotics technology can be seen through the thirty largest patent applicants both in Brazil and Portugal and have as dominant technologies: medical technology and technology for manual implements, according to Figures 20 and 21. The technological categories in robotics are diversified according to the analysis of patents, although limited in several classes of IPC, such as for manual implements, workshop equipment and computing, vision sensor control, teaching and control of robots, control and manipulations of the robot arm. In the general analysis, it is noted that they are common core technologies for industrial robot manufacturers and robot technologies for specific applications such as radiation treatment, medical and sanitary cleaning equipment, household cleaning or retention devices for semiconductors.Figure 20 - Dominant Technologies in Brazil - Industrial Robotics



Source: Orbit da Questel (2020)

Figure 21 - Dominant Technologies in Portugal -Industrial Robotics



*

Fonte: Orbit da Questel (2020)

The analysis of the above technologies and the geographic patterns of patent applicants and companies indicate that US-based companies still account for the majority of applications in robotics and additive manufacturing, as well as AI and IoT, but China is moving forward with greater robustness in deposits of AI and IoT technologies as well as robotics. Certainly, when looking at the intensity of the 4IR patents - the 4IR patents share of the total - China performs a clear leadership role in AI and IoT and stands out in other technologies. On the one hand, new countries are emerging, such as South Korea and other "emerging" countries. However, it is noticeable that most of the applicant companies operate in services not in manufacturing, which is a relative concept within the industry 4.0 insofar the systems predominate as technologies. On the other hand, there is evidence that the average number of patents per company has grown significantly, suggesting its increase in the context of 4IR, with patent activity occurring mainly within multinational companies and new emerging companies in the area of technology, although Chinese universities have high representation in the scenario.

The comparative analysis of patents, carried out in this section and which composed the essence of this work shows that Brazil and Portugal participated, albeit unevenly, both in terms of periods and sectors and intensity, in the general process of development of enabling technologies in the context of digital transformation. Despite the technological "gaps" that still affect both countries, this has not prevented them from taking an active and growing part in the filing of patents, in the search for recognition of their ability to innovate, through their companies and scientific centres of excellence, in technological areas that are not yet much developed internally, but that already require sophistication and advanced scientific knowledge and its application. When many ideas that became current at the end of the last century (for example the initial formulation of the theory of the product cycle, which led to a rigid division of countries into innovators and mere replicators to a varying degree) are abandoned, it can be seen that even countries with a less intense and deep technological past in previous decades, can notably through the emergence of new actors, insert themselves in the global innovative process and benefit from its fruits. As the case of China points out, clear preparation and guidance is also needed in this regard. It is evident that this process has the potential to generate competitive capabilities in the countries that undertake it.

In this research, the main objective was a survey of the Brazilian and Portuguese presence in the field of enabling technologies, using patents as a determining proxy in an industry 4.0 context. Despite the results achieved, we will not be able to consider this methodology as definitive or unique, even with the limitations pointed out in the text, however, the study allows us to answer some of the research questions that have been formulated, showing that both countries can, through innovation, where we used the patent deposit process, not only recover delays but also expand their participation in the process leading to industry 4.0, provided that they take the necessary steps not only in terms of decision but also in the field of management.**5. Conclusions**

The aim of this study was to investigate the indicators of patents of enabling technologies in the process of digital transformation of industries in Brazil and Portugal, considering its implications before 4IR. The research questions were addressed, in particular: How do the total number of patents filed in Brazil and Portugal are evaluated in terms of changes in Science and Technology policies and what are the main differences between these countries? Which are the main enabling technologies of the industry 4.0 and what is the participation of Brazil and Portugal in the global patent process? Which technological domains, countries and actors in the world stand out the most in the period 2008-2018, as well as the endogenous intensity in the search for patents, considering the largest depositors, especially China? Who are the main depositors or what is the main objective of enabling technologies in industrial environments such as those of Brazil and Portugal? For this purpose, and as explained at the beginning of this work, the patent deposits of Brazil and Portugal in the period 2008-2018 were analysed, and their characteristics, including similarities and differences, were detailed.

Based on the information obtained about patents in the database that has been used, the five enabling technologies of the industry 4.0 that are most focused on the methodology applied in the research were identified: (1) additive manufacturing; (2) artificial intelligence; (3) internet of things; (4) industrial robotics; (5) cyber-physical systems. In general, the picture exposed by the results induces some reflections and recommendations.

According to the findings of recent literature, there is evidence of an increase in patenting activity related to industry 4.0 (Benassi et. al., 2019) in the period under review, particularly in network devices and services. Furthermore, empirical results suggest that companies registering 4IR patents in Brazil and Portugal are on average younger in the area of technology. At the same time, there is a steady pace of growth in the average number of patent applications of 4IR filed annually in the last five years of the period considered. As both Portugal and Brazil maintain important gaps in their technological structure - although with different historical pathways and located in different geographical areas - they strive to reduce the innovation gap between them and the most advanced countries, a process known as "catching up". The patent data deposited, identified in both countries, can effectively indicate a degree of innovation performance, including product, process and technology innovation, which is especially more effective and brings more fruit than alternative ways such as the sale of new products, and can have more powerful cross effects.

The results pointed out that the 924 deposits of the five main enabling technologies of the industry 4.0 represent only 0.28% of total patent deposits in Brazil in the period 2008-2018. In Portugal, the 82 applications represent 0.90% of total patent applications in the same period. If we consider the European and international applications, this latter percentage is a little below 0.65%, but still above that of Brazil. In Brazil, the fall in deposits from 2014 did not have an immediate effect on deposits made by the enabling technologies of industry 4.0, which had an increase in deposits from 2016. This condition reflects the fact that the higher number of deposits is not from Brazilian residents, well illustrated by the role of foreign technologies and subsidiaries in the process, presented in section 4. It should also be emphasised that the condition of non-residents among patent applicants is not specific to the Brazilian case, being common among developing countries. Another important reflection is that the increase of deposits in Portugal has followed the deposits of the enabling technologies of industry 4.0. It must be added that in Brazil the number of concessions rose even with the decrease of deposits in the period, reducing the backlog effect that has a positive correlation to the urgency of digital transformation in industry 4.0.

The innovation policies in Brazil and Portugal have also been impacted by the crises that occurred in the period under analysis, but due to the historical formation of manufacturers, the fragility of their innovation systems and in the culture of patenting must be highlighted. There is no doubt about the magnitude of Brazilian industry and its potential because it remains the ninth industrial park in the world, despite financing limitations, the relocation of plants, the preference for financial services, bottlenecks in infrastructure and the complex tax system. In the deindustrialisation that has been observed in Brazil there is sector heterogeneity, after a period of diversification, followed by a specialization in commodities, there was a concentration in services of low productivity and a disregard towards technology intensive segments. In Portugal, the propensity to patent presents significant differences according to the sector; especially considering that patents have always been little encouraged in low and medium technology industrial segments, even considering that the country already has companies well placed in international value chains.

In this context, it is important to note that this study also contributes to fill a gap to the extent that specific technologies that make up the 4IR, such as artificial intelligence, additive manufacturing, robotics and the internet of things are examined on a large scale in the areas of information systems, but that there are much less available studies within the fields of management and economics.

Comparing this analysis with similar research, several studies point out that the countries with the industrial sector with greater technological development, with a higher per capita GDP and with a larger population have greater occurrence in the deposits of patents related to industry 4.0. However, a vast literature (Cimoli and Primi, 2009; Arundel, 2001; Cohen et al, 2000; Harabi, 1995) has explained some issues regarding the costs and benefits of patenting as a technological indicator, even considering in the case of industry 4.0 the possibility of high comparability with countries such as Germany, USA, China, South Korea and Japan. A relevant issue is the fact that some of these studies advocate that patents would not be the best form of technological appropriateness employed by firms as they are somewhat related to inventions that may not reach the market as innovations (Cohen et al, 2000).

Another important aspect to be emphasised, even considering the fact that the patent indicator is a homogeneous reference indicator used by several studies conducted in the realm of international institutions, would be the condition that patents are more relevant as an appropriation mechanism for product innovations, as opposed to economies in which digital transformation advances in services sectors. However, a research in this sense, reflecting a greater and more complex integration between sectors (particularly between manufacturing and services), requires other instruments and could be a future direction for this investigation.

Furthermore, the results confirm that if the assumption was to consider the patent indicator as a proxy for the technological development of countries, it can be said that Brazilian patenting is well below its socioeconomic condition, measured by the size of the gross domestic product (GDP) and its population. The analysis of data on the ownership of patents also showed that multinationals are predominant in patenting industry 4.0 technologies in Brazil, a distinct condition from Portugal in which companies of local residents scaled in the global environment perceiving intellectual property as a strategy to achieve economic and social development, reflected in global indicators that point to the improvement of R&D in the last seven years; in Brazil, the same trend only stands out in the last three years. In the 2020 survey of the Global Innovation Index, Brazil ranks 62nd, and in relation to 2019, the country gained four positions in a group that gathers 131 economies. By the same index, when evaluating the quality of innovation with parameters in local universities, deposited patents and scientific publications, Brazil is ranked 4th in a scale of countries behind China, India and Russia. Portugal, even if she still has important structural flaws, in the 2020 edition of the European Innovation Scoreboard presents the country's passage to the group of “strong innovators” (previously a “moderate innovator”).

Among the limitations of the research, it must be highlighted that this study is a first step for a better understanding of patents as an indicator within 4IR, and the background and effects of patent applications in other competitive dimensions of the two countries were not analysed. In addition, due to a broader classification, particularly relevant in this study, new technologies, such as those of 4IR, are subject to a great degree of uncertainty and to different technological trajectories. It should also be noted that the patent applications were analysed and not the patents granted by the countries, even if the correlation between the two is specified in the analysis.

As a suggestion for future research, quantitative studies by means of a comparative and longitudinal analysis of the requests for patents and patents granted would be an opportunity to compare the technological trajectory between the countries. It must also be noted that the findings highlight that mainly existing companies, which deposit more applications for 4IR patents over time, rather than new companies, explain the increase in total applications. Moreover, there is a general trend whereby companies tend to specialise in a few technological domains.

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